The Isolated Off-Center-Fed Antenna: Some Less-Explored Facets

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Off-center-fed (OCF) antennas seem to offer the amateur with limited space a solution to the problem of being able to work many HF bands with a single wire element. As a consequence, the last few decades have seen many ingenious designs trying to squeeze the maximum number of bands into a single antenna. Because we have a 50-Ω coax fetish, the goal has largely been to minimize the SWR on each included band. We have generally ignored some very interesting facets of OCF behavior in the process. These notes will not bypass matters of SWR, but they will focus on a number of the less discussed aspects of OCF behavior.

Before we can begin our safari into the OCF jungle, we must restrict the area to be explored. Off-center-fed antennas generally fall into three main categories, exemplified by the sketches in **Fig. 1**. Each type of OCF uses a ½ λ transmission line for illustration.

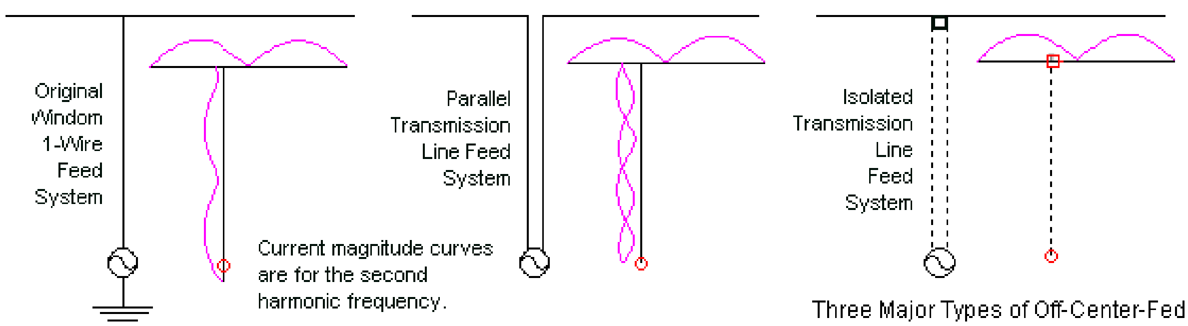


Fig. 1

The earliest OCF was the Windom, explored more fully in "Notes on Mr. Windom's 'Ethereal Adornments'" (http://www.cebik.com/wire/wind.pdf). It employs a single-wire feeder, a rare practice in the 21st century. More common is the OCF that uses a parallel transmission line to an antenna tuner. What the Windom and the parallel transmission-line versions of the OCF share in common is the presence of standing waves or radiation currents on the feedline. The radiation currents on the feedline become part of the overall antenna radiation. Therefore, we have an antenna whose properties depend upon the length, characteristic impedance, and orientation of the transmission line, as well as the horizontal wire length and the position of the junction with the feedline. Although we can find many instances of the antenna sketched at the center of **Fig. 1**, the number of variables is too great for detailed examination. That fact does not prevent innumerable operators from successfully using highly individual versions.

For about 3 decades, designers have focused on the third OCF version. By employing a variety of techniques, including current baluns and ferrite chokes, designers have sought to isolate the antenna from the feedline. Isolation means confining all radiation currents to the horizontal antenna so that the transmission line (normally coaxial cable) contains only transmission-line currents, in other words, currents that at any point along the line are equal in magnitude on the two conductors but opposite in phase. For a primer on line isolation, see Belrose and Bouliane, "The Off-Center-Fed Dipole Revisited: A Broadband, Multiband Antenna," *QST*, August, 1990, pp. 28-34. (Multi-element OCFs are an interesting class of antennas in and of themselves, but outside the basic framework for these notes. The search for an ideal set of OCF elements goes on because, as we shall see, a standard single-element OCF will not handle all of today's HF bands.)

The isolated OCF (or IOCF) eases the challenges facing the designer. Since the transmission line plays no role in the radiation pattern on any included band, the designer can work solely with the horizontal wire in developing as ideal an antenna as possible. We shall follow the lead of OCF designers. But our goal is not to design or even recommend an OCF design. Rather, we want to look into some of the shadows created by the OCF to see if we can shad some light on OCF behavior. For example, we might wonder what relationships exist between the dimensions of an OCF and its resonant impedance on the fundamental or lowest frequency of operation. Free space will be a good modeling environment for looking at this question, but it will not be the last place we look.

Modern OCFs are for multi-band use. In the quest for acceptable SWR levels on all bands of interest, we have tended to overlook that radiation patterns produced on the higher bands. We shall discover that the OCF is less closely related to the center-fed dipole (of which the OCF often seems to be a variation) and more closely related to an end-fed wire. However, a close relationship does not mean that we shall find no differences, especially on the higher HF bands.

On the lowest bands for which amateurs use OCF antennas (80 and 40 meters), installation heights are generally quite low when measured in fractions of a wavelength. For a long time, we have known that the resonant length and the feedpoint impedance of center-fed dipoles undergo cycles of variation at heights below about 2 λ, with larger changes as we decrease the antenna height. If the OCF exhibits similar changes, then we might better understand why some amateurs have difficulty obtaining advertised low-band performance in their own backyards.

Finally, we may look at the relationship of the OCF operated on its fundamental frequency to the use of the antenna at higher frequencies. For a single horizontal element fed off center and with no added components, the frequency for which we cut the antenna has a large bearing on our ability to use it—in the circumstances that define isolation—on higher amateur bands. Although we shall avoid SWR curves for the earlier questions, our last foray will require them.

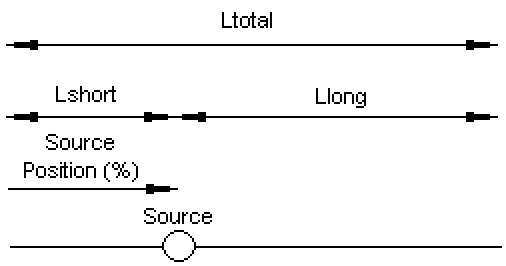
These are perhaps enough questions for a single journey into the land of isolated OCFs. Our aim is not to design an ideal OCF. Instead, we shall be trying to improve our understanding of basic OCF behavior so that we can better evaluate, modify, and successfully use designs that already exist.

Isolated OCFs at Their Fundamental Frequencies

The premise that the OCF is isolated from its transmission line is convenient for our work. We may easily model the OCF either in free-space (our starting point) and over ground of any quality at any height. Since most OCFs use wire, we shall follow the practice, using bare copper. Although Europeans prefer 2-mm diameter wire (0.079”), most U.S. literature specifies AWG #14 (0.0641” diameter). Therefore, all of our models will use #14 wire, although a practical installation might use AWG #10 through AWG #18. Some builders use insulated wire for weather protection. However, there is an antenna velocity factor (not to be confused with a transmission-line velocity factor) associated with insulated wire. The required length compared to bare copper wire may run from 2% to 7% shorter, depending upon the thickness of the insulation and the relative permittivity (dielectric constant) of the insulating material. If we model consistently with bare wire, our results will be self-consistent. For reasons of convenience, we shall arbitrarily set 3.55 MHz as the fundamental frequency for our OCF. We shall have reason to change the frequency, but not until the end of our journey.

By simple habit, certain conventions have grown up around the specifications for an OCF antenna. **Fig. 2** shows the conventions. Since the feedpoint is not centered, we have a long side (Llong) and a short side (Lshort) that together add up to a total length (Ltotal). History might have dictated that we specify the location of the feedpoint as a distance from the wire center, but the normal convention is to give the position of the feedpoint as a percentage of the total antenna length counting from the short side.

Fig. 2



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

Our first question is a simple one: what resonant impedance do we desire from our 3.55-MHz OCF. That question does not have an equally simple answer. We cannot just move the feedpoint farther fro the center of the wire and expect to achieve resonance at a new impedance value. Instead, virtually every dimension of interest undergoes changes, as shown in **Table 1**. The table shows the nearest approximations of the nominal requested impedance within the modeling limitations of using 200 segments for the total wire. Besides dimensions, the table shows the modeled free-space impedance, and it includes a dipole and an end-fed wire for reference.

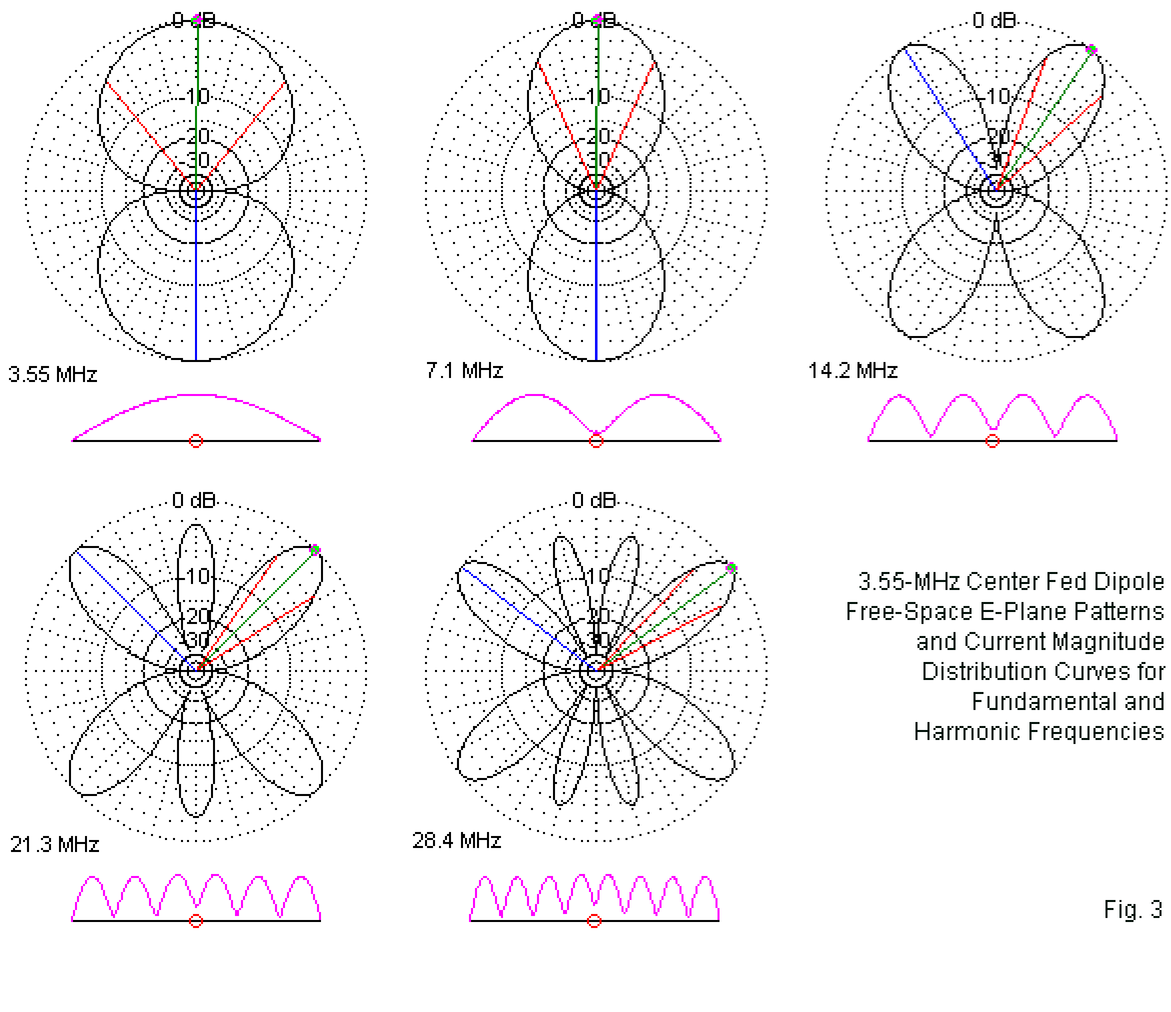
Dimensions with Changes in Desired Fundamental Frequency Impedance						
Test Frequency: 3.55 MHz			Element: AWG #14 copper wire			
Nom. Z	Resist	React	L total	L short	L long	Pos. %
Ohms	Ohms	Ohms	Feet	Feet	Feet	short end
100	99.8	0.4	135.15	44.26	90.89	32.75
150	151.4	0.1	135.35	32.82	102.53	24.25
200	202.8	-0.8	135.51	27.44	108.07	20.25
250	255.0	-0.2	135.70	24.09	111.61	17.75
300	300.0	0.5	135.85	22.08	113.77	16.25
350	359.2	-0.5	136.00	20.06	115.94	14.75
400	411.8	0.0	136.15	18.72	117.43	13.75
450	443.0	-0.1	136.23	18.05	118.18	13.25
Ref.						
Dipole	74.1	0.1	135.00			50.00
End Fed	4383	-51900	135.05			0.25
Notes:	Nom. Z = nominal impedance					
	Resist and React = modeled feedpoint impedance					
	L total, Lshort, Llong, Pos. %: see Fig. 2					
	Model: 200 segments					Table 1

As we increase the resonant impedance, the feedpoint position moves closer to the short end of the antenna, but not in a linear manner. The farther we move from center, the faster the impedance rises per unit of length. As well, the overall length of the antenna increases. Since a model uses a finite number of segments to subdivide the element, the increment limits the possible numbers in the table. As well, the ratio of resistance to reactance in the region of resonance is high enough that absolute precision is not necessary to achieve operational success. The sum of these considerations is that the numbers are overly specific. Values close to the ones shown will do quite as well. For example, if we change the wire size between AWG #10 (0.1019" diameter) and AWG #18 (0.0403" diameter), the feedpoint position for a 200-Ω OCF does not change (20.25%). As well, the overall antenna length changes by only 0.15' (less than 2"). Nonetheless, for an impedance change from 100 Ω to 450 Ω, the total antenna length changes by slightly more than 1', which is a significant difference.

Patterns at the Fundamental and Harmonic Frequencies

Despite the fact that the OCF finds its highest use in multi-band antennas, writers continue to call the antenna a dipole. The practice has led some folks who are interested in the OCF antenna to believe in advance of evidence that the lobe development of the OCF is like the lobe development of a dipole as we operate the element on harmonic frequencies of the fundamental. For that reason, I have added basic information on the dipole and an end-fed half-wavelength wire (both copper AWG #14 like the OCFs) to the table of dimensions.

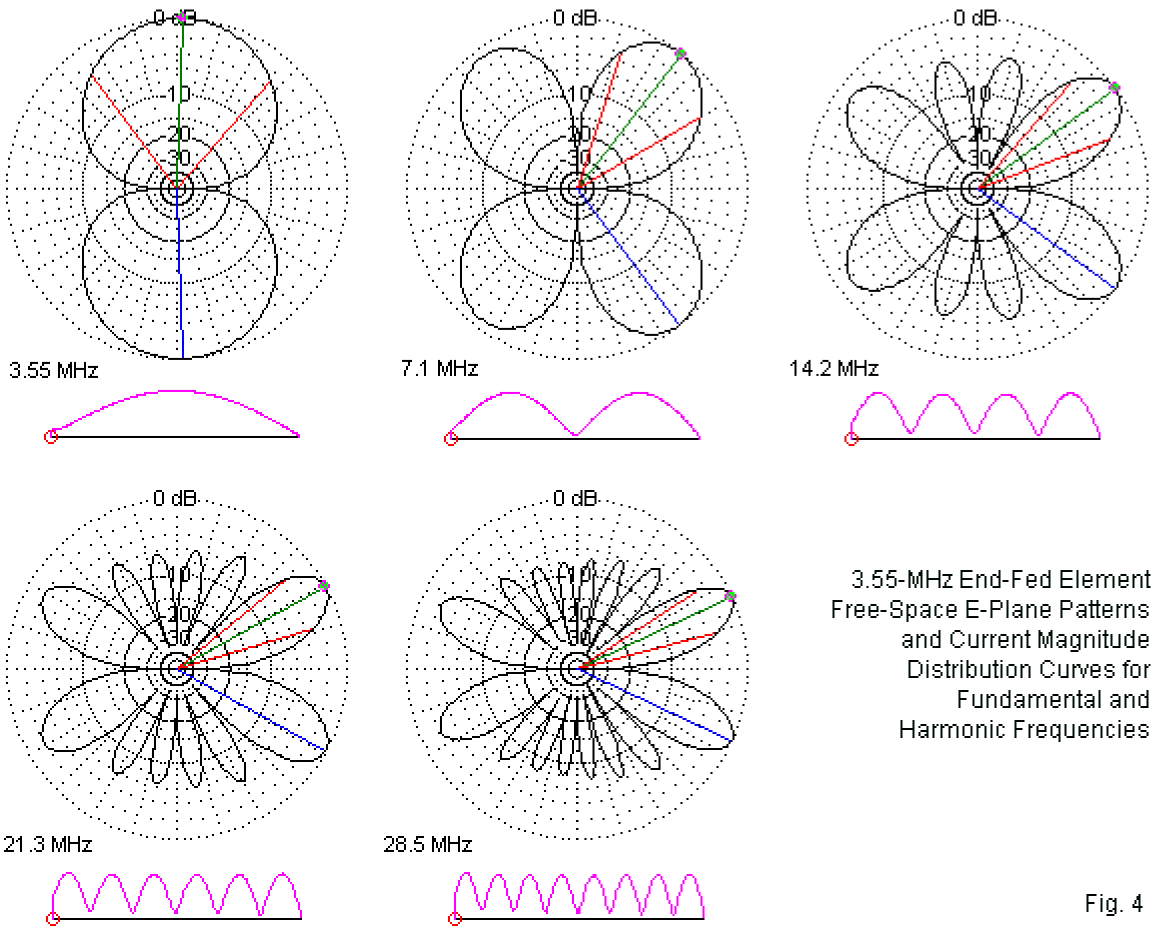
A center-fed dipole, when used on harmonic frequencies, becomes a doublet, because at those high frequencies, we find more than one cycle of current along its length. We may usefully review the development of lobes with a center-fed doublet by examining the free-space E-plane patterns in **Fig. 3**.



3.55-MHz Center Fed Dipole Free-Space E-Plane Patterns and Current Magnitude Distribution Curves for Fundamental and Harmonic Frequencies

Fig. 3

Attached to each pattern is a representation of the element that also shows the relative current magnitude curves. The frequencies shown are harmonics of 3.55 MHz through 28.4 MHz. For each frequency, the total number of lobes in the pattern is the same as the number of current peaks along the wire. (This “rule” applies only on integral harmonics.) We may contrast this development with the lobe structures of an end-fed half-wavelength wire at its fundamental frequency and its harmonics. **Fig. 4** shows the same frequencies with the alternative antenna.



The bi-directional pattern at the fundamental frequency is essentially the same for both types of antennas. At harmonic frequencies, the number of current peals along the antenna wire is also the same for both antennas. However, lobe development is quite different. At each frequency, the total number of lobes is double the number of current peaks and also double the number associated with corresponding doublet models. One consequence of the more rapid increase in the number of lobes is that the dominant lobes for an end-fed wire “tilt” more toward the element ends than do the main lobes of a doublet. As well, the end-fed wire’s strongest lobes without exception point away from the source end of the wire. As we increase the harmonic frequency, the broadside lobes become weaker more rapidly than do the broadside lobes of the doublet.

There are good reasons for not using an end fed wire for HF multi-band service. At the lengths involved, isolating the feedline from the horizontal element is daunting, if not wholly infeasible. However, if we draw the exceptionally high-impedance feedpoint inward from the wire’s end, we can reduce the impedance level and improve the chances of obtaining an isolated feedline. The feedline isolation in turn improves our ability to obtain nearly textbook-quality patterns. If this note suggests that the OCF has more kinship to the end-fed wire than to the center-fed doublet, the impression is correct.

Off-Center-Fed Element Fundamental and Harmonic Frequency Performance in Free Space Referenced to Nominal Impedance											
	See Table 1 for AWG #14 antenna specifications.										
Freq MHz	Nom. Z	100	150	200	250	300	350	400	450	Dipole	End-Fed
3.55	Max Gain	2.02	2.02	2.02	2.02	2.02	2.02	2.03	2.03	2.02	2.01
	Az angle	88	88	87	87	87	87	88	88	90	88
7.1	Max Gain	2.97	2.89	2.86	2.85	2.85	2.85	2.84	2.84	3.69	2.83
	Az angle	55	54	53	53	54	54	53	53	90	52
14.2	Max Gain	3.58	2.89	5.24	5.06	4.97	4.89	4.85	4.83	3.84	4.7
	Az angle	144	54	38	37	37	36	36	36	56	36
21.3	Max Gain	4.34	5.43	4.21	3.12	2.79	6.11	6.42	6.42	4.59	6.02
	Az angle	40	29	27	98	90	31	31	30	45	29
28.4	Max Gain	6.25	4.75	6.99	6.42	5.89	4.81	3.51	3.14	5.28	7.04
	Az angle	25	32	25	25	24	24	31	111	37	25
Patterns		Fig. 5		Fig. 6		Fig. 7				Fig. 3	Fig. 4
Notes:	Max Gain = strongest lobe in dBi										
	Az angle = azimuth angle in degrees of strongest lobe; broadside to wire = 90 degrees										Table 2

Table 2 provides an overview of the free-space performance of various OCFs from the 100-Ω version through the 450-Ω version. It also provides numbers to go with the doublet (fundamental dipole) and end-fed wire patterns in terms of the maximum gain of the strongest lobe(s) and the azimuth angle of those lobes, where 90° is broadside to the wire itself. The numbers—especially the azimuth-angle values—show clearly the affinity of the OCF to the end-fed wire.

Affinities do not denote perfect matches. **Fig. 5** provides a gallery of E-plane patterns for the 100-Ω OCF in free space. If we count lobes for 40, 20, and 10 meters, we find the same number that we find in the corresponding patterns for the end-fed wire. However, we also find differences. At 14.2 MHz, the strongest OCF lobes point roughly toward the short end of the element and not away from the feedpoint and toward the long end. At 28.4 MHz, we discover a considerable variation in the strength of individual lobe. Of course, 21.3 MHz shows an aberrant pattern: it has only 8 lobes when we expect a total of 12.

We can find clues to the differences between the 100-Ω OCF and the end-fed wire by examining the current peaks along the wires. In general, the end-fed wire shows similar strength in the peaks, with only a very small rise in the peak value at each end of the element. In contrast, the OCF current patterns show considerably more variation, even without considering phase-angle variations. For example, at 14.2 MHz, the OCF current peak on the short end of the wire is much stronger than the remaining three peaks. The difference is sufficient to strengthen the short-end main lobes and to weaken the long-end main lobes. At 28.4 MHz, the pattern of current peaks shows considerable disparity between those on the short and long ends of the antenna. The consequence of the lower and higher current regions is not merely a strengthening of the lobes away from the feedpoint, but as well the unevenness of lobe strength in the broadside regions of the element.

The most unusual pattern, of course, occurs at 21.3 MHz, where we find only four pairs of overlapping lobes. The current peak levels do not give us a clue to the lobe structure. However, if we examine the position of the feedpoint along the train of current cycles, we find a hint. The feedpoint coincides with a current minimum so that we have two peaks on the short end and four on the long end. The result is a pattern that resembles the 40-meter pattern, but with an extra null on each of the quartering structures. Hence, in looking at free-space E-plane patterns (or corresponding azimuth patterns over ground), both the relative strength of the current peaks and their positions relative to the feedpoint provide a foundation for understanding the similarities and differences between OCF and end-fed wire patterns at harmonic frequencies.

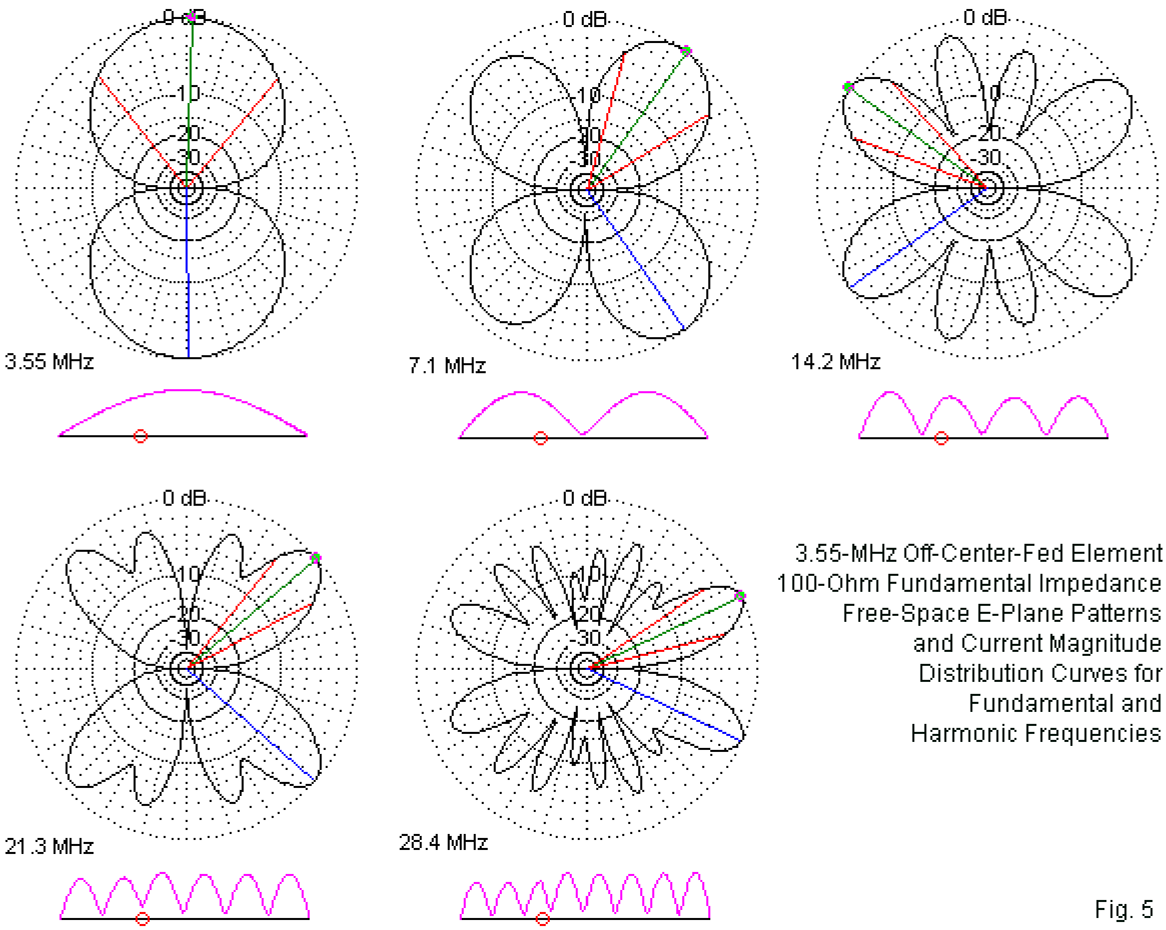
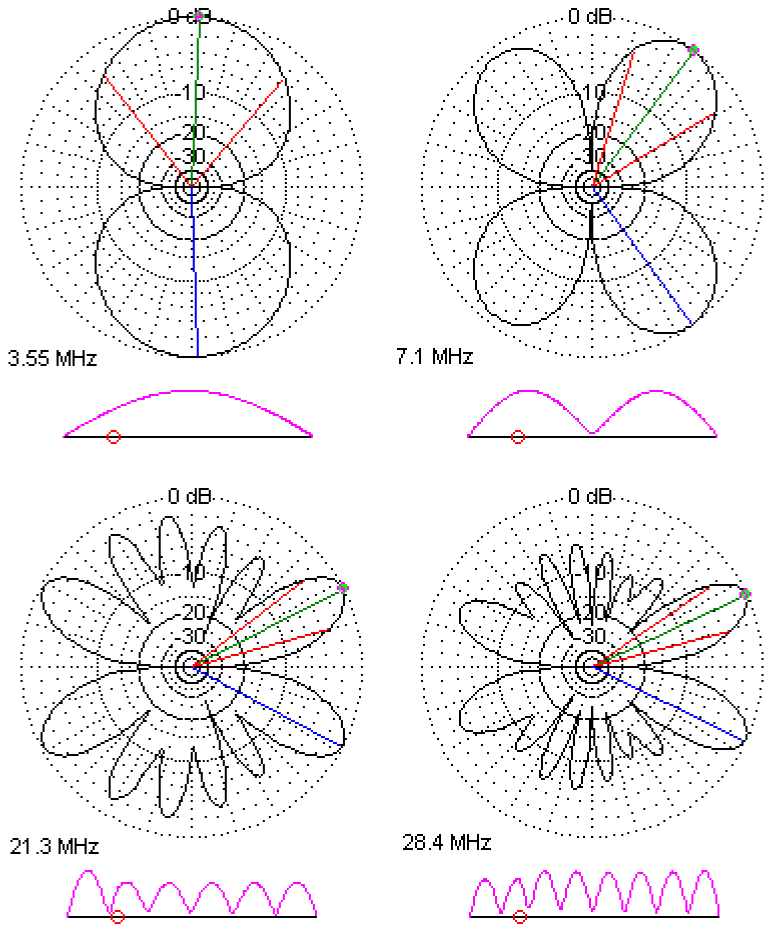


Fig. 5

The movement of the feedpoint as we raise the design impedance of an OCF at its fundamental frequency forewarns us that the harmonic frequency patterns may not be identical for all versions of the OCF. **Fig. 6** provides a gallery of free-space E-plane patterns for the 200-Ω version of the antenna. At first sight, they appear to correspond quite well to the patterns for the end-fed wire. At least we see no major aberrations.

A closer investigation and comparison with the patterns in **Fig. 4** show many lesser differences between the two sets of plots. The 20-meter patterns show weaker development of the lobes toward the shorter end of the OCF. The reduced peak value of the shorter-end current lobe corresponds to this condition. On 15 meters, the OCF pattern shows a set of considerably larger broadside lobes than we find in the end-fed wire pattern. In this case, a higher current peak value on the shorter-end of the OCF suffices to alter the pattern. On 10 meters, we find lower current peaks on the short-end side of the feedpoint. As a consequence, the shorter-end main lobes have reduced strength compared to the end-fed counterpart lobes. Despite these differences, the 200-Ω OCF—among all of the OCF versions explored—provides band-to-band patterns that come closest to end-fed wire patterns.



3.55-MHz Off-Center-Fed Element
200-Ohm Fundamental Impedance
Free-Space E-Plane Patterns
and Current Magnitude
Distribution Curves for
Fundamental and
Harmonic Frequencies

Fig. 6

For contrast, we may examine the patterns in **Fig. 7** for the 300-Ω OCF in free-space. The patterns for 40, 20, and 10 meters are very good replicas of their end-fed wire cousins. For the most part, the relative current magnitude curves do not depart much from the end-fed standard. The one exception is again 21.3 MHz. The feedpoint falls very near to a current minimum, about ½ λ inboard from the short end of the antenna element. The resulting current curve at that end of the antenna has an abnormally high peak value relative to the remaining curves. The resulting E-plane pattern is a very nearly symmetrical pair of 5-lobe patterns broadside to the wire. The pattern is notable for the 5 lobes, since we expect 6 lobes on each side of the wire. Essentially, the two lobes that would normally be closest to the broadside direction shift until they overlap into a single lobe.

The upshot of the exercise is that the harmonic frequency patterns of an OCF change with the fundamental resonant impedance and its corresponding feedpoint position. Although we have shown free-space patterns for only three of the many possible OCF designs, they suffice to establish the variations of OCF patterns from their proper standard: the end-fed wire. The data in **Table 2** provides indicators of the possible variations that attach to other versions of the OCF. The clues to potentially aberrant patterns may appear either in an odd azimuth angle for the main lobe or a much reduced gain level for main lobes in a proper direction.

In general, the 40-meter patterns show the least change from one OCF version to the next. 10-meter patterns tend to vary mostly in the relative strength of the broadside lobes relative to expectations, although the 28.4-MHz patterns for 400 Ω and 450 Ω show a reversal of direction for the strongest lobes. On 20 meters, this situation occurs only with the lowest impedance version of the OCF. The most common frequency for truly variant patterns is 21.3 MHz.

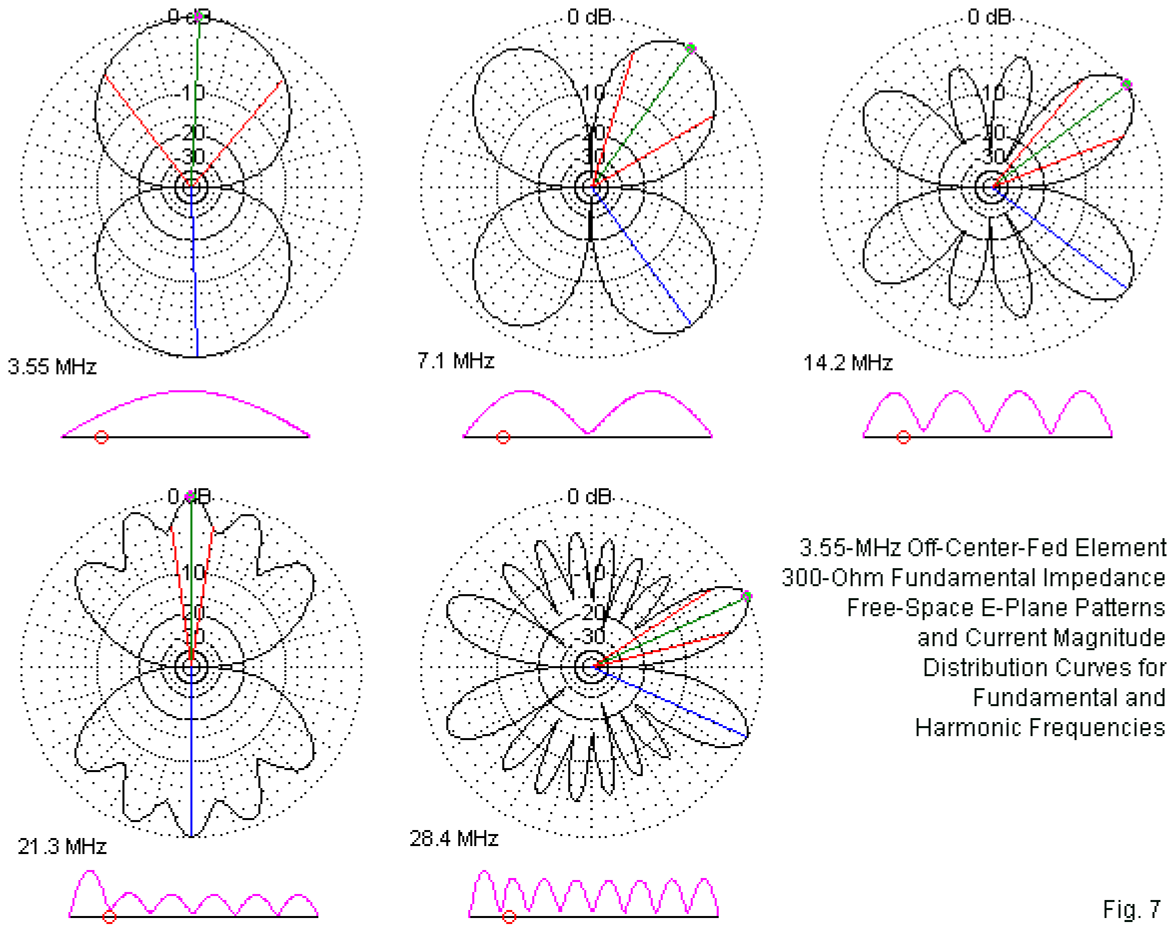


Fig. 7

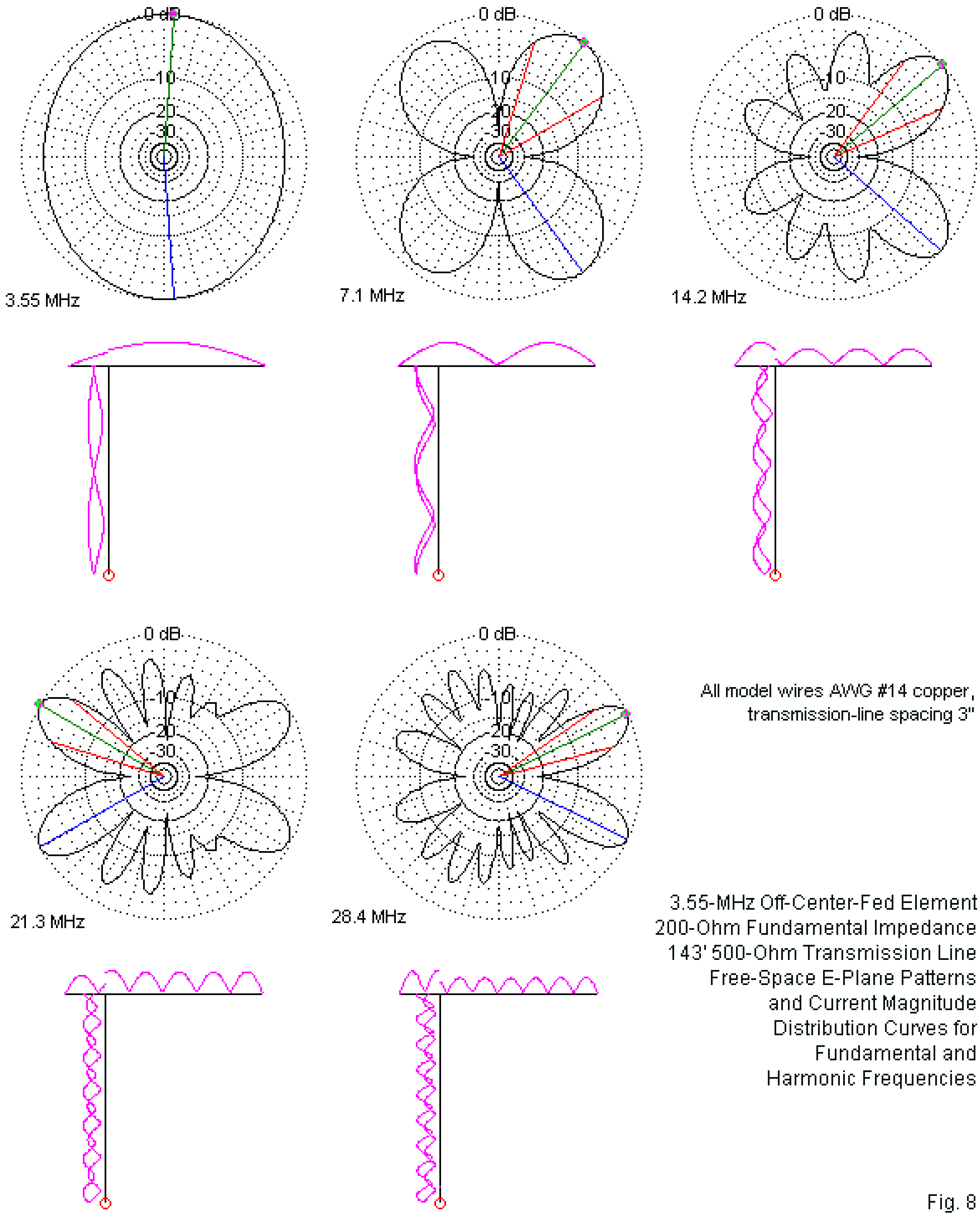
In the end, anyone who proposes to install an isolated OCF should model the antenna and check the patterns on all bands within the operating range. The investigation has two goals. First, the user should satisfy himself that these are all acceptable patterns for the type of operations contemplated. Second, the pattern strength on the various bands may provide useful information on how to orient the antenna on the site for the best results.

Why These Notes Do Not Include OCFs with Parallel Transmission Lines

At the start of these notes, I specifically excluded from coverage versions of the OCF that use parallel transmission lines. My reasons involved the fact that parallel transmission lines in an OCF setting have both transmission-line and radiation currents. The effects of the radiation currents on the antenna patterns depend on the length of the line, which is normally straight in a free-space model. Over ground, the line effects become even more complex, since the feedline may depart the antenna at any angle and may change direction on its path to the antenna tuner. The result is a morass of possibilities, each one with slightly different consequences for the overall antenna patterns.

As shown in **Fig. 8**, even the fundamental frequency is not immune to line effects. The sample OCF uses the 200-Ω version modified to use parallel wire transmission lines to a source

143’ below the antenna. The evident imbalance of current on the two lines shows up in a fundamental frequency pattern that is simply an oval rather than the anticipated figure-8.



3.55-MHz Off-Center-Fed Element
200-Ohm Fundamental Impedance
143' 500-Ohm Transmission Line
Free-Space E-Plane Patterns
and Current Magnitude
Distribution Curves for
Fundamental and
Harmonic Frequencies

Fig. 8

The data for the various frequencies appears on **Table 3**. If we compare the data with the information in **Table 2**, we find that with the specified feedline, the maximum gain values are somewhat low, despite the seemingly good behavior of the pattern shapes (except for the 15-

meter reversal of direction for the strongest lobes). As well we can see in each set of current magnitude curves on the horizontal wire a step in the current, indicating the effect of the current imbalance on the transmission line. The significant exception to this rule is the 40-meter current pattern, which shows no major current step on the horizontal wire since the currents on the transmission lines are very nearly balanced.

Comparative Free-Space Performance: 200-Ohm OCF				
With and Without 143' 500-Ohm Transmission Line				
Freq MHz		No TL	TL	
3.55	Max Gain	2.02	2.65	
	Az angle	87	86	
7.1	Max Gain	2.86	2.08	
	Az angle	53	53	
14.2	Max Gain	5.24	2.08	
	Az angle	38	40	
21.3	Max Gain	4.21	2.48	
	Az angle	27	150	
28.4	Max Gain	6.99	4.14	
	Az angle	25	26	
Patterns		Fig. 6	Fig. 8	Table 3

This sample case is only one of an indefinitely large number of cases, one for each real and possible installation. The sample does not even take the ground into consideration. Nevertheless, it does show the relative futility of trying to design an idealized OCF that uses a parallel transmission line. OCFs with isolated transmission lines present far less formidable challenges. At the same time, the design challenges do not prevent OCFs with parallel transmission lines from providing good results for the general amateur operator who may have few options for an antenna installation. Indeed, the position of the intersection of the horizontal wire with the transmission line is very often a matter of convenience, dictated by available end supports and the shortest transmission line run to the antenna tuner.

The Isolated OCF over Ground at the Fundamental Frequency

Horizontal wire antennas over ground at heights of less than about 2 λ exhibit some interesting cyclical behaviors. I recently documented the phenomena for 80-meter dipoles in an extensive survey of height-related antenna behavior: "80-Meter Dipoles and Inverted-Vs: A Graphical Scrapbook" (http://www.cebik.com/wire/80dp.pdf). I further verified the generality of the behavior in the study of the original Windom OCF. We may sample its effects on the behavior of isolated OCFs at their fundamental frequency (3.55 MHz in these notes). We shall take two approaches to the questions that involve not only the height of the antenna, but as well the quality of the ground below the antenna. For height, we shall use the most normal range of OCF installations, starting at 35' and ending at 95' in 15' increments. The ground qualities will be very good (conductivity 0.0303 S/m, permittivity 20), average (conductivity 0.005 S/m, permittivity 13), and very poor (conductivity 0.001 S/m, permittivity 5).

The first approach will re-size the free-space 200-Ω version of the OCF so that it returns to a source impedance value as close as possible to nominal. The process will involve adjusting both the total length of the antenna and the position of the source as a percentage of the distance inward from the shorted end of the antenna. A change in either dimension will result in changes to the lengths of both the short and the long ends of the OCF. The top portion of **Table 4** records the results of this exercise.

Resonant Dimensions of a 200-Ohm (Nominal) AWG #14 Copper OCF							Table 4
	over Various Ground Qualities at Various Heights						
Height	Ground	Resist	React	L total	L short	L long	Pos. %
Feet	Quality	Ohms	Ohms	Feet	Feet	Feet	short end
35	Very Gd	201.5	-0.7	133.12	19.64	113.48	14.75
	Average	202.6	-0.3	133.55	22.37	111.18	16.75
	Very Pr	206.2	-0.7	134.20	25.16	109.04	18.75
50	Very Gd	205.5	0.6	133.00	24.27	108.73	18.25
	Average	204.1	-0.2	133.52	25.70	107.82	19.25
	Very Pr	201.3	-0.7	134.30	27.20	107.10	20.25
65	Very Gd	198.8	0.0	133.55	29.05	104.50	21.75
	Average	201.0	-0.1	134.05	29.16	104.89	21.75
	Very Pr	198.7	0.4	134.70	29.30	105.40	21.75
80	Very Gd	205.1	-0.8	134.60	31.29	103.31	23.25
	Average	199.7	0.2	134.94	31.37	103.57	23.25
	Very Pr	202.3	0.2	135.30	30.10	105.20	22.25
95	Very Gd	205.3	0.6	135.80	32.25	103.55	23.75
	Average	202.3	-0.3	135.85	31.59	104.26	23.25
	Very Pr	201.5	-0.4	135.85	30.23	105.62	22.25
Feedpoint Impedances of a Constant-Length and Position OCF (Free-Space Resonant							
	at 200 Ohms) over Various Ground Qualities at Various Heights						
Ground	Very Good		Average		Very Poor		
Height	Resist	React	Resist	React	Resist	React	
Feet	Ohms	Ohms	Ohms	Ohms	Ohms	Ohms	
35	136.1	96.0	165.8	77.2	194.9	45.2	
50	201.7	98.7	211.7	74.7	216.1	42.1	
65	250.6	67.3	245.7	48.0	233.6	25.1	
80	268.9	21.7	256.7	11.8	238.0	2.5	
95	259.6	-18.5	246.8	-19.2	229.7	-16.4	
Note: Antenna length = 135.51', feedpoint position 20.25% from shorter end.							
	Free-space feedpoint impedance = 202.8 - j0.8 Ohms						

For any given height above ground, we may examine the systematic differences created by very different ground qualities. The general trend is that as we raise the height above ground, the amount of change of both the antenna length and the source position grow less for a move from one extreme ground quality to the other. Because antenna height affects both the resonant length and the resonant impedance, we find the greatest variation in the length of the short end of the OCF. For the range of ground qualities surveyed, the difference in short-end length is over 5' at an antenna height of 35'. Even at 95', the difference is more than 2'. Over the years, I have received notes complaining that advertised OCFs do not operate correctly mostly on 80 meters. The sensitivity of the OCF dimensions to ground height and quality provides one possible explanation.

The range of heights in the survey—even though they represent the most common heights for amateur installations—only cover a range from about 1/8 λ to about 1/3 λ above ground. These are very low heights for any horizontal antenna at 80 meters. (At 10 meters, the heights run from a minimum of 1 λ to nearly 3 λ above ground.) The closer the horizontal antenna is to ground, the wider the swing in values as we move the antenna up or down. We may view the swings for the sampled range by using a constant total antenna length and a constant feedpoint position. As we move the antenna along the range of heights and over the set of three ground qualities, we can examine the resulting feedpoint impedance of our antenna that shows a 200 Ω resistive impedance in free space. The lower portion of **Table 4** provides this data.

Very poor ground shows the narrowest range of values. Still, the resistive component varies by over 43 Ω, while the reactive component shows a 61-Ω range. If we move to average ground, the resistive component range increases to nearly 91 Ω, while the reactive component is over 96 Ω. Over very good soil, the resistance changes by a total of nearly 133 Ω, while the reactance range is about 117 Ω. As we increase the quality of the soil but maintain a constant set of sampled heights, both components of the feedpoint impedance show wider ranges of variation. However, the effect of ground quality on the resistive component is greater than it is on the reactive component.

The significance of this exercise lies mainly in the operation and adjustment of an isolated OCF on its fundamental frequency. Any isolated OCF deserves design work for a range of anticipated heights and ground qualities in order to ensure adequate operation by those who buy or replicate a design. At higher frequencies, the height above ground increases as a fraction of a wavelength and both the height and ground quality have correspondingly lesser effects on performance. As well, anyone who contemplates building an isolated OCF from an extant design needs to carefully analyze the design to see what modifications the local installation will require for adequate 80-meter operation.

Multi-Band Coverage

The chief use of isolated OCF antennas in this era is to allow operation on many bands with a single antenna. As we check the coverage permitted by a pair of sample antennas, we may also review some of the topics that we have discussed on the way to this part of our exploration. For very good reasons that we shall note along the way, most modern isolated OCFs employ a lower nominal impedance at the fundamental frequency. We shall initially stay with our design frequency (3.55 MHz), although for good reason, we shall change it before we are through.

Our procedure will be simple and reflect a method used by many OCF designers. We shall simply perform an SWR sweep from 3.5 to 30 MHz in 0.1-MHz steps to detect which frequencies allow operation at a relatively low SWR. In this procedure, we are not concerned with the patterns of the antenna at each frequency, although any final design would need to check those patterns for acceptability. We shall perform three sweeps for each sample antenna: one in free space, another at 35’ above average ground, and a final one at 65’ above average ground. Although this restriction is acceptable for sampling the territory, any final design would need to undergo sweeps using the actual height and ground quality of the installation.

Our first sample employs the free-space model for a 100-Ω nominal impedance. The initial sweep will use a 100-Ω SWR reference on the premise that the designer can transform this impedance to a desired value for the transmission line and also isolate the line from the antenna. **Table 5** provides data for the three environments using the frequencies and 100-Ω SWR values that appear within the sweep. Since the sweep is limited to 0.1-MHz steps, the recorded values are not necessarily the absolutely lowest value that one might find, but they are close enough to give us vital information about the behavior of the antenna. **Fig. 9** graphs the entire sweep to allow correlations with the tabular data.

The data shows that we can find relatively low SWR values at 6 frequencies including the fundamental frequency. An examination of the lowest frequencies shows that the three SWR curves have somewhat different positions, while the higher frequencies (from 14.4 MHz upward) show virtually identical results for all three sweeps. This situation confirms our restriction of ground-effect concerns to the lowest frequencies, where the antenna is at a very low height as measured in wavelengths.

SWR Minimums from 3.5 to 30 MHz: 100-Ohm OCF under Various Conditions							
				Height			
Free Space		35' Average Ground		65' Average Ground		65' Average Ground	
Fr. MHz	SWR 100	Fr. MHz	SWR 100	Fr. MHz	SWR 100	Fr. MHz	*SWR 200*
3.6	1.4	3.5	1.39	3.5	1.11	3.6	1.86
7.2	1.32	7.1	1.35	7.2	1.33	7.2	1.51
14.4	1.69	14.4	1.82	14.4	1.71	14.5	1.25
18.1	1.59	18.1	1.57	18.1	1.59	18.1	1.35
25.3	2.07	25.3	2.11	25.3	2.08	25.3	1.16
29	1.68	29	1.69	29	1.67	20	1.22
Note: See Fig. 9 and Fig. 10 for SWR curves.							Table 5

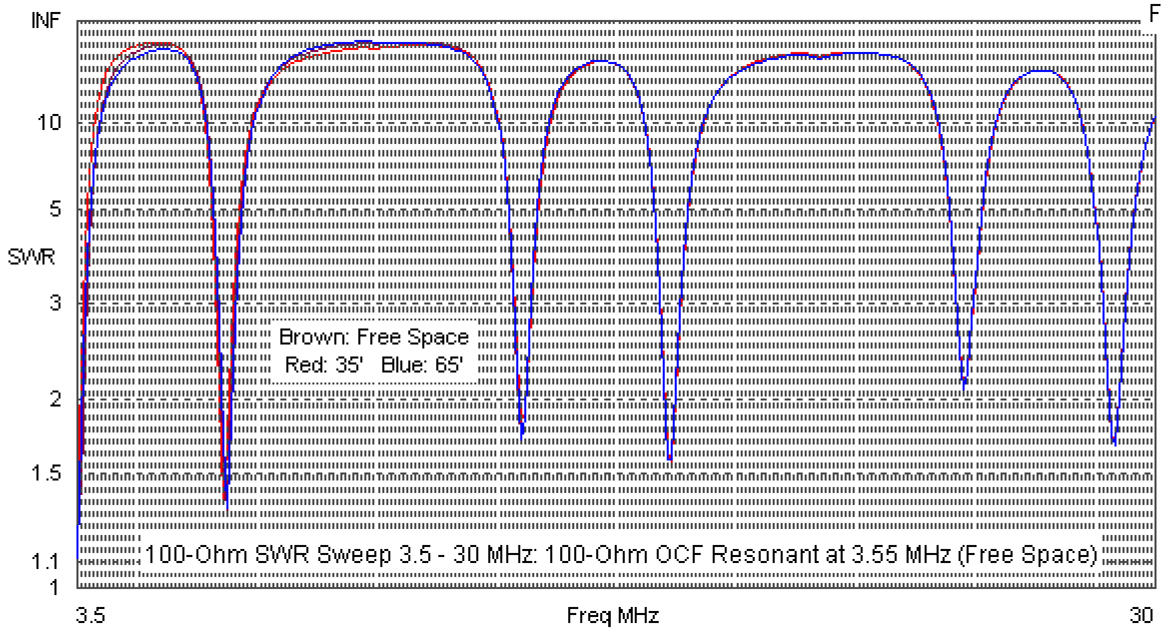


Fig. 9

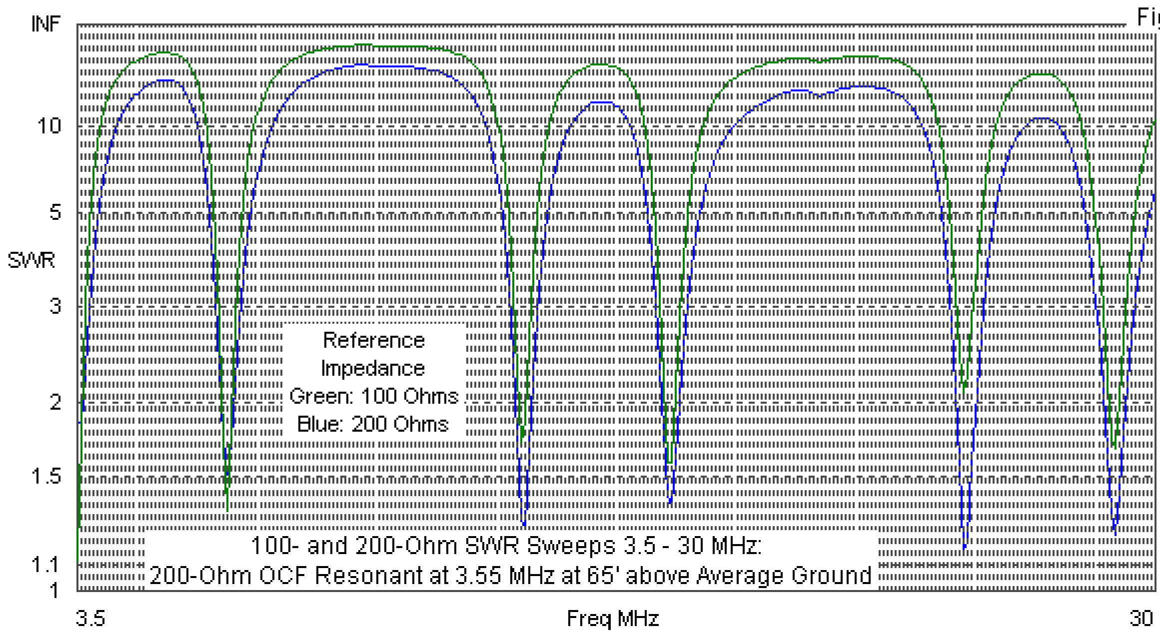


Fig. 10

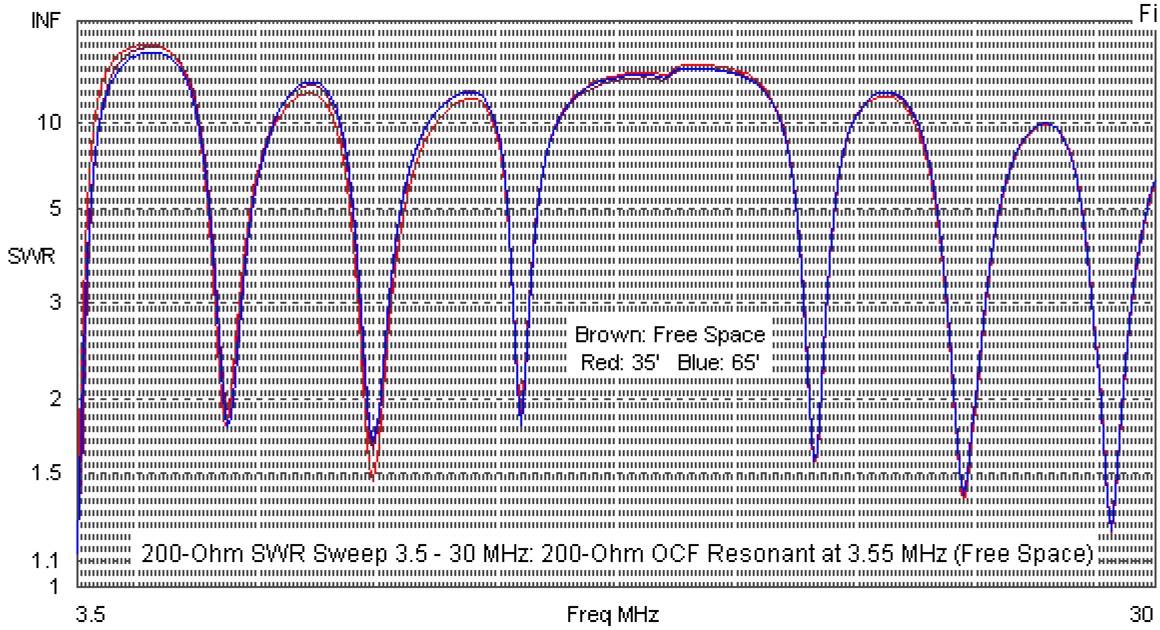
The available operating frequencies form very narrow bands. As shown in **Fig. 9**, we do not obtain truly low SWR values except on the lowest bands. On the upper bands, the 100-Ω SWR remains higher, although not impossible to use. The higher SWR values relative to 100 Ω stem from impedance values that are higher than the reference value. This condition is natural to the harmonic operation of virtually any horizontal antenna. When the element is ½ λ long, we obtain the lowest resonant impedance. When it is operated at a higher frequency, the low-impedance points have minimum values that are higher than the minimum, although they eventually level off in the 300-400-Ω region. Therefore, at the upper bands, using a 100-Ω SWR reference may not be the best reference. **Fig. 10** overlays SWR sweeps using both 100-Ω and 200-Ω SWR reference. Except on 80 and 40 meters, the 200-Ω minimum SWR values decrease to much more desirable levels. (In addition, the 200-Ω reference is also convenient since high-quality impedance transformation devices with an impedance ratio of 4:1 are readily available, allowing the use of a coaxial cable transmission line.)

Missing from the list of frequencies available for low-impedance use is 15 meters (although there is a window in the 17-meter region and another near 12 meters). When we explored the pattern formation of OCFs, we found that the 21.3-MHz pattern showed considerable abnormalities relative to the end-fed-wire standard. The major source of those oddities was the feedpoint position, which coincided closely with a minimum current magnitude position along the wire at 21.3 MHz. The coincidence of the feedpoint with the low-current (high impedance) point results in a very high SWR at this frequency, despite the fact that the reactance values are not excessively high. In both sweep graphs, the situation shows up as a very slight “dimple” in the SWR in this frequency region. We noted other versions of the OCF showing similar coincidences between the feedpoint position and a minimum current point, and these cases also produced aberrant patterns relative to end-fed-wire expectations. If we wish the OCF to allow operation on 15 meters with a relatively low SWR at the nominal fundamental impedance, the design must avoid such cases. Both the 100-Ω and the 300-Ω versions of the OCF are such cases.

Within the primary group of feasible fundamental impedances, only the 200-Ω version avoids the feedpoint position conflict with the current magnitude curves. Although not immune to all pattern aberrations, the 200-Ω patterns in **Fig. 6** approximate standard patterns most closely. When we create an SWR frequency sweep using a 200-Ω reference impedance, we find an additional band with a relatively low SWR value. As expected, the band is 15 meters. **Table 6** provides the minimum SWR values for each frequency within the sweep step limit. The entire sweep appears in **Fig. 11**. The data and graph contain values for free-space, 35’, and 65’, with the latter to heights above average ground. As was the case with the previous sweep, we find the greatest differences in the curves at the lower frequencies, where ground-effects are higher due to the low height of the antenna as measured in wavelengths.

200-Ohm SWR Minimums from 3.5 to 30 MHz: 200-Ohm OCF with Various Conditions							
Free Space			35' Average Ground		Height	65' Average Ground	
Fr. MHz	SWR200		Fr. MHz	SWR200		Fr. MHz	SWR200
3.6	1.4		3.5	1.37		3.5	1.13
7.2	1.91		7.2	1.79		7.2	1.79
10.8	1.65		10.8	1.47		10.8	1.71
14.4	1.87		14.4	1.92		14.4	1.81
21.6	1.55		21.6	1.55		21.6	1.57
25.3	1.39		25.3	1.35		25.3	1.39
28.9	1.23		28.9	1.21		28.9	1.22
Note: See Fig. 11 for SWR Curve							Table 6

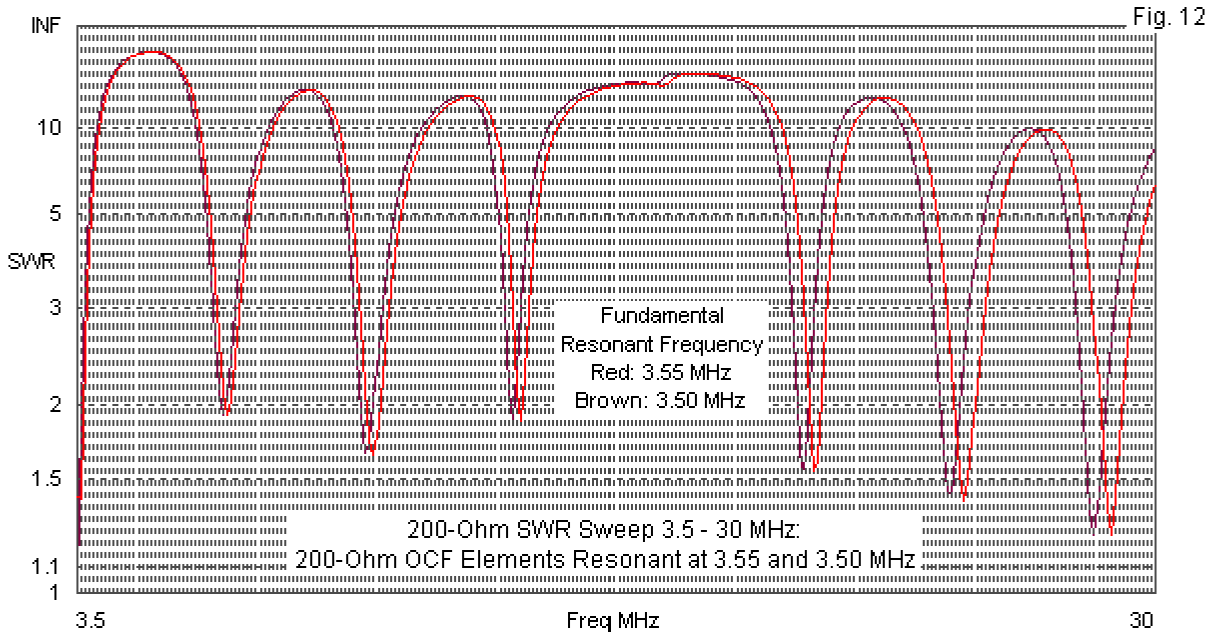
Fig. 11



The availability of the 15-meter band within the sweep of the 200-Ω version of the OCF eliminates another band: 17 meters. Moving the feedpoint position closer to the short end of the element results in a coincidence of the new position with the current minimum in this region (about 18 MHz). An azimuth pattern in this region would show a highly aberrant pattern. The SWR curve shows the condition as a dimple in the mid-range high-plateau of SWR values.

The 200-Ω SWR sweep appears promising but has a flaw. Virtually all of the SWR minimums above 40 meters fall either above the nearest amateur band or in lesser-use portions of the band (for example, 10 meters). One way to provide a potential cure is to scale the 3.55-MHz down slightly, perhaps to 3.50 MHz. **Table 7** shows the dimensions of both the 3.55-MHz and 3.50-MHz versions of the 200-Ω OCF.

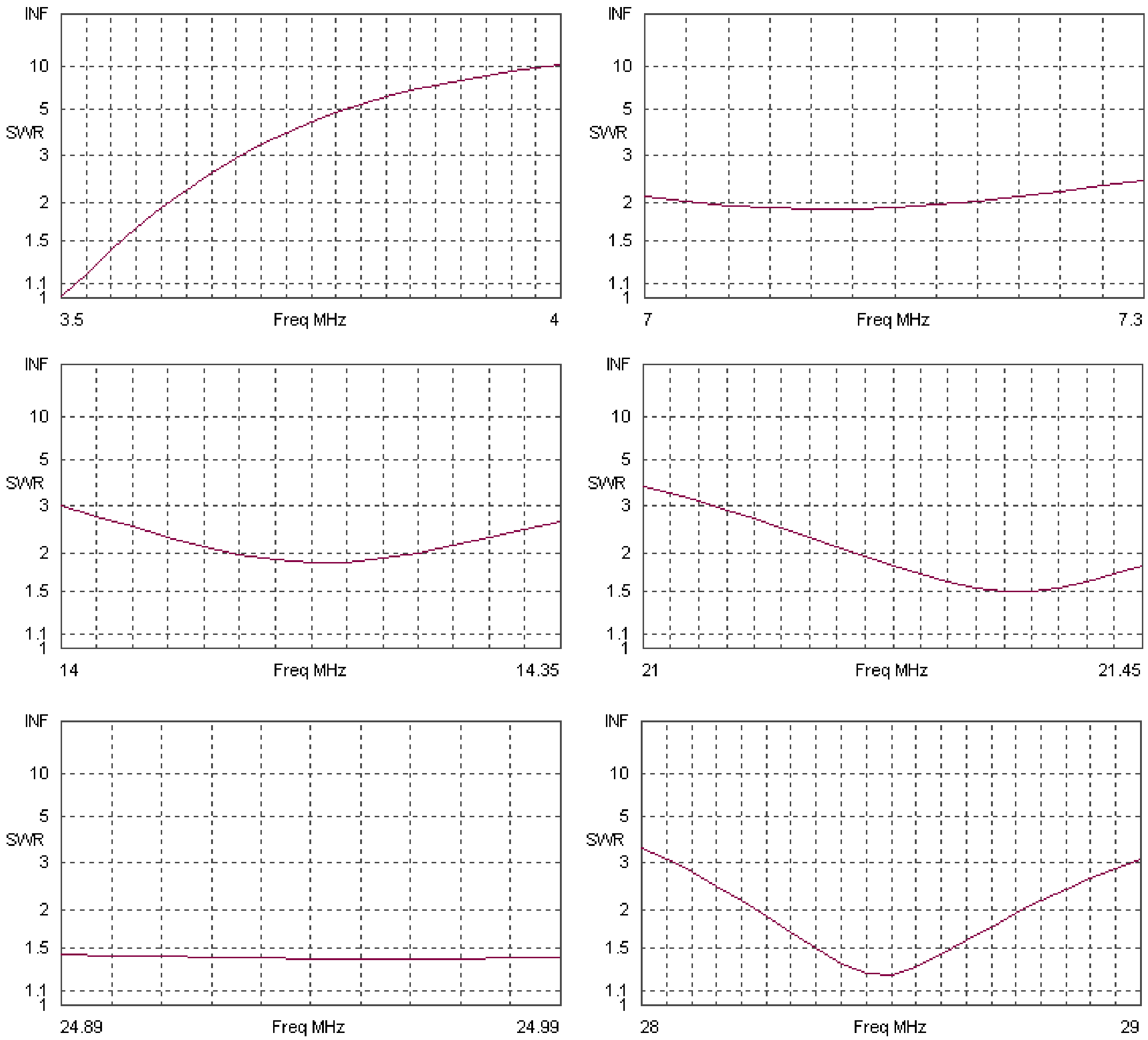
SWR Minimums from 3.5 to 30 MHz				Table 7
200-Ohm OCF: Free-Space Environment				
Fundamental Resonance: 3.55 MHz and 3.50 MHz				
Res: 3.55 MHz			Res: 3.50 MHz	
Fr. MHz	SWR200		Fr. MHz	SWR200
3.6	1.4		3.5	1.02
7.2	1.91		7.1	1.91
10.8	1.65		10.6	1.66
14.4	1.87		14.2	1.87
21.6	1.55		21.3	1.54
25.3	1.39		25	1.42
28.9	1.23		28.5	1.23
Note: See Fig. 12 for comparative SWR curves and				
	Fig. 13 for 3.50-MHz in-band SWR curves.			
Antennas		Element: AWG #14 copper wire		
Resonant	L total	L short	L long	Pos. %
Fr. MHz	Feet	Feet	Feet	short end
3.55	135.51	27.44	108.07	20.25
3.5	137.45	27.83	109.62	20.25



The data in the upper portion of the table, along with the full comparative SWR sweep in **Fig. 12**, show how this simple change moves the harmonic bands downward enough to allow operation in the amateur bands. Only the SWR minimum for 30 meters remains too high in frequency to allow coverage of that amateur allocation (10.1 to 10.150 MHz). However, centering the upper band SWR minimums within the amateur bands to the degree possible does not overcome all limitations of the OCF.

To illustrate some of the remaining limitations, **Fig. 13** provides SWR curves for each covered amateur using the free-space model of the 200-Ω re-scaled isolated OCF. Only the narrow 12-meter band shows wholly acceptable results. Most of the other bands show acceptable SWR values over only portions of the band using the usual 2:1 SWR limit. If we expand the limit to a 3:1 value, some of the bands become completely covered, while other show small portions of a band above the limit. Perhaps the 80-meter band suffers most, since resonance is at the lower edge of the band. The 3:1 SWR limit appears at about 3.67 MHz, with the 2:1 limit at 3.60 MHz. These curves apply to the free-space version of the isolated OCF. For best 80-meter service, the exact dimensions of the antenna might require revision according to the height above ground and the quality of that ground. The resulting dimensional changes may have consequences for the SWR curves on the upper bands. As a result, the design of any isolated OCF is always site specific.

Inevitably, the isolated OCF will require a length of transmission line between the antenna and the equipment. In most designs, the transmission line is coaxial cable, with its associated matched loss value and the inevitable SWR loss multiplier. Inexperienced operators tend to use RG-58 and RG-8X, which are among the lossier cables. As well, the junction of the feedline will reveal some form of isolation and impedance transformation. Together with the cable, these devices will introduce losses that will tend to broaden the SWR curve at the station end of the antenna system. Most isolated OCF users tend to rely on these losses to permit operation across the covered amateur bands—or across wider portions of them. The losses also show up as reduced gain in the pattern lobes of the antenna. Nevertheless, the losses are not sufficiently high as to disable the antenna from good service for general operating needs.



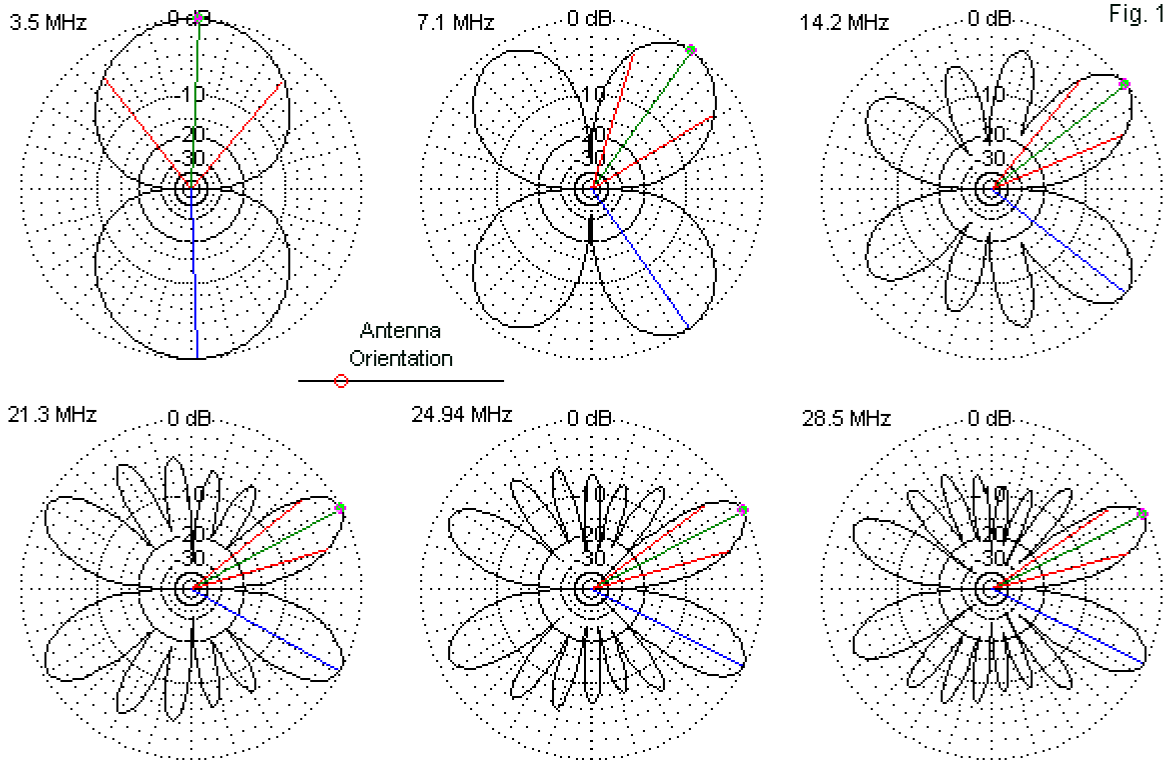
200-Ohm SWR Sweeps on Amateur Bands
200-Ohm OCF Resonant at 3.50 MHz (Free Space)

Fig. 13

With respect to patterns within each amateur band, the 200-Ω revised OCF yields perhaps the most satisfactory set. **Fig. 14** provides a small gallery of patterns for the six bands covered by the SWR plots. In all cases, the patterns show normal lobe development that is generally in accord with the end-fed-wire standard. The upper band lobes broadside to the wire may show deviations from those produced by an end-fed wire, but the amount of deviation is relatively small.

The one factor that no simple single-wire multi-band antenna can overcome is the shifting direction of the strongest lobes relative to the wire orientation as we increase the operating frequency. Above 40 meters, we must treat the antenna as being somewhat directional, with the strongest lobes forming an angle with the long end of the element. On 80 meters, the strongest lobes are broadside to the wire, while on 40, the cloverleaf pattern allows coverage in many directions. From 20 through 10 meters, the two main lobes form angles with the wire end. Although the angle narrows as we move up the HF spectrum, the main lobes are broad enough to permit a single antenna orientation to focus all bands from 20 through 10 meters toward a desired target region.

Fig. 14



Free-Space E-Plane Patterns: 200-Ohm OCF Resonant at 3.50 MHz

Not all amateurs have the option of setting the antenna to favor desired target regions. However, those who may have some options in the matter may wish to do some careful planning before erecting the end supports for the isolated OCF.

Conclusion

We have examined in broad outline and with limited sample cases many of the facets of isolated OCFs that other writers bypass in the effort to provide information on a very usable multi-band antenna. The collection of topics has included general design questions relating to antenna dimensions, pattern generation by some of the versions with different nominal fundamental frequency impedance values, the effects of antenna height and ground quality at the lower frequencies, and band coverage as a function of the nominal impedance and the antenna dimensions. Along the way, we have brought into play a number of antenna behavior elements that rarely find mention, for example, the relationship of the feedpoint position to the current magnitude curves along the element at each operating frequency. We discovered that this relationship—even in the simplified terms used in these notes—has consequences for both the shape of the radiation patterns and the presence or absence of an SWR minimum that allows operation in a band within the techniques normally used to transform impedances to the ubiquitous coaxial cable feedline. Perhaps the most important aspect of these notes is the fact that all of our considerations come together as part of the design process for a single-wire isolated OCF for a specific site and operating environment.

These notes have not covered a variety of embellishments to the single-wire isolated OCF. For example, there are 2-element versions in the literature, where the elements join at a common feedpoint to allow coverage of virtually all HF amateur bands. As well, there are techniques for combining impedance transformation with lengths of transmission line that may offer inherently broader operating bandwidths on at least some amateur bands. There are also techniques of element loading that may allow the use of more amateur bands. (See for example, the web site of Serge Stroobandt, ON4AA: http://hamwaves.com/cl-ocfd/index.html for some promising design ideas, plus a history of OCF developments.) All of the ideas are worthy of consideration and evaluation, but would take us far from the fundamental ideas that we have been exploring.

The isolated OCF antenna has a venerable history of successful use, and an equally long history of user frustration. Much of the frustration is most likely the result of treating the antenna as if it were simple and basic. The isolated OCF is neither, but it is certainly not beyond mastery. I hope these notes contribute to a better understanding of OCF behaviors and thereby to better mastery of a highly usable amateur multi-band antenna.