Is COCO Your Cup of Tea?

L. B. Cebik, W4RNL

The coaxial-collinear (COCO) array has existed for a very long time. Patents and articles on various forms of the array go back to about 1930. The antenna has aroused considerable amateur interest in the new century as a potential "miracle" high gain, omni-directional antenna for VHF and UHF repeater service. The seeming simplicity of the array, the ready availability of materials, and the promise of easy construction together have yielded dozens of erstwhile copies of the antenna. The question that faces us is whether we really understand how and why the antenna works. Does the coaxial-collinear array really surpass other antenna types in very low-angle radiation strength when placed in vertical VHF service?

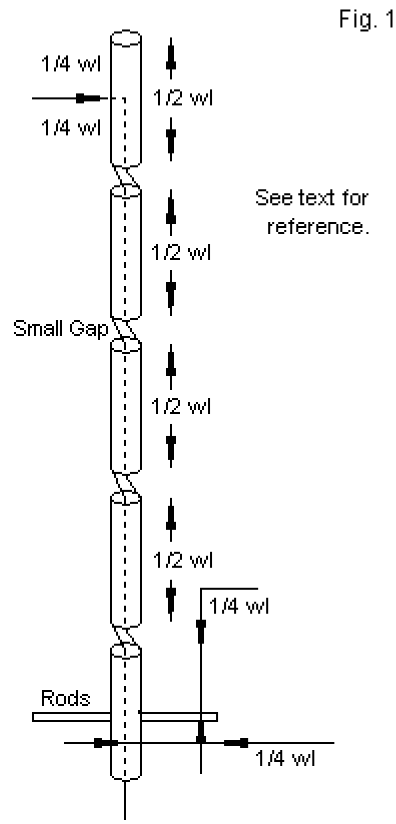
The following notes aim to provide some (but by no means all) of the answers. We shall place the antenna among phased collinear arrays that use other means of effecting a required phase shift from one half-wavelength section to the next. We shall also examine some of the limitations of modeling the coaxial-collinear array. Finally, we shall look at an alternative array that provides similar, but not identical, properties. It, too, will have limitations.

The Conventional Picture of COCO

Perhaps the most universal picture of COCO emerged from H. A. Wheeler's 1954 article, "A Vertical Antenna Made of Transposed Sections of Coaxial Cable" (*IRE Cons. Rec.*, Vol. 4, Pt. 1, pp. 160-164). **Fig. 1** is adapted from the article's initial sketch that outlines the basic ideas behind the array. (See the End Note for some other references to coaxial-collinear antennas.) The most fundamental concept is inherent in any collinear array that wishes to concentrate radiation in a single lobe at right angles to the main axis of the antenna wire or wires. Each half-wavelength section must have the same phase orientation. Without a means of achieving this objective, the pattern would break up into many lobes, since the array would be equivalent to a single wire that was *n*-half-wavelengths long.

The required step is to reverse the phase of current at the end of one half-wavelength section as it is applied to the starting end of the next half-wavelength section. Coaxial cable is a convenient method of achieving this goal, since the currents at the section end are equal in magnitude but opposite in phase angle. Hence, simply reversing the connection of the braid and the center conductor in the transition from one section to the next will reverse the phase and start the next section with the same conditions that appeared at the bottom of the first section. In principle, we may string together as many sections as we wish to achieve increases in gain and decreases in the beamwidth of the main lobe that circles the main axis of the antenna wire (or cables).

The technique of reversing the phase of the current has a limitation when we use coaxial cable to implement the process. Every coaxial cable consists of a center conductor and an outer conductor separated by a dielectric. The presence of the dielectric produces a velocity factor that gives the ratio of the physical cable length to its electrical length. For common coaxial cables, values range from about 0.66 for solid dielectrics to 0.84 for foam dielectrics. The half-wavelength sections of a coaxial-collinear array are electrically that long. Physically, the sections are the velocity factor times a half-wavelength. Hence, a COCO antenna will be somewhat shorter (15% to 40%) than a collinear array made from bare wire and using other means to create the phase reversal between sections.



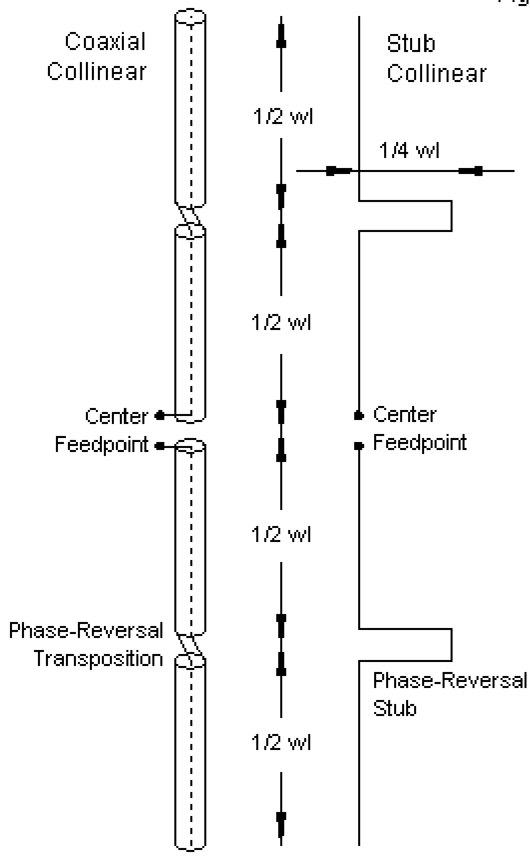
Wheeler Coaxial Collinear Antenna

The Wheeler version of COCO found its way into commercial production in the 460-MHz range. The antenna used a dielectric housing for support of the somewhat floppy coaxial cable and for weather protection. To place the antenna at DC ground relative to its mounting location, the top section used a short between the inner and outer conductors at the ¼-λ mark, although the section continues for the full section length. Along the base section, also a full electrical half-wavelength, the makers installed three ¼-λ rods connected to the coaxial cable braid 1/4-λ from the bottom of that section. However, section continues below the rods for its full length. The feedpoint—close to 50 Ω in the antenna described in the article—is at the base of the lowest section. (I am indebted to Giuseppe Rossi, IZ1BLH, for providing me with a copy of the Wheeler article and other papers on coaxial-collinear antennas.)

COCO's Proper Home

Despite its technique for obtaining a phase reversal in the antenna currents between half-wavelength sections, the coaxial-collinear array remains a version of more conventional collinear arrays designed to achieve equivalent results by other means of obtaining the phase reversal. To understand better the performance potential of COCO, let's compare a short center-fed version of the antenna with one of the conventional collinear arrays. We might use a simple 4-section array and place the feedpoint at the center. This arrangement is common to horizontal implementations of the array. In fact, amateurs have been using such arrays since the 1930s, and similar coaxial versions of the array were used as late as the 1970s in certain radar installations. **Fig. 2** provides a side-by-side sketch of the two antennas.

Fig. 2

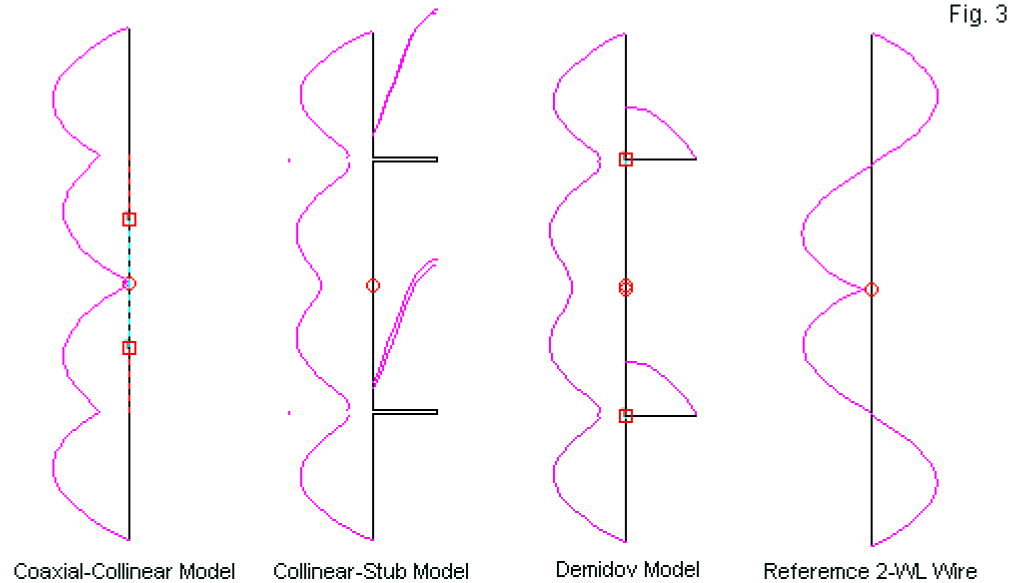


Equivalent Collinear Antennas

The conventional array on the right employs phase-reversal stubs that consist of ¼-λ shorted transmission lines. Whatever the current magnitude and phase at the end of a ½-λ section counting from the feedpoint, the current at the far end of the phase line has equal magnitude but a 180° phase shift. The conventional stub performs essentially the same operation as the coaxial line reversal, but without the need to account for a velocity factor, since the conventional collinear array uses bare wire. Indeed, the only velocity factor involved lies in the stub itself, if the builder chooses to use a length of existing transmission line to create it.

In either collinear array, the phase shift is absolutely necessary to achieve a coherent single major lobe that circles the antenna at right angles to the axis of the wire. **Fig. 3**, on the right, shows a center-fed 2-λ wire with no phase reversal mechanism. The current magnitude curves also show the relative phase angle, and the change of phase is readily evident. Such an antenna in free space would show 4 lobes in a 2-dimensional E-plane pattern. Each lobe would angle about 45° from the line of the wire. Over ground, the lower lobes would reflect upward. The result would be very high-angle radiation, with virtually no radiation at or just above the ground line to the horizon. Such an antenna would be virtually useless for line-of-sight communications.

The three sets of current magnitude curves to the left show the patterns for the collinear arrays with phase-reversal methods in place. The leftmost pattern is for the coaxial-collinear model. Both of the center patterns are for the sub-collinear array. The second-from-left pattern is for an all-wire model, as the outline shows. The next pattern is for a special model.

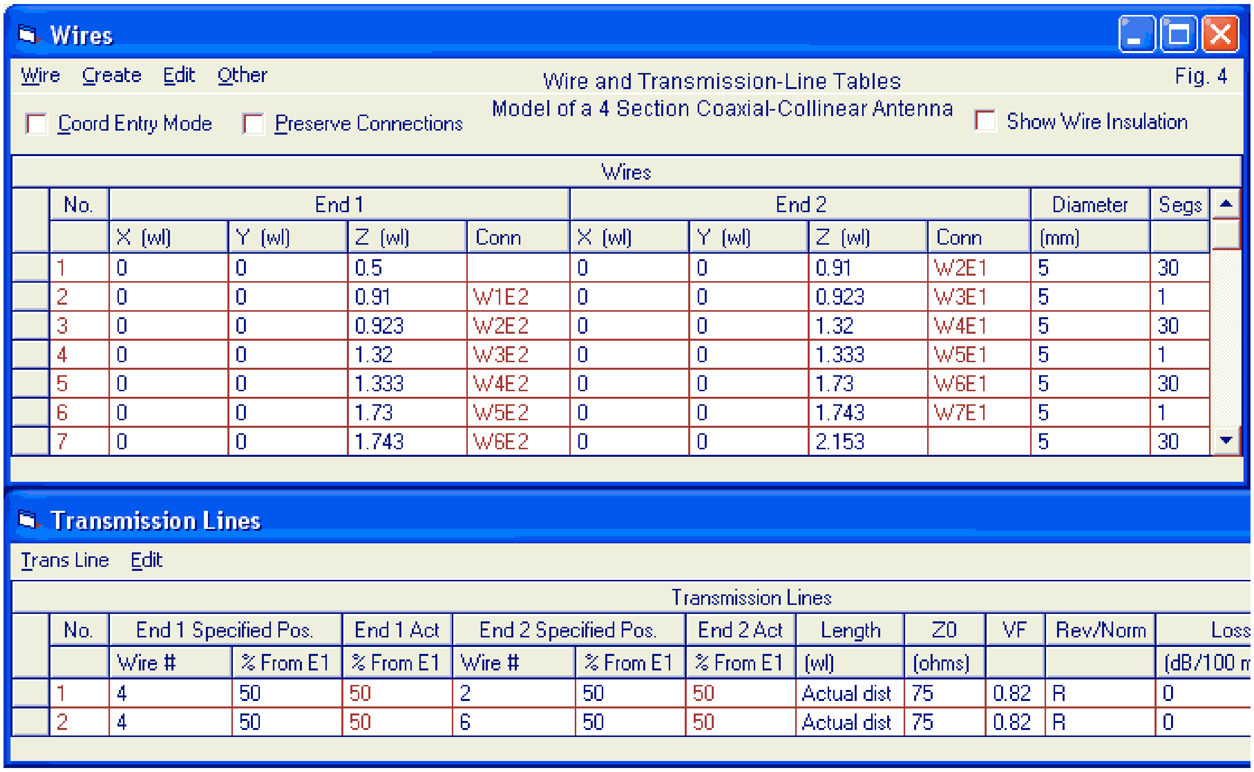


Current Magnitude Distribution on 3 Models
of a 4-Section Collinear Array

The Demidov model shows only the radiation current pattern on the stubs. Compare the stub current curves for both central models. The all-wire model shows both the transmission-line and radiation currents. By isolating the radiation currents, the Demidov model provides a view of the currents that are likely to produce extra lobes in the overall elevation pattern of the standard stub model when used over ground. In practice—dating as far back at the early 1970s or earlier—builders commonly wound the stub lines into a near circle around the central vertical wire to minimize any imbalance in the pattern. Such techniques tend to reduce higher-angle elevation lobes by 2 dB or more. For some details related to a slightly different antenna, see "The Case of the Curly Collinear" (http://www.cebik.com/vhf/cc.html).

Modeling Collinear Arrays

Each of the models of the collinear arrays carries with it a set of modeling restrictions and limitations. The coaxial-collinear array defies direct physical modeling in NEC (or MININEC), since the program cannot handle coaxial wire situations. However, some modelers have become adept at separating the transmission-line and the radiation functions of coaxially arranged wires, as illustrated by the EZNEC model shown in **Fig. 4**. The model uses a single wire segment (as long as any other segment in the model) as the center source or feedpoint segment. Moving away from this segment we find two longer ½-λ sections on each side of the feedpoint, with a short 1-segment wire between sections. These wires handle the radiation currents. To simulate the transmission-line functions, the modeler stretches a TL transmission line from the first section segment to the gap wire on each side of center. To ensure a phase reversal in the model, the line receives a reversal command, shown as an "R" in the transmission-line portion of the table. For this exercise, the example uses 75-Ω transmission-line with a velocity factor of 0.82. Note that the section lengths are about 0.41-λ long, since the transmission line dominates the current distribution. Since the end sections require no concern for the transmission line current phase angles, the model simply omits adding TLs to these sections. This model is derivative from a model received from Robert Moore, WB2L, who in turn received it from Roy Lewallen, W7EL. However, the more distant originating source of the modeling technique is not known.



Wires

Wire Create Edit Other

Wire and Transmission-Line Tables

Model of a 4 Section Coaxial-Collinear Antenna

Fig. 4

Coord Entry Mode — Preserve Connections — Show Wire Insulation

Wires

No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(mm)	
1	0	0	0.5		0	0	0.91	W2E1	5	30
2	0	0	0.91	W1E2	0	0	0.923	W3E1	5	1
3	0	0	0.923	W2E2	0	0	1.32	W4E1	5	30
4	0	0	1.32	W3E2	0	0	1.333	W5E1	5	1
5	0	0	1.333	W4E2	0	0	1.73	W6E1	5	30
6	0	0	1.73	W5E2	0	0	1.743	W7E1	5	1
7	0	0	1.743	W6E2	0	0	2.153		5	30

Transmission Lines

Trans Line Edit

Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(wl)	(ohms)			(dB/100 m
1	4	50	50	2	50	50	Actual dist	75	0.82	R	0
2	4	50	50	6	50	50	Actual dist	75	0.82	R	0

The model of the coaxial-collinear array is not a physical model of the antenna. Therefore, it is subject to numerous restrictions in use. Although the model is useful in showing the general properties of COCO arrays, we should not presume that it mirrors physical reality as closely as all-wire models of a stub-collinear array might. In this model, for example, the lines have not received values reflecting line losses—one of the newer features of EZNEC Version 5. As we shall see before we conclude these notes, the feedpoint impedance of the COCO model will be very sensitive to changes in the velocity factor, changes as small as 0.01. Because the model has no physical-model correlative, we cannot determine whether the sensitivity applies to physical implementations of COCO or whether it is simply an artifact of the particular substitute modeling technique.

All-wire versions of the stub-collinear array have correlations to physical reality, but nevertheless are subject to some restrictions. Due to the fact that the stub-collinear places the phase-reversal transmission lines at a high-voltage, low-current region of the antenna—where values change very rapidly with only small changes in wire length or position—the use of the NEC TL (transmission-line) facility is not recommended. Instead, the modeler should use transmission-line stubs created from wire. Essentially, the characteristic impedance of the stubs does not make any difference to the operation of the stub, since it will be ¼-λ long. Hence, the stub width can be a convenient value. The most convenient value for the model is the length of 1 wire segment, since all segments in the model should be about the same length. The shorting wire at the end of the stub determines the segment length for both the phase-line and the antenna wires. Since NEC tends toward errors with angular junctions of wires having different diameters, the stub wires should also have the same diameter as the antenna wires. **Fig. 5** shows the wire table for an EZNEC model of the all-wire stub-collinear illustrating these points.

Wires

Wire Create Edit Other

Wire and Transmission-Line Tables: All-Wire Model of a 4 Section Stub-Collinear Antenna

Fig. 5

Coord Entry Mode Preserve Connections Show Wire Insulation

Wires

No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(mm)	
1	0	0	0.5		0	0	0.97	W2E1	5	30
2	0	0	0.97	W1E2	0.24	0	0.97	W3E1	5	15
3	0.24	0	0.97	W2E2	0.24	0	0.984	W4E1	5	1
4	0.24	0	0.984	W3E2	0	0	0.984	W5E1	5	15
5	0	0	0.984	W4E2	0	0	1.433	W6E1	5	30
6	0	0	1.433	W5E2	0	0	1.447	W7E1	5	1
7	0	0	1.447	W6E2	0	0	1.896	W8E1	5	30
8	0	0	1.896	W7E2	0.24	0	1.896	W9E1	5	15
9	0.24	0	1.896	W8E2	0.24	0	1.91	W10E1	5	1
10	0.24	0	1.91	W9E2	0	0	1.91	W11E1	5	15
11	0	0	1.91	W10E2	0	0	2.38		5	30

To maintain as close a correlation among models as possible, the all-wire model of the stub-collinear array uses 5-mm diameter wire, as used also in the model of the coaxial-collinear array. The original modeler's selection likely rested on wishing to use 0.2"-diameter 75-Ω video cable for his antenna. Although exact dimensions may change for any implementation of a COCO or a stub-collinear array, the exact dimensions make little difference to our project to examine collinear array properties. Therefore, I also retained the same element diameter for the Demidov version of the model, which shows only the radiation currents on the stub. Vadim Demidov graciously supplied me with a different sort of substitute modeling technique that is useful for stub-collinear arrays. As the tables in **Fig. 6** show, the stub consists of a single ¼-λ wire. The transmission-line portion of the table-set shows why the technique works. Demidov reasoned that the ¼-λ stub operates as a perfect transformer, essentially transferring the current magnitude and phase angle from the end of an inner section to the start of an outer section. We can simulate such a transformer by using a near-zero-length transmission line between the last segment of the inner section wire and the first segment of the outer section wire. However, the stub also carries radiation currents. We simulate this function with a single wire at right angles to the antenna wire. As a result, the stub currents shown in **Fig. 3** differ between the two models of the stub-collinear array.

There is a difference worth noting between the substitute Demidov model and the substitute COCO model. The Demidov model of the stub-collinear array has an all-wire version of the model by which we can evaluate the modeling adequacy of the technique. In fact, using comparable wire diameters, lengths for both the antenna and stub wires, and virtually identical segmentation, the Demidov and all-wire models of the stub-collinear array correlate very well. In contrast, the COCO model lacks a corresponding all-wire model to use for evaluation. As a result, the level of confidence that we can assign to the COCO model remains well below the level that we can assign to the Demidov model. Nevertheless, the set of three models is enough to show some first-order similarities of performance that establish the coaxial-collinear antenna as a simple variant of the standard collinear array.

Wires

Wire Create Edit Other

Wire and Transmission-Line Tables: Demidov Model of a 4 Section Stub-Collinear Antenna

Fig. 6

Coord Entry Mode · Preserve Connections · Show Wire Insulation

Wires

No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(mm)	
1	0	0	0.5		0	0	0.95	W2E1	5	30
2	0	0	0.95	W5E1	0	0	1.4	W3E1	5	30
3	0	0	1.4	W2E2	0	0	1.85	W4E1	5	30
4	0	0	1.85	W6E1	0	0	2.3		5	30
5	0	0	0.95	W1E2	0.25	0	0.95		5	15
6	0	0	1.85	W3E2	0.25	0	1.85		5	15

Transmission Lines

Trans Line Edit

Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(wl)	(ohms)			(dB/100 m
1	1	100	98.3333	2	0	1.66667	1E-10	300	1	N	0
2	3	100	98.3333	4	0	1.66667	1E-10	300	1	N	0

Initial NEC Performance Reports

Table 1 summarizes the free-space data for each of the three model arrays. The table also contains data over average ground (conductivity 0.005 S/m, permittivity 13) when the base of the antenna is 0.5-λ above ground. Values may vary slightly, since the COCO antenna is slightly shorter than the stub arrays. AGT is the average gain test score, which leads to the corrected gain values. E-BW is the E-plane beamwidth in degrees.

Table 1. Free-space and over-ground performance of 4-section, center-fed collinear arrays

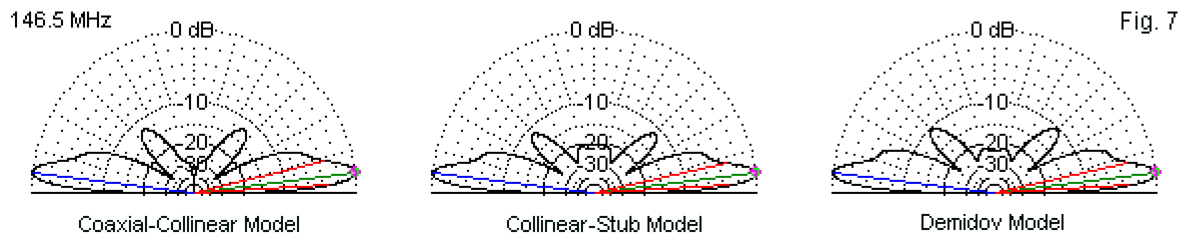
Free-Space

Type	Gain dBi	AGT	Cor. Gain dBi	E-BW degrees	Feedpoint Z R +/- jX Ω
COCO	5.76	1.005	5.74	29	644 + j195
All-Wire Stub	5.82	1.008	5.79	27	850 – j92
Demidov Stub	5.76	1.001	5.76	29	832 – j71

0.5-λ over Average Ground

Type	Cor. Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω	Second Elevation Lobe El. Angle	Strength
COCO	6.70	7.3	643 + j194	51°	-12.0 dB
All-Wire Stub	6.96	6.8	850 – j93	43°	-11.2
Demidov Stub	6.88	6.9	832 – j71	45°	-10.4

Given the differences in modeling techniques, the basic performance of the antennas is virtually the same with respect to gain, the TO angle, the E-plane beamwidth, and the strength of the second elevation lobe. The Demidov and the all-wire source impedance values agree well. The lower figure for the COCO model may result from its shorter length overall (2.15-λ vs. 2.3-2.4-λ), or it may result from the substitute modeling technique.



Elevation Patterns: 4 Section Collinear Vertical Arrays
Antenna Base 0.5-Wavelength Above Average Ground

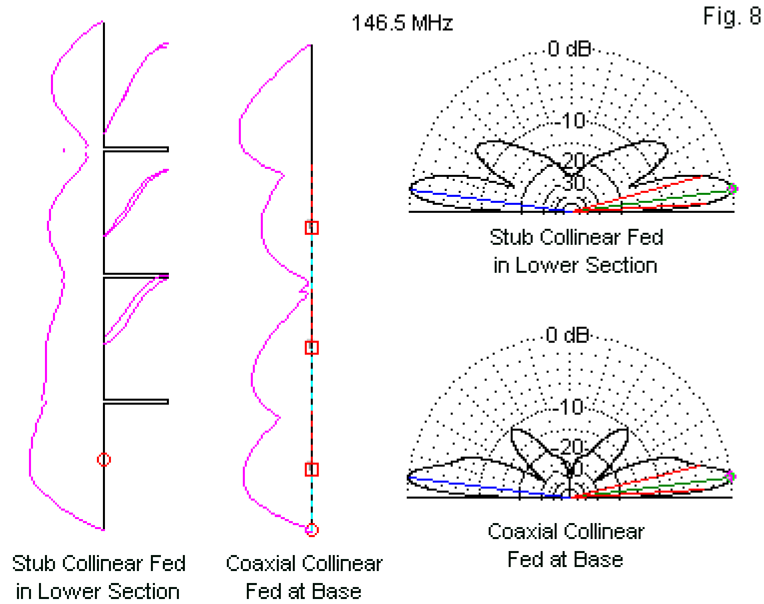
Fig. 7 provides a gallery of elevation patterns for the three models. The key difference among the patterns lies in the small upward lobe structure for the two stub models. The upward lobes likely result from the radiation currents in the horizontally oriented stub wires. The similarity between the all-wire and the Demidov patterns is an indication that the all-wire model has only the radiation currents of the Demidov model, even though the total wire current curves (including both transmission-line and radiation currents) might give an alternative impression. A second function performed by the small upward lobes is to force the angle of the second elevation lobes downward by about 5° relative to those in the COCO model. Of course, the COCO model lacks any horizontal wires to create the small upward lobes, as shown by the deep null on the COCO pattern at an elevation angle of 90°.

The results of our initial modeling inform us that the coaxial-collinear array is in the same class as and has similar performance to other variations of collinear arrays. It does not live up to any reputation as a miracle array, a reputation that exists only in amateur lore about the antenna. The antenna may have other advantages, but raw performance is not one of them—once we place the antenna in the proper category and use relevant comparators.

Lower-Section Feeding of 4-Section Collinear Arrays

The exercise so far has had an air of artificiality to it, since we have used center-fed vertical collinear arrays in all cases. Suppose that we try to feed the array at a lower point, as might well be the general case for vertical antennas above ground or a ground plane. In this arena, the benefits of the coaxial-collinear begin to show themselves. For example, with a bare-wire stub-collinear array, we would normally place the feedpoint at the approximate center of the lower section. Therefore, we would need to add a new stub to replace the old feedpoint connection. The left-hand outline in **Fig. 8** shows the antenna revision.

In contrast, as suggested by the Wheeler version of the coaxial-collinear array, the normal COCO feedpoint is at the very base of the antenna. The model requires a TL transmission line from the feedpoint segment to the first gap in addition to those for the second and third sections of the antenna. (Note that I have not successfully modeled the Wheeler shorting pin in the top section of the array, since it does not appear to be compatible with the substitute modeling method. As well, I have not found an effective way to model the three Wheeler rods. Nevertheless, the limited base-fed model used here is sufficient to provide a relevant comparison to the all-wire stub-collinear array fed at the center of the lowest section.)



Outlines, Current Distribution, and Elevation Patterns of Collinear Antennas with Feedpoint Moved to a Low Position

The data from the two models appears in **Table 2** for models in free space and ½-λ above average ground at the antenna base.

Table 2. Free-space and over-ground performance of 4-section, base-fed collinear arrays

Free-Space

Type	Gain dBi	AGT	Cor. Gain dBi	E-BW degrees	Feedpoint Z R +/- jX Ω
COCO	5.75	1.004	5.73	29	630 + j150
All-Wire Stub	5.75	1.002	5.74	29	313 + j1

0.5-λ over Average Ground

Type	Cor. Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω	Second Elevation Lobe El. Angle	Strength
COCO	6.75	7.1	630 + j149	49°	-10.5 dB
All-Wire Stub	5.90	8.1	313 + j2	34°	-6.1

Differences between the two antennas in free-space seem to be negligible, but over ground, the elevation patterns and the data show significant variation. COCO has a full-dB gain advantage and a lower TO angle. The explanation for the differences become at least semi-apparent from an examination of the current curves attached to the outlines in **Fig. 8**. COCO maintains good symmetry around its center point, despite the change in the source position. In contrast, the stub version shows higher current levels lower in the overall antenna structure. It is possible to alter the structure of the stub-collinear to achieve more equal currents in all section, but the process is both tedious and a problem to replicate when fabricating the antenna. In fact, when I first built a 4-section collinear array in the 1970s, it failed to live up to expectations, most likely for the reasons made clear by the current distribution curves. The coaxial-collinear array maintains a good level of symmetry with strong radiation from the highest section as well as to lowest section. In fact, the high-section radiation leads us to another alternative possibility for similar performance to COCO.

In-Phase-Fed Dipoles

Let's consider briefly two simple vertical dipole elements fed in phase and spaced 1-λ apart at the centers. The 1-λ spacing tends to yield close to the maximum gain that we can achieve from such a pair of dipoles. If we place the lower dipole 1-λ above ground at its center, the base (with a 5-mm-diameter element) will be about 0.76-λ above ground. The top of the pair will be 2.24-λ above ground, about the same height as the 4-section COCO array. **Table 3** shows the results of the modeling both in free space and over average ground. The table includes the results for the base-fed COCO array for comparison.

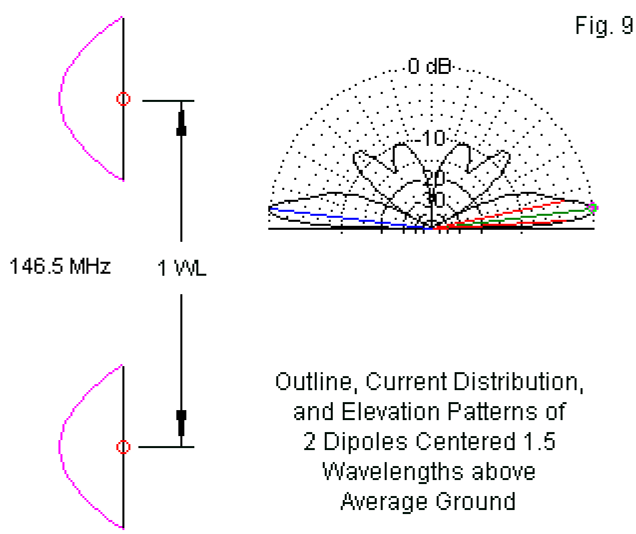
Table 3. Free-space and over-ground performance of a coaxial-collinear array and 2 dipoles

Free-Space

Type	Gain	AGT	Cor. Gain	E-BW	Feedpoint Z
	dBi		dBi	degrees	R +/- jX Ω
COCO	5.75	1.004	5.73	29	630 + j150
Dipoles	5.40	0.999	5.40	27	67 – j2 (x2)

0.5-λ over Average Ground

Type	Cor. Gain	TO Angle	Feedpoint Z	Second Elevation Lobe	
	dBi	degrees	R +/- jX Ω	El. Angle	Strength
COCO	6.75	7.1	630 + j149	49°	-10.5 dB
Dipoles	6.78	7.0	67 – j2 upper 66 – j2 lower	45°	-7.1



The set of dipoles, as outlined in **Fig. 9**, shows slightly lower gain in free-space than the based-fed COCO, but equal low-angle performance above ground. As the dipole-pair elevation pattern shows, the dipoles have stronger and more complex high-angle lobes than COCO, but the lowest lobe is virtually identical to the corresponding COCO lobe. The differences between the two alternatives come down to matters of construction and feeding.

The dipole pair, of course, requires a coaxial-cable "harness" to assure correct in-phase feeding. As well, the dipoles require a means of support that will not disturb the omni-directional pattern of the array. In contrast, the coaxial-collinear array requires careful construction and a weatherproof housing. In addition, COCO requires a method of converting the relatively high feedpoint impedance to the characteristic impedance of a standard coaxial-cable feedline.

The model of the coaxial-collinear array shows a feature that is at once disturbing and uncertain. As we noted earlier, the model is a substitute for a physical wire model that NEC cannot produce due to its inability to handle directly wires in a coaxial situation. Hence, we cannot definitively ascribe the phenomena at the feedpoint to the array itself, since they might also be simply artifacts of the modeling technique. Nevertheless, the model shows a disturbing variation in the reported feedpoint impedance with very small variations in the velocity factor assigned to the transmission line. **Table 4** shows the reported differences in the performance values as we vary the velocity factor from 0.84 down to 0.80 with no other changes in the model.

Table 4. Variations in reported COCO performance 0.5-λ over average ground with small variations in coaxial cable velocity factor with a constant 75-Ω characteristic impedance

Velocity Factor	Gain	TO Angle	Feedpoint Z	Second Elevation Lobe	
	dBi	degrees	R +/- jX Ω	El. Angle	Strength
0.84	6.76	7.3	105 + j236	49°	-10.6 dB
0.83	6.75	7.1	240 + j315	49°	-10.5 dB
0.82	6.75	7.1	630 + j149	49°	-10.5 dB
0.81	6.76	7.2	445 – j310	49°	-10.5 dB
0.80	6.77	7.3	163 – j280	49°	-10.7 dB

As the data show, virtually nothing changes except the feedpoint impedance. The impedance most closely approaches self-resonance at the design velocity factor. At all other values, the resistive component drops in value. At the same time, the reactive component increases in value, resulting in ratios of reactance to resistance that are likely to narrow the operating bandwidth for normal matching methods. The total change in the velocity factor in the table is under 5%. In practice, variations of this order are common relative to the difference between the measured and the listed values of velocity factor for a given line.

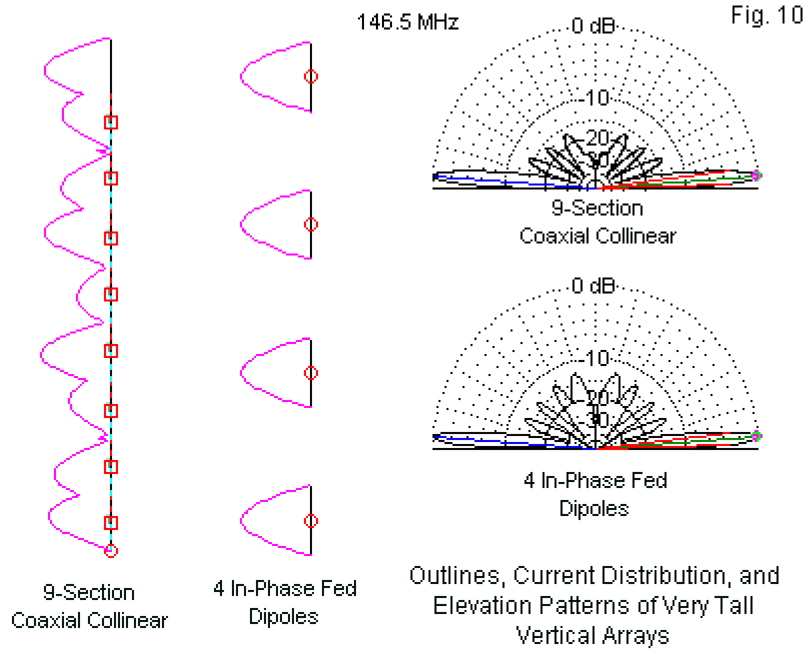
If the phenomenon holds true of a physical implementation of the coaxial-collinear array, then the effect is to move the self-resonant frequency by about 1.5 MHz with each 0.01 change in the velocity factor, with lower velocity factors producing lower self-resonant frequencies. The result is an antenna that requires the utmost care in pre-construction line measurements and in fabrication to arrive at satisfactory performance. However, this consequence only follows from the premise that the substitute COCO model is a reasonably accurate representation of the array's physical performance, a premise that we cannot test via modeling software.

Bigger (and Better?) COCOs

If a 4-section coaxial-collinear array is good, then a 9-section version should be better. If we limit the base height to 0.5-λ above ground, the performance improvement ought to be greater than 3-dB, since the top height will increase considerably. To test this hypothesis, I increased the size of the 4-section, based-fed version of the array to 9 sections by the simple expedient of adding sections of both wire and transmission line. The expanded antenna now extends from

0.5-λ to 4.18λ. **Fig. 10** shows the outline of the large array. The total antenna length at 146.5 MHz is about 24.5'.

The sketch also shows the outline of 4 dipoles fed in phase, a simple means of providing a comparator for the large version of COCO. The dipoles have center heights of 1-λ through 4-λ in 1-λ increments. Hence, the dipole array extends from 0.76-λ up to 4.24-λ. We shall assume a satisfactory cable harness that yields in-phase feeding.



Outlines, Current Distribution, and Elevation Patterns of Very Tall Vertical Arrays

As we add sections to COCO while using a base feedpoint, the current curves remain in phase, but the maximum current values tend to show greater variation. However, the overall pattern remain quite symmetrical about the center point of the array so that we have high current values at the top of the array as well as lower down the collection of sections. **Table 5** shows the results of modeling both arrays in free-space and above average ground.

Table 5. Free-space and over-ground performance of a 9-section coaxial-collinear array and 4 dipoles

Free-Space

Type	Gain dBi	AGT	Cor. Gain dBi	E-BW degrees	Feedpoint Z R +/- jX Ω
COCO	8.91	1.002	8.90	13	177 + j137
Dipoles	8.62	0.999	8.62	13	62 – j2 (center dipoles)
					66 – j2 (top/bottom dipoles)

0.5-λ over Average Ground

Type	Cor. Gain dBi	TO Angle degrees	Feedpoint Z R +/- jX Ω	Second Elevation Lobe El. Angle	Strength
COCO	10.66	4.3	187 + j134	24°	-14.0 dB
Dipoles	10.59	4.0	65 – j2 bottom	79°	-13.0
		(62 – j2 second, 62 – j2 third, 66 – j2 top)			

As the data and the elevation patterns show, there is very little difference in the performance of the two arrays compared in this sample. The large-base-fed model of COCO is self-resonant with a velocity factor assignment of 0.814, with a resistive impedance of about 290 Ω. Essentially, the large version of the coaxial-collinear array follows the same pattern as the smaller version with respect to impedance shifts with small changes in the velocity factor of the line—at least within the confines of the limited model that is possible within NEC. For reference, **Fig. 11** shows the wire and transmission-line tables of the original model used to develop the tabular data.

Wires

Wire Create Edit Other

Wire and Transmission-Line Tables
9-Section Coaxial Collinear Antenna

Fig. 11

☐ Coord Entry Mode ☐ Preserve Connections ☐ Show Wire Insulation

Wires

No.	End 1				End 2				Diameter	Segs
	X (wl)	Y (wl)	Z (wl)	Conn	X (wl)	Y (wl)	Z (wl)	Conn	(mm)	
1	0	0	0.5		0	0	0.897	W2E1	5	30
2	0	0	0.897	W1E2	0	0	0.91	W3E1	5	1
3	0	0	0.91	W2E2	0	0	1.307	W4E1	5	30
4	0	0	1.307	W3E2	0	0	1.32	W5E1	5	1
5	0	0	1.32	W4E2	0	0	1.717	W6E1	5	30
6	0	0	1.717	W5E2	0	0	1.73	W7E1	5	1
7	0	0	1.73	W6E2	0	0	2.127	W8E1	5	30
8	0	0	2.127	W7E2	0	0	2.14	W9E1	5	1
9	0	0	2.14	W8E2	0	0	2.537	W10E1	5	30
10	0	0	2.537	W9E2	0	0	2.55	W11E1	5	1
11	0	0	2.55	W10E2	0	0	2.947	W12E1	5	30
12	0	0	2.947	W11E2	0	0	2.96	W13E1	5	1
13	0	0	2.96	W12E2	0	0	3.357	W14E1	5	30
14	0	0	3.357	W13E2	0	0	3.37	W15E1	5	1
15	0	0	3.37	W14E2	0	0	3.767	W16E1	5	30
16	0	0	3.767	W15E2	0	0	3.78	W17E1	5	1
17	0	0	3.78	W16E2	0	0	4.177		5	30

Transmission Lines

Trans Line Edit

Transmission Lines

No.	End 1 Specified Pos.		End 1 Act	End 2 Specified Pos.		End 2 Act	Length	Z0	VF	Rev/Norm	Loss
	Wire #	% From E1	% From E1	Wire #	% From E1	% From E1	(wl)	(ohms)			(dB/100 m
1	1	0	1.66667	2	50	50	Actual dist	75	0.82	R	0
2	2	50	50	4	50	50	Actual dist	75	0.82	R	0
3	4	50	50	6	50	50	Actual dist	75	0.82	R	0
4	6	50	50	8	50	50	Actual dist	75	0.82	R	0
5	8	50	50	10	50	50	Actual dist	75	0.82	R	0
6	10	50	50	12	50	50	Actual dist	75	0.82	R	0
7	12	50	50	14	50	50	Actual dist	75	0.82	R	0
8	14	50	50	16	50	50	Actual dist	75	0.82	R	0

Once more, the gain of the coaxial-collinear array is a function of the antenna's total length and top height. The array of 4 dipoles roughly equals this performance level, since it matches the collinear array in the two vital statistics, total length and top height. The decision as to which direction one should go in developing an antenna with the listed performance rests largely on the methods of construction and feeding with which one is most comfortable.

Conclusion

These notes have not tried to recommend or dis-recommend the coaxial-collinear array (at any size). The tentativeness of the modeling techniques precludes such conclusions. Instead, I have tried to place COCO among its proper class of antennas, in part to dispel the amateur reputation that it is somehow a miracle antenna. Instead, it turns out to be a straightforward and venerable member of the class of collinear arrays, with just about the performance of other members of the class. Indeed, as we discovered in our consideration of phase-fed vertical dipoles, the coaxial-collinear array has only the gain that its length and height permit for virtually any array in which all of the section are in phase with each other. The COCO array does have both advantages and disadvantages relative to construction and feeding relative to other alternatives. On these factors will rest an ultimate decision whether to build one for FM repeater service on one of the amateur bands.

References

H. A. Wheeler, "A Vertical Antenna Made of Transposed Sections of Coaxial Cable," *IRE Cons. Rec.*, Vol. 4, Pt. 1, 1956 (pp. 161-164)

P. V. Hendel, W. Pfister, "Ausbritung der Mikrostrahlen," *Zentrale fur Technischwissenschaftliches Berichtwesen uber Luftfahrtforschung*, Germany, Res. Rep., FB 338, May 9, 1935

S.I.F. Fayard, Au Brevet d'Invention No. 782,901, "Perfectionnements aux antennas de T.S.F.," Ministry of Commerce and Industry, France; patent published September 12, 1935

W. Moser, H. E. Paul, "Antenna Systems," U.S. Patent 2158376, April 28, 1936-May 16, 1939

Judasz, Thierry, J. and Balsley, Ben, B., "Improved Theoretical and Experimental Models for the Coaxial Collinear Antenna," *IEEE Transactions on Antennas and Propagation*, VOL. 37 NO. 3 March 1989, pp. 289-296

Pozar, D., "Directivity of Omnidirectional Antennas," *IEEE Antennas and Propagation Magazine* (Antenna Designer's Notebook), Hal Shrank ed. VOL. 35 NO. 5 October 1993, pp. 50-51

Bancroft, R., and Bateman, B., "An Omnidirectional Planar Microstrip Antenna," *IEEE Transactions on Antennas and Propagation*, 2004, vol. 52, no. 11, p. 3151-3153.