Preface to SCVs

In 1998, I published a series of short articles on SCV antennas in *The National Contest Journal*. Nearly a decade has gone by, and I still receive questions about these interesting antennas. Therefore, I decided to return to ground zero and re-formulate the information in those articles—and much, much more—to create this volume. I have expanded coverage in terms of several factors: the fundamentals upon which SCVs operate, antenna types that fit within the group, frequency coverage, and special applications and opportunities.

What is an SCV?

The letters SCV are an abbreviation for self-contained vertical. Although I generally do not favor adding terms to the lexicon of antennas, circumstances in the late 1990s led me to introduce the term. First, a debate was going on within amateur circles about whether all vertical antennas, especially those near to the ground, required a ground radial system in order to perform correctly. That discussion has largely ended, as folks began to understand some of the distinctions that mark talk about the ground relative to various parts of an antenna system.

Second, many amateurs seemed not to realize the close inter-relationship among members of the SCV family, let alone the fundamentals of their operation. Even the highly regarded compendium called *Low-Band Dxing* by ON4UN (John Devoldere) scattered members of the family in separate chapters (10 and 12) of his book (2nd Edition). In order to create a family union, I coined the term SCV.

An SCV is a self-contained vertically polarized antenna, usually constructed from copper wire for upper MF and lower HF use. Most basic family members use 1-λ of wire for the antenna structure, although there are also doubles and even larger members of the family. Among the basic SCV shapes are deltas (triangles), diamonds, rectangles, and open-ended versions (the half-square). **Fig. 0-1** shows some (but not all) of the basic family members.

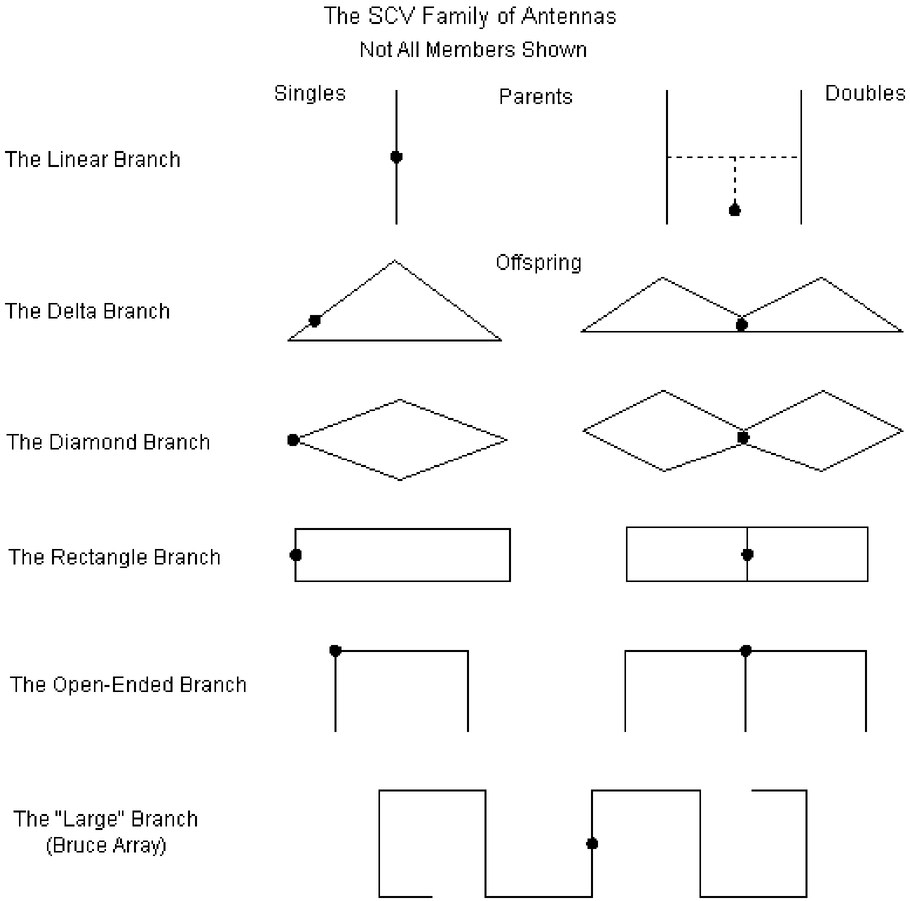


Fig. 0-1

None of the SCV family requires a buried or surface ground radial system. Such systems are necessary with vertical monopoles, since the radials form a portion of the antenna structure. The SCV family members are each complete in themselves. We shall have occasion along the way to see what a ground radial system and other forms of ground treatment may do for this collection of antennas.

The SCVs are offspring of more basic antennas, indicated at the top of **Fig. 0-1**. All basic or single members of the family are forms of phased vertical dipoles, called a double in the figure. Of course, phased vertical dipoles derive from the single vertical dipole, the most fundamental vertically polarized antenna of all. (Despite the fact that much antenna lore begins with the ¼-λ vertical monopole and its radial system, we shall treat the monopole and its radials as a version of the dipole.) One consequence of using the vertical dipole as our fundamental antenna is that this volume will not discuss monopoles and their radials systems. For information on these types of antennas, consult *Ground-Plane Notes* published by *antenneX*.

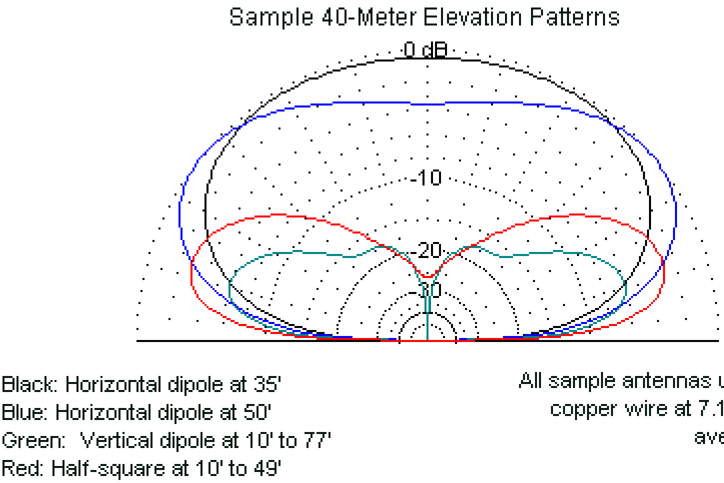
The offspring of the vertical dipoles have a special feature: they all use a single feedpoint. The reduction in the number of feedpoints simplifies questions of matching the antenna to a desired feedline. However, that same fact presents some challenges, because for many SCV users, a 50-Ω coaxial cable is the favored transmission line. This fact alone has a role in shaping some of the SCVs in the collection.

Why Use an SCV?

The primary realm for the SCV is the upper MF region (160 meters) and the lower HF region (80 through 30 meters). Although we shall examine some special VHF and UHF applications for SCVs, the primary motivation for turning to the SCV designs was to improve performance of vertically polarized antennas without requiring a complex and often uncertain phasing system to interconnect vertical elements. In addition, all of the SCV designs require only inexpensive copper wire.

Fig. 0-2 presents a few overlaid elevation patterns for some typical 40-meter antennas. Within the group is a pair of wire horizontal dipoles, one at the amateur average backyard height of 35’, the other at a more beneficial 50’ level. The elevation angle of maximum radiation depends upon the antenna height as measured in wavelengths. Even the higher dipole is only about 0.7-λ high on the sample frequency.

Fig. 0-2



The figure also contains the elevation pattern for a wire vertical dipole that extends from 10’ to about 77’ above ground. Its pattern is omni-directional, and therefore we expect lesser gain in any particular direction. However, the SCVs are all bi-directional, as are the horizontal dipoles. The half-square is the representative SCV for this exercise. We may note that below 20°, the region most favorable to DX skip, the half-square has more gain than either of the two dipoles. In addition, both of the vertical antennas have very weak far-fields at high angles, which is often a source of QRN. Hence, many operators from 160 through 30 meters prefer vertical antennas as much for their quietness as for their low-angle gain. (Of course, there are noise sources, usually local, that may affect vertically polarized antennas more than horizontal antennas. Hence, one may not reap the benefits of the SCV at every possible location for an amateur installation, where control of local noise sources may range from limited to none.)

The SCV does not pretend to compete with directional beams that are at least ½-λ above ground. Unfortunately, that height becomes more difficult to achieve as we lower the operating frequency. For reference, **Table 0-1** lists the height of 1 λ, ½ λ, and ¼ λ in both feet and meters for the lowest amateur bands.

Table 0-1. Heights of a wavelength and some fractions of a wavelength at typical amateur "low-band" frequencies

Band	Frequency	Height in Feet			Height in meters		
Meters	MHz	1 λ	0.5 λ	0.25 λ	1 λ	0.5 λ	0.25 λ
160	1.85	531.66	265.83	132.92	162.05	81.03	40.51
80	3.55	277.06	138.53	69.27	84.45	42.22	21.11
75	3.95	249.01	124.50	62.25	75.90	37.95	18.97
60	5.368	183.23	91.61	45.81	55.85	27.92	13.96
40	7.15	137.56	68.78	34.39	41.93	20.96	10.48
30	10.125	97.14	48.57	24.29	26.61	13.30	6.65

In the end, an SCV is a practical antenna. In absolute terms, it is far from the perfect radiator. Nevertheless, when we add in a healthy dose of realism in the form of acreage and height restrictions that surround the average amateur installation, it may become the perfect practical choice for a given situation.

How Shall We Study the SCV?

A wide-ranging survey of antenna types calls for a systematic means of study. Antenna modeling software is the obvious tool for the investigation for two reasons. First it permits a rapid survey of antenna performance potential in a variety of situations in which we may vary the soil quality, the antenna size and height above ground, and the wire size. Second, modeling software is completely reliable with respect to these antennas because the antenna construction does not press any of the limits of most modeling software. The software of choice for these notes is NEC-4. For most models, NEC-2 would do very well. However, a few models used in the study will involve buried radial systems, which only NEC-4 can handle. Most of the models used in this study will employ EZNEC Pro/4.

Models carry with them a few notable presumptions that may vary from an average amateur installation. Foremost among variables is the amount of ground clutter in the immediate area of the antenna. The models will contain no clutter to adversely interact with the antenna. Most amateur antenna sites are not so fortunate. In fact, trees and posts that already exist in a yard may be necessary as supports for an SCV. All that I can do is give somewhat abstract advice: keep the vertical radiators of the antenna as far as feasible from conductive or semi-conductive objects, especially vertical ones. As well, keep the broadside areas of the antenna's fields as free of vertical objects as possible. Among the SCV designs, we shall note that some versions show a higher gain potential than others. Anecdotal reports sometimes reverse the order in terms of successful operation. In many, if not most, cases, the reversal arises from the difference in the antenna geometries relative to interactions with nearby objects.

We shall divide the work in each chapter or set of chapters into different categories. The first or initial foray into an SCV design will examine general principles. To even the playing field for all such initial entries, I shall use a standard frequency (7.15 MHz), a standard wire size (copper AWG #12 or 0.0808" diameter), and a standard ground (average: conductivity 0.005 S/m, permittivity 13).

Next, we shall examine some factors that contribute to SCV effectiveness for selected bands. Here, I shall use 160, 80, and 40 meters (1.85, 3.55, and 7.15 MHz) as targets, as we examine how SCV dimensions and height above ground influence performance—and with what rates of changes as we vary these dimensions. We shall have occasion to see changes (or their absence) as we vary the soil quality. **Table 0-2** lists the three standard soil qualities that we shall use.

Table 0-2. Standard soil quality parameters for SCV tests

Soil Label	Conductivity (S/m)	Relative Permittivity
Very Good	0.0303	20
Average	0.005	13
Very Poor	0.001	5

We may in fact perform the category-2 survey more than once, since some of the antennas have both single and double versions.

The final category of investigation is for each SCV a potpourri of special considerations. Some of them may involve methods of feeding the wire antenna. In addition, we shall look at extended applications. Many of the SCV forms that we think of as lower HF antennas also have VHF and UHF applications. We shall examine those applications only far enough to show their intimate relationship to the wire versions that form main object of study.

Attached to this volume is a collection of models in EZNEC (.EZ) formats. The Appendix provides the dimensions for each basic (1-λ) SCV form. The collection cannot include the hundreds of models and variations required to perform the surveys. Instead, for each type of SCV, I shall include what I believe to be an optimized version of the antenna using AWG #12 copper wire over average ground. These models will provide a foundation for antenna installation planning and a vehicle for modification in case you wish to replicate any of the surveys that appear here. I recommend that you transfer the files to your hard drive before opening them so that you can save any interesting variations.

What Is the Plan of Attack?

Since all SCVs rest on a foundation anchored by the vertical dipole, Part 1 of the study will examine some of the basic properties of this antenna, especially as the behavior of the vertical dipole over ground differs from the behavior of its horizontal brother. Chapter 1 will look at the single vertical dipole. As simple as the antenna may be, as shown by the omni-directional pattern in **Fig. 0-3**, it may still contain a few surprises for amateurs who have experience only with horizontal dipoles. We shall see how elevation patterns change as we alter the height above ground. As well, we shall discover whether a ground radial system beneath the antenna has a significant affect on its performance. In fact, we shall digress into a discussion of different types of ground as they apply to different aspects of antenna performance, with special attention to various methods of feeding the vertical dipole—at its center and at its base, either with a high-impedance circuit or network or with a transmission line section (the J-pole). We shall even briefly explore how to bend the vertical dipole to form an inverted-L.

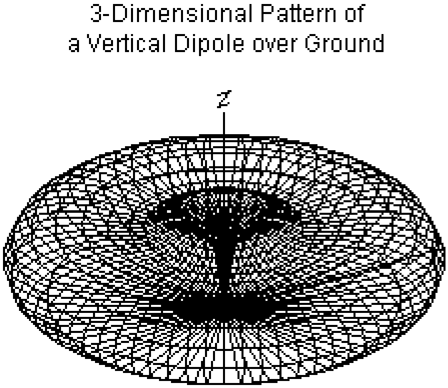

3-Dimensional Pattern of
a Vertical Dipole over Ground

Fig. 0-3

In Chapter 2, we shall expand our view of vertical dipoles to include 2 or 3 of them in a line, all fed in phase. **Fig. 0-4** shows the bi-directional pattern for 2 such dipoles over ground. We shall want to find the conditions for optimizing the pattern and to learn of any limitations associated with the technique.

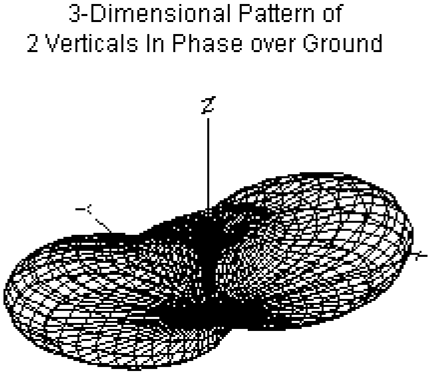

3-Dimensional Pattern of
2 Verticals In Phase over Ground

Fig. 0-4

Not all uses of multiple vertical dipoles involve feeding every element. We shall briefly look at some ways to create parasitic beams, including triangular arrays that allow an operator to cover the full horizon with a switch rather than a rotator. Finally, we shall explore an “ideal“ vertical array in which the parasitic elements are pseudo-guy wires.

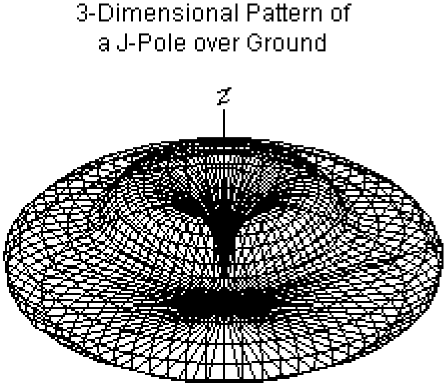
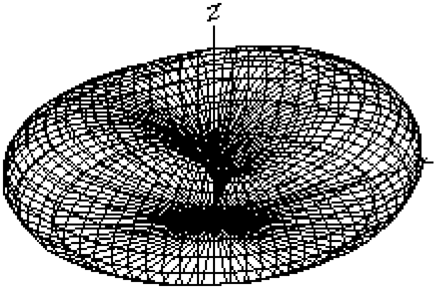


Fig. 0-5

The final chapter of Part 1 will introduce special considerations that apply to the use of the vertical dipole in VHF and UHF service. For example, the antenna height is many times that of the same antenna in the lower HF region, and that fact will make a large difference in the patterns that we obtain. We shall also explore the use of radials with such antennas, with emphasis on the relationship of a so-called sloping-radial monopole to a true vertical dipole. The J-pole that has such limited use in the HF region (see **Fig. 0-5** for a representative pattern) becomes commonplace. As well, we can create antennas in the VHF and UHF region that low-band operators can only dream about, such as collinear vertical dipoles.

Part 2 of our work takes us into the region of SCVs, understood as resting on a 1-λ length of wire in fundamental forms. We shall examine them in roughly an ascending order of performance potential. See **Fig. 0-1** to review the basic SCV shapes. Chapter 4 begins with the delta or triangular form, a pattern for which appears in **Fig. 0-6**. We shall look at both the physical and performance differences between the two most common delta forms: the equilateral and the right triangle. The exercise will help us understand just how all SCVs work. The delta has a doublewide variation, and we shall look at its requirements and its promise of improved performance.



3-Dimensional Pattern of
a Delta Loop over Ground

Fig. 0-6

The side-fed square diamond loop is an alternative to the delta. However, in the lower HF region, few amateurs have experimented with stretching the loop into an elongated diamond form both to increase the gain and to lower the impedance to coax-compatible values. **Fig. 0-7** shows the pattern for such an antenna. We shall discover how far we may stretch a diamond before we lose the benefits of the process. Even less common in the lower HF region are double diamond arrays with a single feedpoint. The rarest form of the diamond is a single or a double used in conjunction with a planar reflector to obtain a directional beam with broader-band characteristics than we can obtain from either the driver alone or from a parasitic diamond array. However rare these forms are in the HF region, they are commonplace in the UHF spectrum. We shall sample some of those potentials.

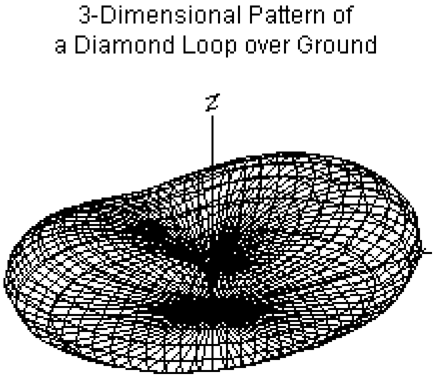
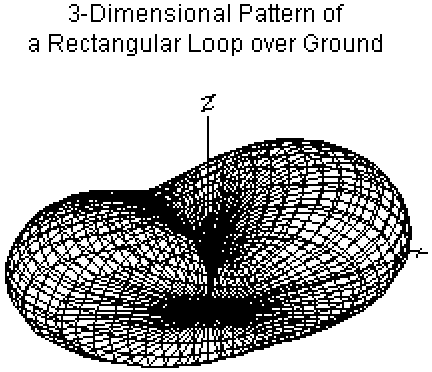

3-Dimensional Pattern of
a Diamond Loop over Ground

Fig. 0-7

Chapter 6 investigates a different form of SCV also derived from the side-fed square quad loop. This time, we begin with a square, with two wires parallel to ground and two wires vertical. If we stretch the loop parallel to the ground and shrink its height, we increase the gain and lower the side feedpoint impedance. **Fig. 0-8** gives us a representative pattern. In principle, stretching the square into a rectangle does the same job as stretching the diamond into an elongated diamond. Nevertheless, there are some interesting differences. For example, maximum gain for a stretched rectangle requires a shape that yields very low impedance values. One answer to this potential matching problem is to double the rectangular winding to create a parallel transmission line. The result is a multiplication of the feedpoint impedance by a factor of 4, creating a better match for the ubiquitous coaxial cable feedline. Alternatively, we may create a doublewide rectangle for additional bi-directional gain. We shall look at potential feedpoint positions for this long and thin array. Unlike the diamond, we may also create asymmetrical double rectangles (a generalized term coined by Dan Handelsman, N2DT). The most common version is the horizontally polarized hentenna. However, we may easily lay the antenna on its side and acquire its benefits with vertical polarization.



3-Dimensional Pattern of
a Rectangular Loop over Ground

Fig. 0-8

All of the SCV versions that we have examined so far use closed loop structures. However, we may open the loop and obtain a better phase relationship between the vertical elements. The half-square is the most fundamental version of this technique, even though it appeared in amateur literature after the development of its doublewide big brother, the bobtail curtain. **Fig. 0-9** provides a representative pattern for the half-square. Fundamental theory tells us that the horizontal sections of each antenna should be ½-λ, while the verticals should be ¼-λ. However, we shall discover that these rough dimensions require considerable variation in order to achieve maximum performance. Moreover, the ratios required for vertical to horizontal sections are not the same for the half-square and the bobtail curtail. Among all of the SCV forms, the half-square and the bobtail curtain lend themselves best to the creation of parasitic beams. In fact, we may even create reversible beams using the half-square. Like all SCV forms, the half-square and the bobtail curtain have VHF and UHF applications, especially with planar reflectors. Both of these open-ended forms of the SCV also allow us some versatility in feeding them. We can feed the antenna at the upper junction with horizontal wire for a low-impedance system. Alternatively, we can feed one of the verticals at the lower end using standard high-impedance techniques. In the earliest days of their lives, high-impedance feed systems were most common.

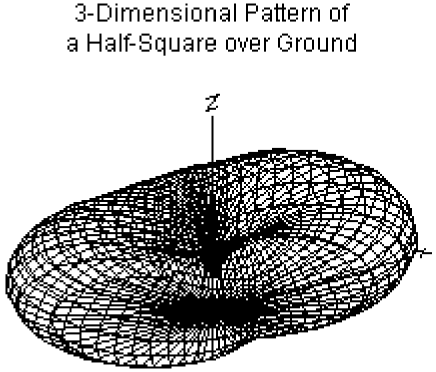


Fig. 0-9

Our final chapter works with an array that we might not think of as an SCV had we skipped the half-square. The Bruce array, whose pattern appears in **Fig. 0-10** is an open-ended array with indefinitely great potential.

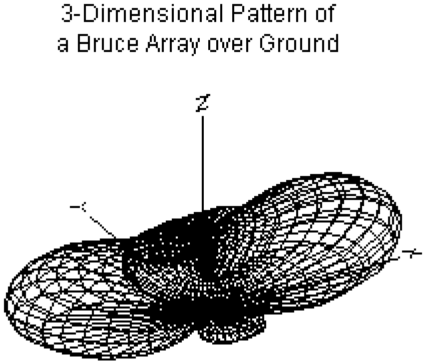


Fig. 0-10

The outline sketch of the Bruce array appears in only one guise in **Fig. 0-1**. It has 5 vertical sections, using a center feedpoint for the systems. Hence, many Bruce arrays use an odd number of sections. 4- and 5-section arrays are the most common amateur forms. The end wires point inward, although we can easily point them outward as well. The twist on the Bruce array is that it is ¼-λ tall, with ¼-λ between vertical wires. Hence, in its most rudimentary form, it is a side-fed quad that forgot to turn back upon itself. The result is a relatively high-gain array with a narrowing beamwidth as we increase the number of sections.

Like the Bruce array, our investigation is unending in principle. As a practical matter, we must draw these notes to a close somewhere, and the Bruce array is as appropriate a point as any. However, this preliminary survey has only begun our detailed look at SCVs and their roots. It is now time to acquire some data to give our understanding a firmer foundation.