Some Basic Fixed 3-Band NIVS Antennas

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In the past, most amateur NVIS activity occurred on 75 and 40 meters. Recently, amateurs have begun expanding their coverage to include 60 meters. That has brought requests and suggestions for NVIS antennas that cover all three bands—without resorting to lossy terminated antenna configurations. An added requirement often cited is the need to switch bands rapidly without having to readjust an antenna tuner. Although it is possible to set up a single wire with a parallel feedline to a tuner and by careful selection of both the antenna height and length to achieve adequate pattern from 75 through 40 meters, this last requirement effectively precludes this option without the use of very fast automatic tuners with memories to eliminate tuner searching for settings while changing bands. Let's omit this option from our exercise.

The goal, then, is to develop wire antenna options for 3-band operation in the NVIS mode so that we may ideally switch bands without attention to the antenna. (We shall add a final option that requires only a single antenna switch.) Next, let's face reality. The ideal height for a linear or level antenna for maximum NVIS of upward gain falls in the 0.15-λ to 0.22-λ range. The upper end of the range places an 80/75-meteer antenna at about 60'. Higher antennas—up to 0.25-λ above ground—will work well for NVIS, but are physically prohibitive for most amateur installations. The upper limit of the NVIS height range also increases the radiation at lower elevation angles, a fact that favors an antenna that must do double duty by providing both NVIS and medium-range communications duty. However, for pure NVIS work, such antennas tend only to increase atmospheric noise levels while receiving.

Therefore, let's restrict, for our exercise alone, the maximum height of our NVIS antennas to 35'. Some of our examples will also use a 25' height. As the data in **Table 1** show, these heights are very low on 75 meters, but approach optimal NVIS heights on 60 and may even exceed them on 40 meters. The main reason for using heights of 35' and 25' is that most amateur installations cannot usually exceed these heights without considerable difficulties.

Table 1. Heights of antennas in these notes in feet and wavelengths

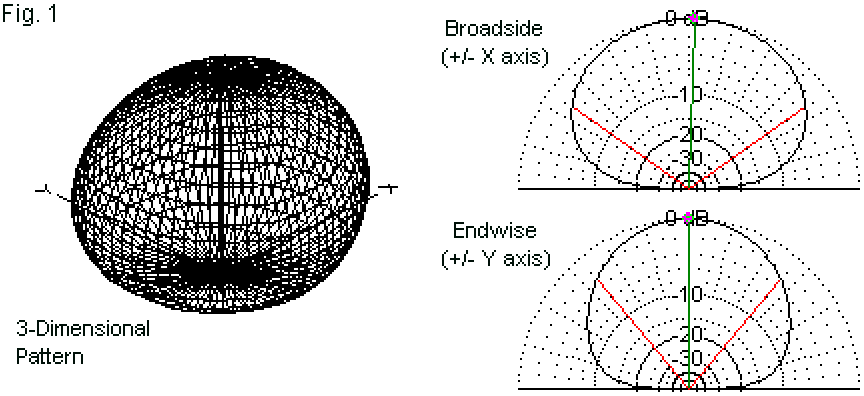
Band	75 Meters	60 Meters	40 Meters
Height		Height in Wavelengths	
35'	0.14	0.19	0.25
25'	0.10	0.14	0.18

With very low antenna heights come a few very important cautions. The antennas in these notes will use either AWG #12 (0.0808" diameter) or AWG #14 (0.0641" diameter) copper wire. Dimensions will be in feet but may show up to 2 decimal places. These decimals result from the antenna modeling software used to generate the models. In fact, all dimensions are only starting points. Any replication of the antenna designs shown will require considerable field adjustment and dimensions may depart by a noticeable amount from the listed dimensions.

There are two major reasons for the potential variance between the model and reality. Antennas at very low heights vary their impedance values and their resonant lengths with only small changes in height. In addition, at very low heights, the resonant length and impedance of a basic antenna types vary with the quality of ground beneath the antenna. All of the models use average ground with a conductivity of 0.005 S/m and a permittivity (relative dielectric constant) of 13. Your ground quality may differ considerably from these numbers, ranging very likely from very good (0.0303 S/m, 20) down to very poor (0.001 S/m, 5). Ideally, you should plan your antenna by remodeling the samples in these notes for the most precise height values that you can obtain and for the best estimate of ground quality. Even so, expect significant field adjustment when you assemble the antenna.

Ideally, a perfect NVIS antenna in the abstract would have a circular azimuth pattern at any elevation angle with peak gain in the zenith or straight upward direction. Real antennas only approximate this condition. **Fig. 1** shows the 3-dimensional pattern of an inverted V. Beside the obviously imperfect pattern are two 2-dimensional elevation plots that we shall use to characterize the radiation patterns of the antennas we discuss. Broadside to the inverted V (and to all of the antennas in these notes) we find a pattern with a rather broad 3-dB beamwidth (as indicated by the red lines). Off the ends of the antenna, the pattern tends to have a somewhat narrower beamwidth. We shall use the dual elevation pattern system to characterize all of the antennas under discussion. High-angle azimuth patterns have systematic conical section errors.

Fig. 1



General Properties of a NVIS Radiation Pattern

From the two elevation patterns, you may infer the general departure from the ideal circular pattern. The inference may prove useful in orienting an actual antenna to provide a desired degree of coverage. As you continue to raise the height of a NVIS antenna, the broadside pattern tends to increase its beamwidth until the top flattens and the radiation pattern evolves into a pair of lobes, one in each broadside direction.

The reason that we may usefully spend some time looking at basic antennas for 3-band operation has to do with the properties of NVIS propagation. At night, the ionosphere lacks the absorbing D-layer and so 75 meters (and 160 meters) become very useful for refracting (reflecting) radiation from the nighttime F-layer, which may not be strong enough for usable return signals on 40 meters. In the daytime, the F-layer strengthens, but the D-layer reforms, effectively closing 75 meters (and below) to NVIS propagation. However, the stronger F-layer allows good use of 40 meters. The attraction of 60 meters is for those transition time periods between the closing of one band and the opening of the other. Of course, like all HF communications making use of ionospheric refraction, there will not only be daily cycles of change, but as well both seasonal and sunspot-cycle variations, not to mention special conditions, such as solar flares.

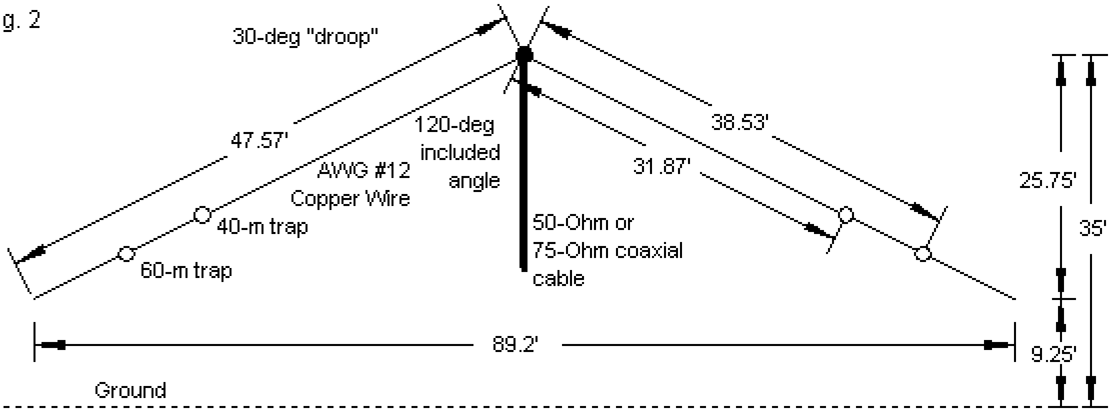
Numerous web sites provide details of basic NVIS propagation phenomena as well as other basic data on the propagation mode and its use by radio amateurs. Essentially, NVIS propagation is most relevant to communications at distances from zero to about 200 to 300 miles, especially where intervening terrain may block ground wave communications or VHF/UHF line-of-sight activity.

The following notes will examine three basic candidates for a 3-band NVIS antenna covering 75, 60, and 40 meters, with emphasis upon SSB operation. The first section evaluates the pros and cons of a 3-band trap inverted V antenna. The second looks at the potential for converting a common arrangement into a slightly more complex configuration. The use of crossed 75-40-meter dipoles, laid out at 90° angles but with a single feedpoint, is common. We shall explore both level and inverted V versions of dipoles for the three bands, each separated by 60° from an adjacent element. Finally, we shall look at the advantages and disadvantages of nested 1-λ loops for each band. Each arrangement has both physical and electrical properties that go into the evaluation process. Our goal is not to make a final decision, but instead to organize some of the factors on each side of the ledger.

A Trap Inverted V for 75-60-40-Meter NVIS Use

The design of a trap dipole is straightforward. Beginning with the highest band, we create a dipole or inverted V and place a trap at the end. The trap is tuned to a frequency just below the lowest frequency used on the highest band. When we wish to add the use of a lower band, we add wire to the assembly to extend its length. Since at the lower frequency, the trap acts like an inductive load for the lower frequency, the total element length is shorter than would be a full dipole or V for that frequency. We may continue the process indefinitely, but we need add only one more set of traps to achieve 3-band operation.

Fig. 2



General Structural Outline of a Representative Trap NVIS Inverted V for 75, 60, and 40 Meters

Fig. 2 shows the dimensions for a trap inverted V for 75, 60, and 40 meters using AWG #12 wire, which is normally strong enough to support the weight of the traps. The dimensions are suited to a 35' center height above average ground with a 30° element slope (or a 120° included angle below the center point). The dimensions place the wire ends 9.25' above ground. The design aims for feedpoint impedance values that are compatible with either 50-Ω or 75-Ω coaxial cable. (I might note in passing that most cables, such as RG-59, have 70-Ω characteristic impedance values, but tradition allows a collective reference to 75-Ω cable.) The overall leg length for 75-meter operation is less than 48', although a simple inverted V for 75 meters might use leg lengths of about 60.5'. Hence, the trap 3-band V has the smallest footprint of all of our test designs. It requires less than 90' of horizontal length and only the wire or cable thickness for width. As well, it normally requires only one 35’ support pole, while 10’ poles can support the wire ends. Of course, the antenna design allows instant band changing with no required action upon the antenna itself once successfully installed. These are perhaps the major advantages of using a 3-band trap inverted V.

Table 2. Key properties of the 3-band trap inverted V 35’ above average ground with traps designed for a Q of 200

Band Meters	Wire Length feet	Trap L µH	Trap C pF	Max. Gain dBi	B-S BW degrees	E-W BW degrees	Resonant Z R+/- jX Ω
75	47.57	---	---	2.13	102	87	52.5 – j0.6
60	38.53	8.5	60	3.24	110	81	73.6 + j0.5
40	31.87	11.3	80	4.80	123	78	73.3 – j0.0

Table 2 supplies some of the major properties, both physical and electrical, for the antenna. Trap design is standard and almost any antenna handbook will provide guidance in construction. To the list of conditions that may require adjustment of the wire lengths for each band, we can add that small variation in trap values will also change the required length of the 60-meter and the 75-meter extensions. To reinforce the need to create a final design using height and ground quality values as close as possible to reality, we can compare the modeled resonant impedance values to free space values for the same assembly. On 75 meters, the free-space impedance is about 50 – j50 Ω. On 60, the value is 69 – j29 Ω, while on 40 meters, the resonant free-space impedance is 63 – j19 Ω. Note that the free-space values depart more radically from the values over ground—especially in the reactance column—as we place active parts of the antenna closer to ground.

In **Fig. 3**, we find pairs of elevation patterns for each band at the frequencies of resonance. Off-resonant patterns do not depart from the ones shown. As we increase the operating frequency, the antenna height increases as a fraction of a wavelength. The broadside patterns show an accompanying increase in beamwidth. In fact, the 40-meter pattern levels at the top, as indicated by the tilted line. The endwise patterns show a slight decrease in beamwidth with rising frequency.

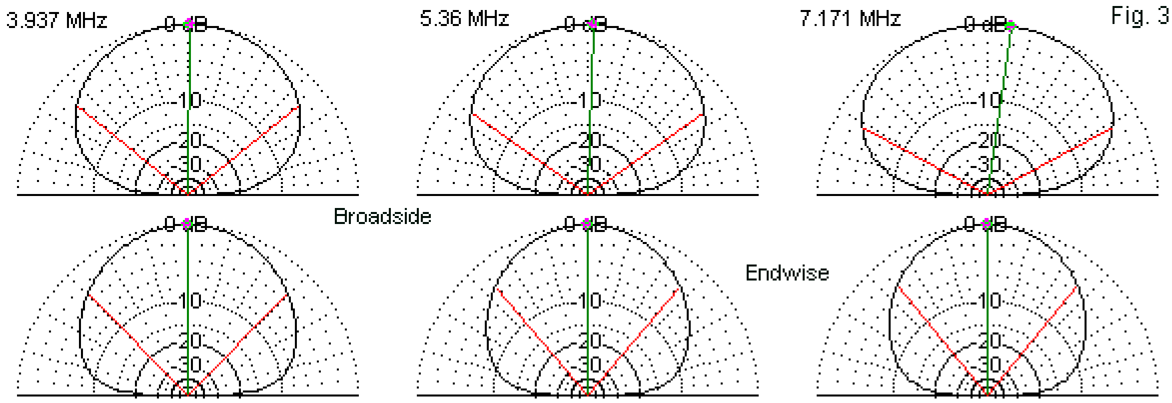
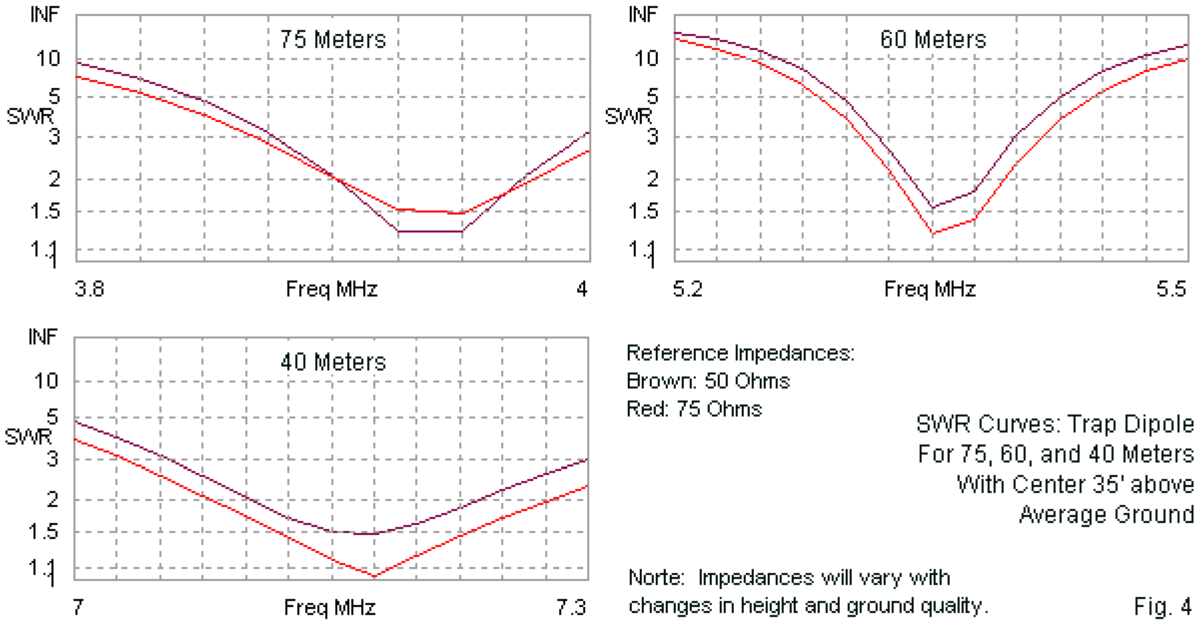


Fig. 3

Sample Broadside and Endwise Elevation Patterns of a Trap Dipole for 75, 60, and 40 Meters

One deficiency of the trap inverted V is the relatively low possible gain. The tabular gain values show that the closer we place active parts of the antenna to the ground, the less gain that we can obtain from the antenna. As well, the inverted V structure inherently has less gain than a level trap dipole would have if at a 35' height. The combination of close ground spacing and inverted-V structure may provide mechanical simplicity to an installation, but it limits the antenna's possible performance. The gain at 40 meters (4.8 dBi) is typical of an inverted V at 0.25-λ above ground, but the gain of a level dipole can be up to a full dB or more higher. Moreover, on the two lower bands, there are trap losses, about a half-dB per trap pair.

The design does not use a lower wire as what some call a "counterpoise" (in a total misuse of that term). Extensive modeling has shown that a single wire near ground below a NVIS element does not significantly change the antenna gain. The ground itself is the primary reflective surface and it extends far beyond the limits of a low reflector wire. A way to improve performance is to lay out a series of 7-9 wires or a full (chicken-wire) screen that exceeds the active element dimensions by 0.4 λ to 0.5 λ in every dimensions. Then the local ground acts like a planar reflector, but only to a certain point. A full ground screen improves performance only to the level of very good ground. For a basic installation, the antenna element itself is all that one needs unless one creates ground screening or an elevated tuned reflector.



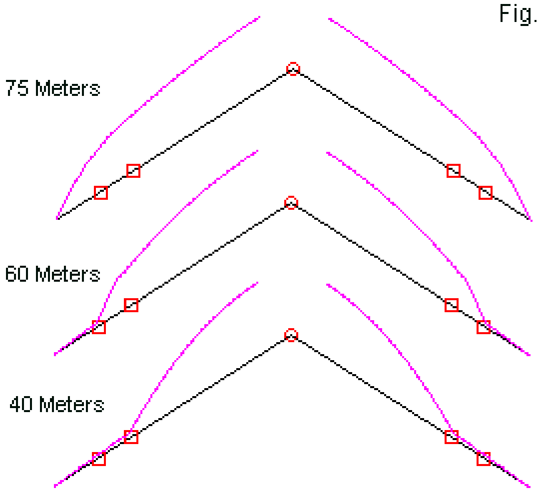
SWR Curves: Trap Dipole
For 75, 60, and 40 Meters
With Center 35' above
Average Ground

Fig. 4

The SWR curves in **Fig. 4** show the relative sizes of the operating windows for each band. Since the antenna would require field adjustment as a matter of course, you can adjust the wire lengths to move the windows anywhere within the bands. Compared to other antenna types, the SWR windows of the 3-band trap inverted V tend to be fairly narrow, calling for careful field adjustment. A final set of lengths for one installation my not prove satisfactory for another. One limitation of the trap inverted V is the fact that on bands with trap ends, the impedance tends to be higher than on the lowest band. As a result, 75-Ω coax provides wider SWR windows on 40 and 60 meters, while 50-Ω coax is best for 75 meters. If we add a significant length of coax between the antenna center point and the station equipment, line losses will broaden the SWR windows. However, the total energy available for radiation (and the receiving sensitivity) will undergo proportional reduction. These notes do not include a level version of the trap dipole at 35' for a significant reason. Leveling the antenna yields impedance values on 60 and 40 meters close to 90 Ω, while the 75-meter impedance remains close to 50 Ω. With even a 75-Ω feedline, the operating windows shrink on at least one band below a usable level. The inverted V configuration tends to lower all of the impedance levels to yield a usable antenna. However, obtaining usable feedpoint impedance values comes at a price: on all three bands, the maximum gain of a level 3-band trap dipole at 35' above ground falls between 5.3 and 5.7 dBi. Compare these gain values to those listed in **Table 2**.

For those unfamiliar with the action of traps, **Fig. 5** presents a set of current magnitude distribution curves along the inverted V on each of the three bands. The center gap is a function of the sloping element halves, since the magnitude is measured from the wire itself. On the two lower bands, note the increase in the slope of the curve as it passes a trap, which acts like a non-radiating load inductance on the lower bands. Only on 40 meters do we find a normal current distribution up to the first pair of traps. Although we normally think of the current magnitude in wires beyond an operative trap as zero, the value is not quite that low. This fact adds to the somewhat finicky adjustments required of any multi-band trap antenna.

Fig. 5



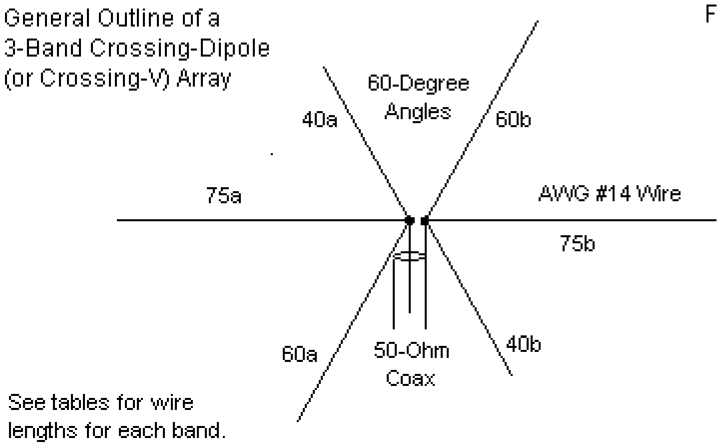
Current Distribution on a NVIS Trap Inverted V Dipole
on 75, 60, and 40 Meters

Assuming that trap construction is not a hindrance, the trap inverted V for 75, 60, and 40 meters in NVIS operation provides one of the simplest physical installations. Offsetting that advantage is the relatively low gain on the two lower bands and the relatively narrow SWR windows for operation. In addition, the antenna requires careful adjustment to the conditions of the installation site.

Crossing Dipoles for 3 Bands

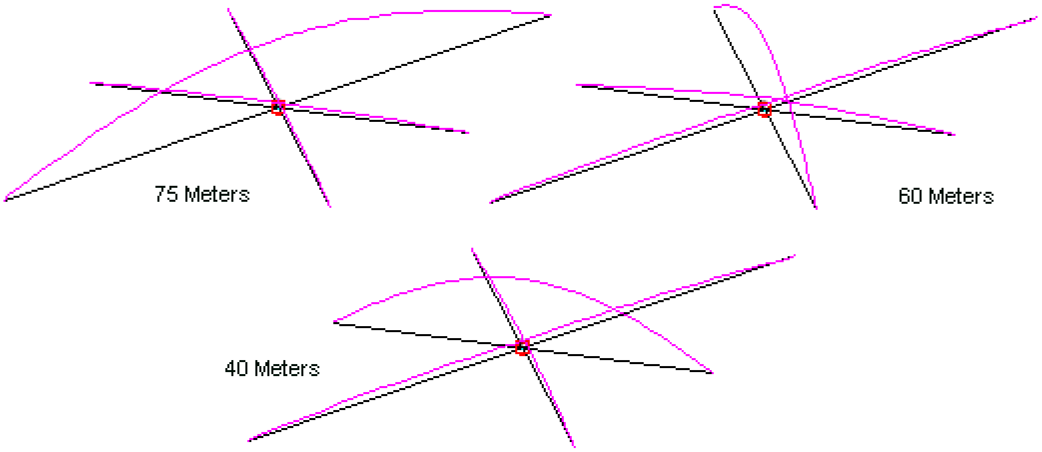
One popular system for obtaining 75- and 40-meter operation with an antenna having only one feedline employs dipoles for each band in a cross, with each dipole oriented 90° from the other to minimize interaction. The system often uses the inverted V configuration so that a single center support with shorter wire-end supports simplifies the mechanical needs. We may expand the system to include 3 bands by separating the dipoles by 60°, as shown in outline form in **Fig. 6**. The legs may be level or slope to form Vs. The interactions among the dipoles are greater than we find in the 2-band version but are completely manageable.

Fig. 6



Feeding the antenna requires only a feedline, although adding a common-mode current attenuation device at the feedpoint is a useful precaution to take. **Fig. 7** shows the relative current magnitude distribution as we operate the array on each band. The distribution does not change with height or by using an inverted V configuration. Note that the unused elements are relatively quiescent, but not completely inactive. The chief effect of the low currents on the inactive elements is to require careful pruning of the dipoles for each band to place the low SWR passband to cover the operating frequencies on each band.

Fig. 7



Current Magnitude Distribution on a 3-Band Crossing Dipole Array for 75, 60, and 40 Meters

For NVIS operation, a level system of linear dipole would likely require seven full-length supports, one at the center and one at each wire end. Although this system is probably more complex than most amateurs wish, let's examine it to see what level of performance we can obtain. We shall place the system at 35' above average ground and then drop it to 25' above ground. If you refer to **Table 1**, you can gauge the height of each dipole as a fraction of a wavelength and estimate the probable performance relative to performance at an optimal height (0.15-λ to 0.22-λ above ground). **Table 3** provides the modeled dimensions and performance data for both heights.

Table 3. Key properties of the 3-band cross-dipole arrays at 35’ and 25’ above average ground

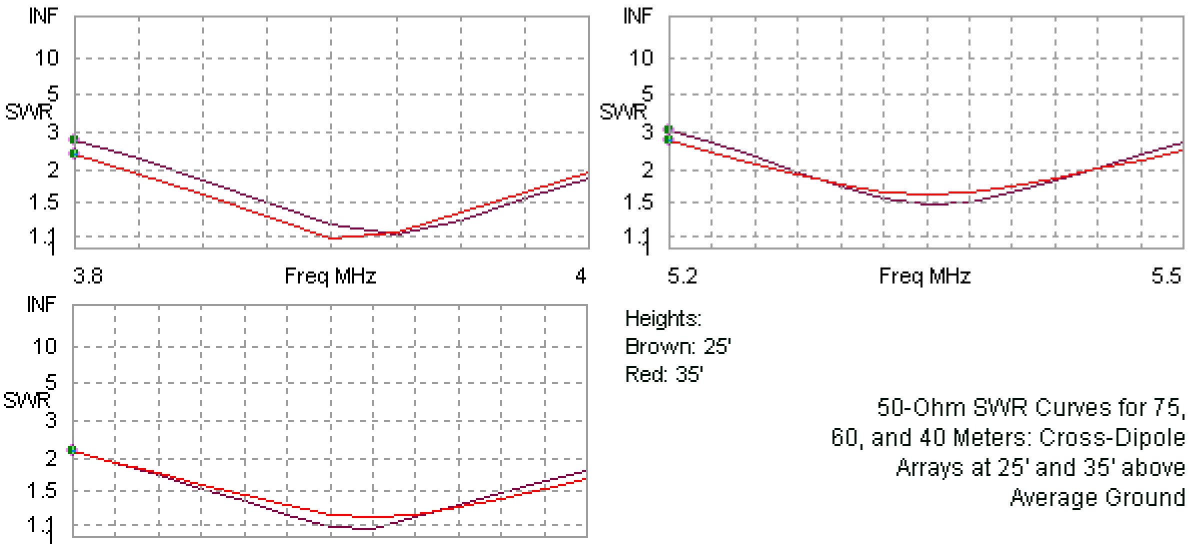
Height: 35’

Band	Dipole Length	Max. Gain	B-S BW	E-W BW	Resonant Z
Meters	feet	dBi	degrees	degrees	R+/- jX Ω
75	121.00	6.08	106	65	54.1 – j0.5
60	88.35	6.23	117	69	88.0 + j0.6
40	66.30	5.52	134	74	60.9 – j0.8

Height: 25’

Band	Dipole Length	Max. Gain	B-S BW	E-W BW	Resonant Z
Meters	feet	dBi	degrees	degrees	R+/- jX Ω
75	121.00	5.04	101	66	44.3 – j0.2
60	88.35	5.30	107	67	74.5 + j0.3
40	66.30	6.10	121	66	47.2 + j0.3

A single set of dipole lengths is sufficient for both heights chiefly because the 50-Ω low SWR windows are considerably broader than those we encountered with the trap inverted-V 3-band antenna. **Fig. 8** provides SWR curves for both heights with the level dipole system. The current magnitude curves showed higher off-band current activity on the 60-meter dipole than when using either 75 or 40 meters. This condition shows itself in the numerical impedance data and in the SWR curves in the form of a higher resonant impedance value and a narrower SWR operating window. However, the 60-meter SWR window extends beyond the limits of the 60-meter channel assignments.



Heights:
Brown: 25'
Red: 35'

50-Ohm SWR Curves for 75, 60, and 40 Meters: Cross-Dipole Arrays at 25' and 35' above Average Ground

Fig. 8

The broadside and endwise beamwidth and the gain values in the table are worth noting. At a height of 25’, only the 40-meter dipole is at optimal height for maximum gain straight up. The other dipoles fall increasing below the optimal height and therefore show lower gain, largely due to ground absorption. All patterns follow the model in **Fig. 1** with wider broadside beamwidth values than endwise values. When we move the antenna upward by 10’, the 75- and 60-meter dipoles are closer to optimal NVIS height and show better gain than at 25’. However, the 40-meter maximum gain value decreases relative to the value at 25’. As well, the beamwidth significantly increases. **Fig. 9** compares the broadside elevation patterns of the 40-meter dipole at both heights. Above optimal NVIS height, the pattern begins it evolution into two separate broadside lobes. Note that there are two peak-gain lines equally spaced (in degrees) from the zenith angle. As well, the gain straight up is slightly less than maximum. The differences between the two patterns are not sufficiently great to disrecommend the higher installation level. In fact, if the station is also used for medium-range communications, the higher level provides more energy at lower elevation angles to enhance this operation. The increased beamwidth is the chief reason for finding a slightly lower maximum gain value at 35'. The exercise is useful as a caution against raising NVIS antennas too high. Eventually, the very slight reduction in zenith gain will develop into a very deep upward null.

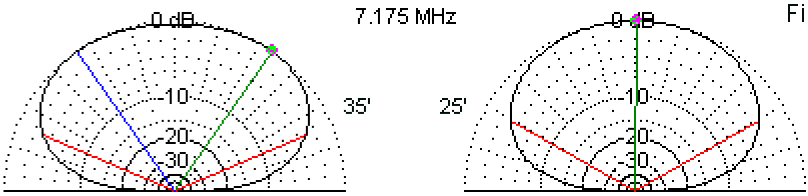


Fig. 9

Broadside 40-Meter Elevation Patterns at 35' and 25' above Average Ground:
Cross-Dipole Array

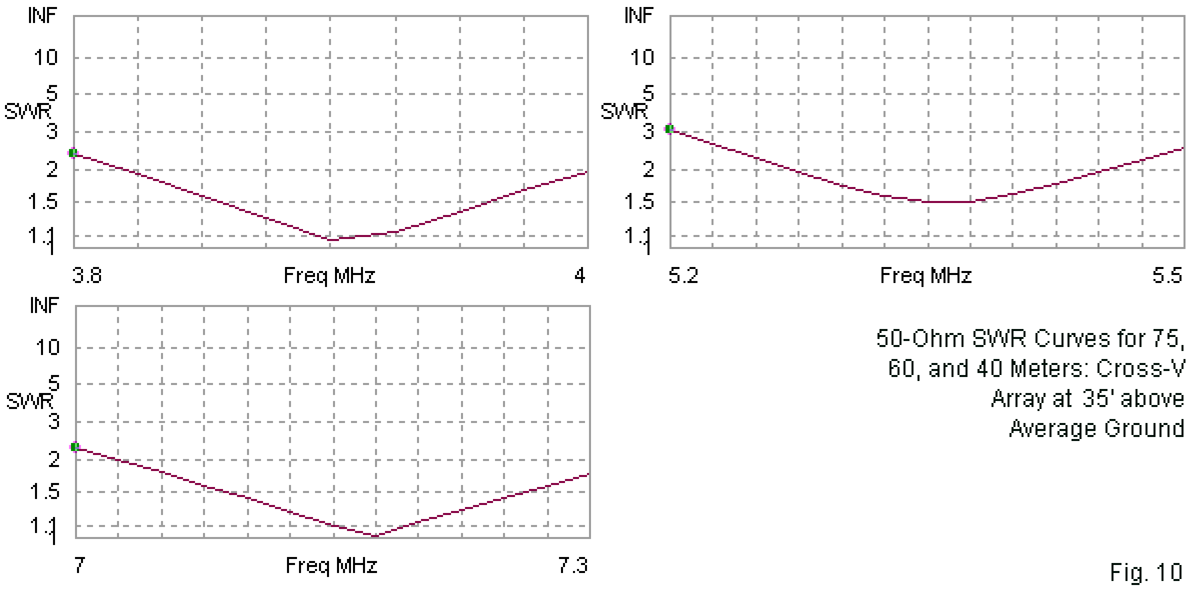
Although the crossed-dipole array requires too many supports for most amateur installations, the exercise provides us with a reasonable perspective on dipole performance in NVIS service. It also shows us that 3 crossing dipoles separated by 60° angles is a perfectly feasible multi-band array. Its final function will be to provide a baseline for comparing the performance of an inverted V form of the same array. The top-down outline would follow the pattern in **Fig. 6**, but the horizontal dimensions would shrink to about 0.866 of the dipole lengths as a result of sloping each dipole 30° below the level dipole line. **Table 4** provides the dimensions and performance data from the model.

Table 4. Key properties of the 3-band cross-V array at 35' (at center) above average ground

Band Meters	Element Length feet	Max. Gain dBi	B-S BW degrees	E-W BW degrees	Resonant Z R+/- jX Ω
75	119.80	3.07	102	86	51.6 + j0.1
60	88.50	4.82	111	79	74.6 + j0.9
40	66.80	5.30	127	75	49.7 + j0.9

The V system uses a standard 30° angle for the wire slope. One result is a variation in the wire-end heights, which range from 5.8' on 75 meters up to 19.15' on 40 meters. A practical installation might wish to select a common height for all wire ends. For example, 10' end supports would place all wires above the potential for accidental contact but with reduced gain on the higher bands. However, to obtain a 30° slope angle, the center height needs to be about 35' to prevent the 75-meter V from touching ground.

Veeing a set of elements tends to lower the feedpoint impedance relative to level dipoles. However, in the crossed V configuration, interactions tend to limit the degree of feedpoint impedance decrease. Hence, the 50-Ω SWR windows shown in **Fig. 10** are about the same size as those for the level dipoles. To place the windows within approximately the same frequency limits on each band requires a slightly different set of overall element lengths. Because the element ends are close to ground level, the actual lengths needed for the three bands will vary with small structural variations from the model and with changes in the ground quality below the antenna. The width of each SWR passband is great enough to keep the adjustment task from becoming too onerous.



50-Ohm SWR Curves for 75, 60, and 40 Meters: Cross-V Array at 35' above Average Ground

Fig. 10

We often hear a sound bite about inverted V antennas, namely, that their gain values are nearly as good as the gain of level dipoles. Unfortunately, this nugget of wisdom applies to inverted V antennas at significant heights above ground for use in long distance communication. Close to the ground and used for NVIS communications, the proximity of the antenna ends to ground creates a significant gain deficit straight up. Compare the gain values to those for the level dipoles at 25' and 35'. Only the 40-meter V dipole, with its ends at over 19' above ground is clearly competitive with the level dipole versions. As the V ends more closely approach ground level, the gain decreases. The 75-meter maximum gain is nearly 3 dB lower than the gain of the dipole at 35'. Although the inverted V version of the cross dipole array is mechanically simpler than the level dipole version, there is a gain price for the convenience. (As a side note, compare the crossed V array gain values to those of the trap dipole in **Table 2** to obtain a rough estimate for the further losses due to trap construction.)

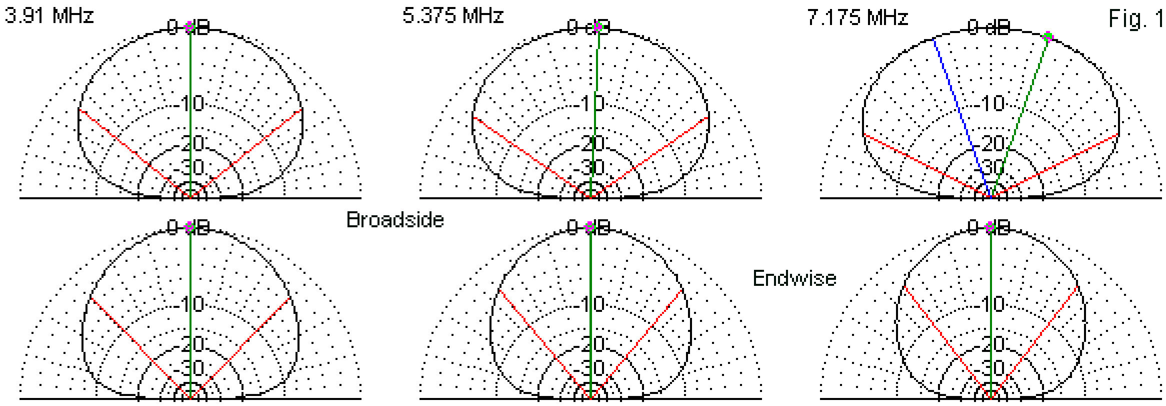


Fig. 11

Broadside and Endwise Elevation Patterns for 75, 60, and 40 Meters Cross-V Array at 25' and 35' above Average Ground

Fig. 11 provides broadside and endwise elevation plots for the crossed V array for each of the three bands. All but one pattern follows the nearly ideal NVIS pattern form. The broadside 40-meter pattern, with a center height of 35' above ground, shows similarities to the 40-meter pattern for a level 35'-high dipole in **Fig. 9**. Because the V element ends droop, the effective height of the 40-meter V is slightly lower than its center height, so the pattern is less distinctly split into separate broadside lobes.

A 3-band crossed dipole or V array can provide quite adequate NVIS service on a single feedline. However, there are trade-offs for each version. The dipole system provides better performance, but requires up to 7 tall supports. (A little ingenuity with ropes might reduce the required number of supports to 5.) The crossed V configuration reduces the required height of wire-end supports, but imposes a penalty on performance on at least two of the bands.

A Nest of Three 1-λ Square Loops

An alternative to the crossed dipole system can reduce the number of required supports to 4, one at each corner of the array. **Fig. 12** shows the very general outline of a set of three 1-λ loops that are the core of this NVIS array.

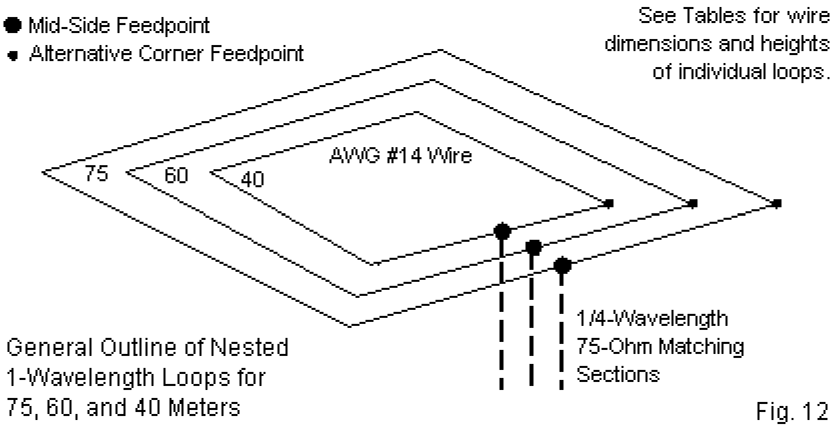


Fig. 12

Each loop is independent and assumes an antenna switching arrangement. Depending upon the installation and its distance from the operating equipment, the switch may be either at the station (with three lines) or at the antenna at the equipment end of the required ¼-λ 70-75-Ω matching sections The feedpoint impedance of the loops themselves falls in the range of 90 Ω to 130 Ω. The series matching sections are a very simple way to yield impedance values compatible with 50-Ω coaxial cable. The sketch shows a mid-side feedpoint. However, the alternative feedpoint at the array corner is just as apt. As well it would allow cable support along the support post at that corner.

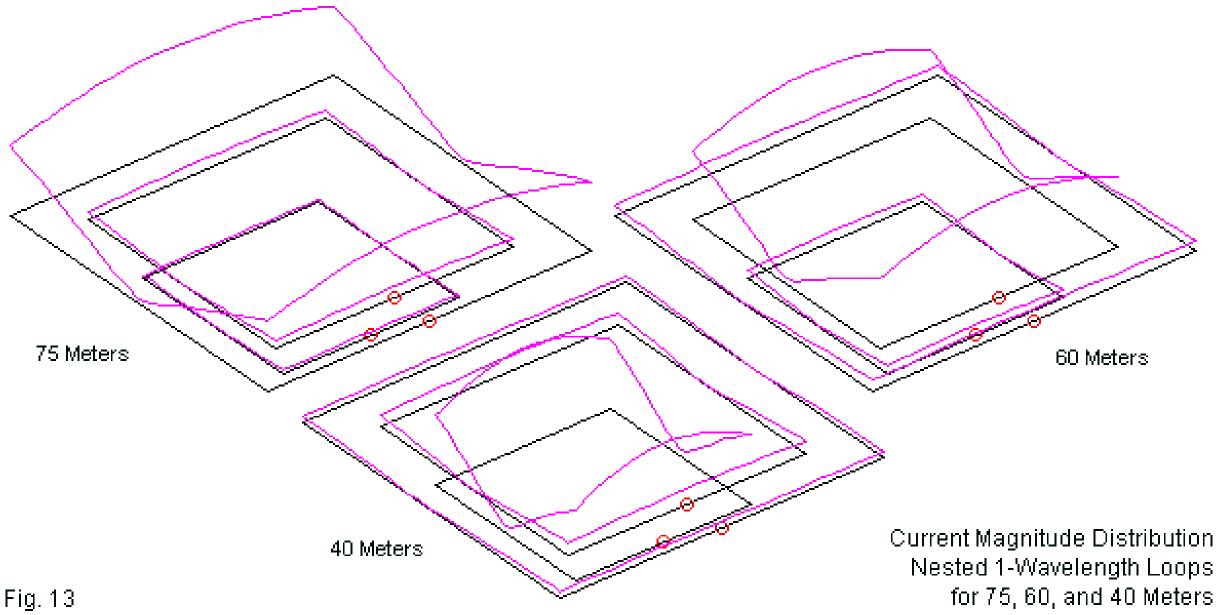
Although the basic sketch shows the loops on a level plane, the model for them places the 75-meter and the 60-meter loops at 35', heights closer to optimum for those frequencies. (In fact, a height of 45' to 50' would be best for the 75-meter loop, but we started this exercise with a 35' height restriction.) In fact, even within our restriction, we might lower the 60-meter loop slightly so that ropes from the corner support posts would place each loop at a slightly lower height, with a 25' height minimum for the 40-meter loop. 60-meter performance would drop to about the 75-meter level. With the 35'/25' split, **Table 5** provides dimensions and performance data for the nested loops using both mid-side and corner feedpoints.

Table 5. Key properties of the 3 nested 1-λ loops above average ground

Band Meters	Side Length feet	Circumference feet	Max. Gain dBi	B-S BW degrees	E-W BW degrees	Resonant Z R+/- jX Ω
Mid-side fed						
75	64.4	257.6	6.71	85	69	62.3 – j4.6
60	47.0	188.0	6.83	94	71	49.2 – j3.2
40	23.5	139.2	6.43	94	70	45.6 – j1.8
Corner fed						
75	64.4	257.6	6.71	86	68	62.4 – j5.0
60	47.0	188.0	6.83	97	70	49.2 – j2.6
40	23.5	139.2	6.43	97	69	45.7 – j1.3

Note: Impedance values assume a ¼-λ 75-Ω matching section at each feedpoint. 75- and 60-meter loops are at 35'; 40-meter loop is at 25'.

Note that we need not change any dimensions when we change the feedpoint position; indeed, all performance values show only undetectable differences in the modeled performance values. (Of course, like the dipoles, the loops may require dimension adjustments with small changes in height or significant changes in soil quality.) In the table, we determine the broadside pattern by drawing a line from the feedpoint to a point just opposite on the loop. Endwise patterns are along a line at right angles to the original line. Broadside for a corner-fed system means a line from one corner to the opposite corner, while mid-side feeding defines broadside from wire center to wire center.



Current Magnitude Distribution
Nested 1-Wavelength Loops
for 75, 60, and 40 Meters

Fig. 13

Even with separate feedlines, the loops do show some interaction between the most active loop and the next adjacent loop. As shown in **Fig. 13** for mid-side feeding, the 60-meter loop shows activity on both the 75- and the 40-meter loops. These interactions have a bearing on the final loop dimensions, but are low enough to create no hindrance to the formation of typical NVIS patterns. A sampling of those patterns (with mid-side feeding) appears in **Fig. 14**.

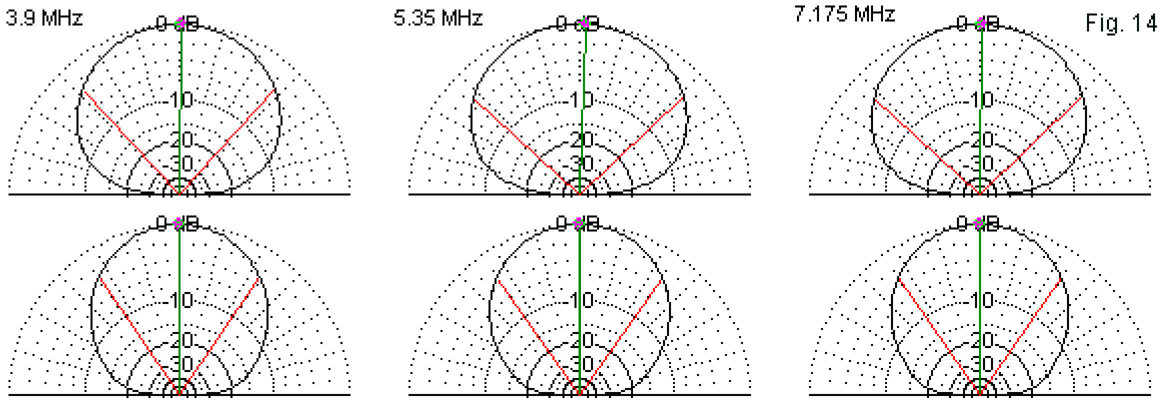
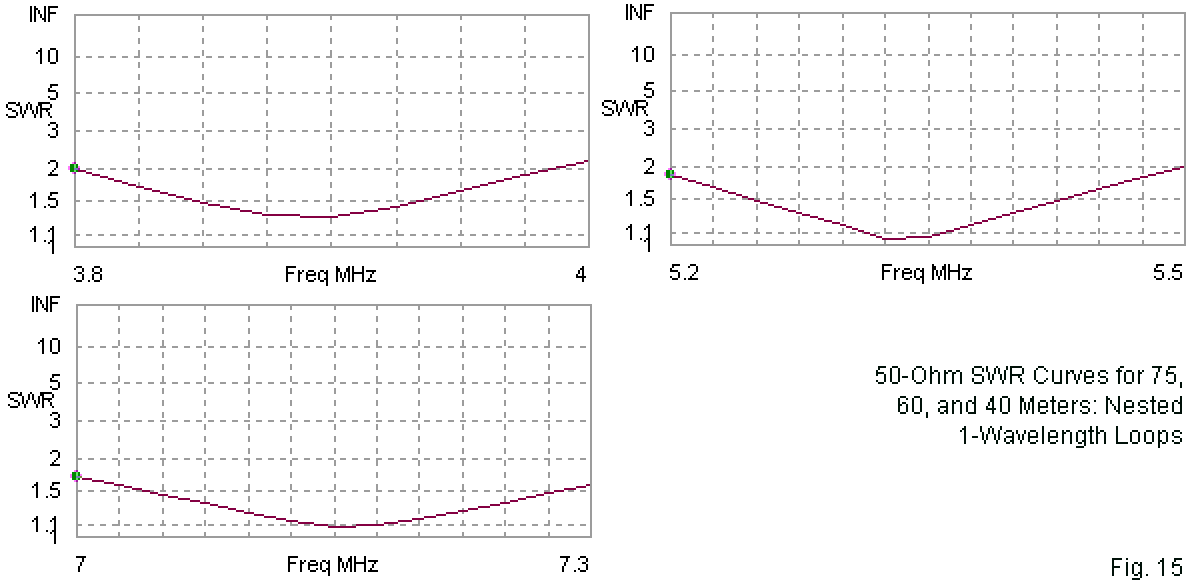


Fig. 14

Broadside and Endwise Elevation Patterns for 75, 60, and 40 Meters
Nested 1-Wavelength Loops

The 75-meter loop is below its optimum height and shows a slightly narrower broadside beamwidth than the broadside patterns for 60 and 40 meters, both of which are at close to optimal heights. Loops tend to produce more circular patterns than dipoles, as suggested by the endwise patterns, which vary from the broadside beamwidths by only about 20°. As well, loops have slightly higher gain values than dipoles. For the nest shown, the gain varies between 6.4 and 6.8 dBi.



50-Ohm SWR Curves for 75, 60, and 40 Meters: Nested 1-Wavelength Loops

Fig. 15

Fig. 15 provides another advantage inherent in the nested loop array. With series ¼-λ 75-Ω matching sections, all of the loops show the widest 50-Ω SWR bandwidths of any of the options under discussion. The worst case is 75 meters: the 90-Ω loop impedance under conversion by a standard ¼-λ 75-Ω cable only drops to about 62 Ω. However, the SWR passband changes values very slowly, allowing access to the entire top 200 kHz of the band.

The nested loops do have constraints. They require a square installation region about 70' per side, including support posts. As well, the system needs 4 full-height posts. Finally, the loops require independent feedlines with either a station or a remote switch.

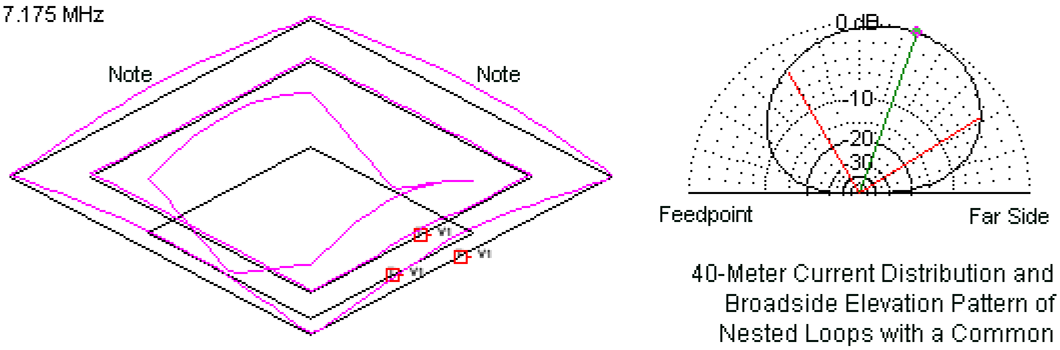


Fig. 16

40-Meter Current Distribution and Broadside Elevation Pattern of Nested Loops with a Common Feedpoint

Unlike quad beams, some of which use a common feedpoint, the nested NVIS loops should use separate feedlines and line switching. **Fig. 16** shows why. On 40 meters, with a common feedpoint for all loops (simulated but not shown in the model), we obtain significant activity on the 75-meter loop, which is close to 2 λ long. Each side of the 75-meter loop is about ½-λ long on 40 meters. One consequence appears in the offset broadside pattern, with the main lobe tilting away from the feedpoint. A second consequence follows from the fact that the impedance of the 75-meter loop, when excited on 40 meters, is about 220 Ω. The parallel combination of impedances for the 40- and 75-meter loops yields a net impedance value that is more difficult to match. The impedance challenge is not insurmountable by careful adjustment of loop lengths. However, the pattern offset will remain.

If the 4-corner support system is feasible, the nested 1-λ-loop array provides the highest performance of any of the systems in these notes, all of which have observed a 35' maximum height restriction.

Conclusion

Our goal has been to explore some basic 3-band antenna systems for NVIS operation on 75, 60, and 40 meters. We have tried to portray reasonably the advantages and disadvantages of each system. As well, we have used the occasion to address some basic issues in NVIS antennas, such as the ineffectiveness of so-called single-wire reflectors or "counterpoises," and the effects of using the inverted V configuration in contrast to level dipoles. The trap inverted V uses the least real estate as measured by its area, but has overall the lowest performance level. Crossed dipoles improve performance significantly but require an extensive structure. Setting the dipoles into a V-configuration eases the support requirements but at the cost of severe performance reductions, especially on 75 meters. The nested 1-λ loops require 4 full-height supports and separate, switched feedlines, but provide the highest level of performance of the group of candidates.

These notes have not covered all possibilities. For example, we did not discuss using a single antenna across the entire spectrum by employing either a lossy terminating resistor (or set of resistors) or by using high-speed matching systems. Our aim was to stick to basic antennas and basic installation techniques. These notes do not form in any way a complete menu of tri-band NVIS coverage. Indeed, they are at most appetizers, food for thought.