Narrowband NVIS Antennas

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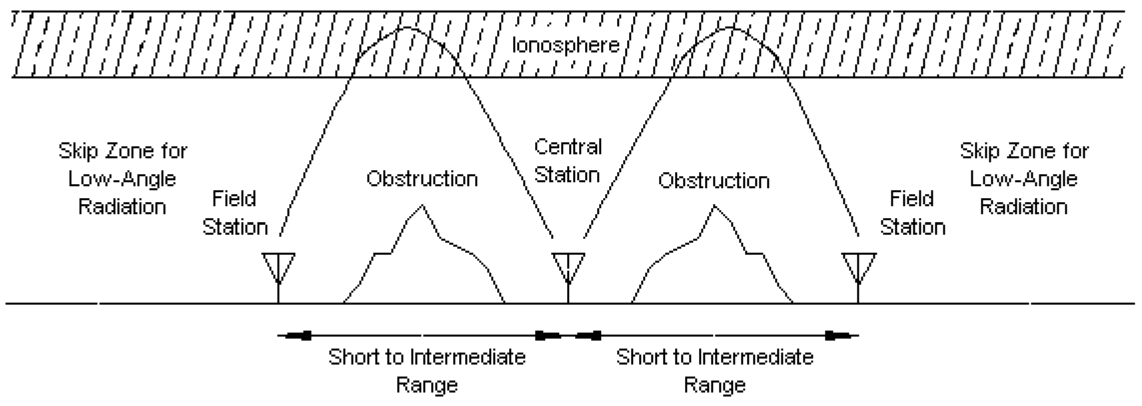
Dean Straw, N6BV, wrote an article for *QST* in December, 2005: "What's the Deal About 'NVIS'?" The article provides some excellent guidance for obtaining the best results from Near Vertical Incidence Skywave (NVIS) operation. The discussion limits itself to using a simple inverted-V antenna, which prompted the following notes. We have a number of options for potentially effective NVIS antennas. In this episode, we shall look at antennas that are narrow band, that is, antennas that cover one or part of one amateur band. We have enough to learn about them to occupy us fully.

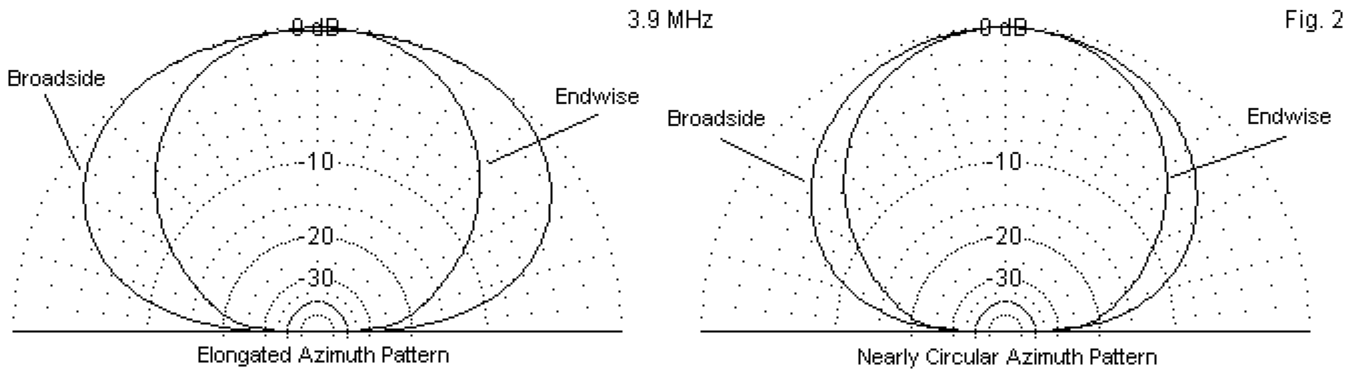


The NVIS Situation

Fig. 1

Figure 1 sketches the NVIS situation in the most general terms. Regular amateur operations seek to elevate antennas to provide low-angle radiation. Ionospheric refraction results in a skip zone, an area between the central station and the nearest communications target. In addition, many central stations have obstructions that limit the range of point-to-point communications methods. In both cases, directing a lower HF signal upward can result in a sufficient return to provide short to intermediate range communications. Many government services consider the NVIS frequency range to extend from 2 to about 10 MHz. As Straw notes, the 7-MHz region is most suitable for nighttime work, while the 80/75-meter band provides the best results for daytime operation by radio amateurs.

Although you may set up many antennas for somewhat directional patterns, most operators strive to have an omni-directional antenna. Unfortunately, pure omni-directionality is hard to obtain with simple antennas. However, you can approximate a circular azimuth pattern by choosing the right antenna, as shown on the left in **Figure 2**. The elongated azimuth pattern shown on the right may also be useful. For simple wire antennas, the broader pattern is off the ends of the wire. If the installation area permits, you can go some distance in planning your coverage. The figure also shows a convention that I shall use in these notes: listing the broadside and the endwise half-power beamwidth. The closer these numbers are to each other, the more circular will be the pattern. The greater the difference, the more elongated that the oval pattern becomes. The ratio of one to the other is a useful measure of pattern circularity.



Elongated Azimuth Pattern

Nearly Circular Azimuth Pattern

Fig. 2

Examples of More Circular vs. More Elongated NIVS Azimuth Pattern

The final preliminary note concerns the antenna environment. We shall be looking at narrow-band antennas for use at the central station. In amateur terms, that generally means a durable home installation for which one may plan and then construct with care. The short-masted AS-2259 antenna is designed for field use, which might be a central station on a military battlefield. The antenna is useful to amateurs in Field Day and similar exercises. However, for long-term NVIS antennas, we can do far better.

The Lowly Dipole

The standard AWG #14 copper wire dipole will be our starting point for these NEC-4 modeling tests. All antennas will use average ground (conductivity = 0.005 S/m, relative permittivity = 13). The test frequency will be 3.9 MHz. A wavelength is about 252.2' at this frequency. The tabular data will be in fractions of a wavelength, so this number is handy for translating the information into numbers for physical planning. The trends that we uncover will be applicable throughout the lower HF range. **Figure 3** sketches the 4-dipole configurations that we shall examine.

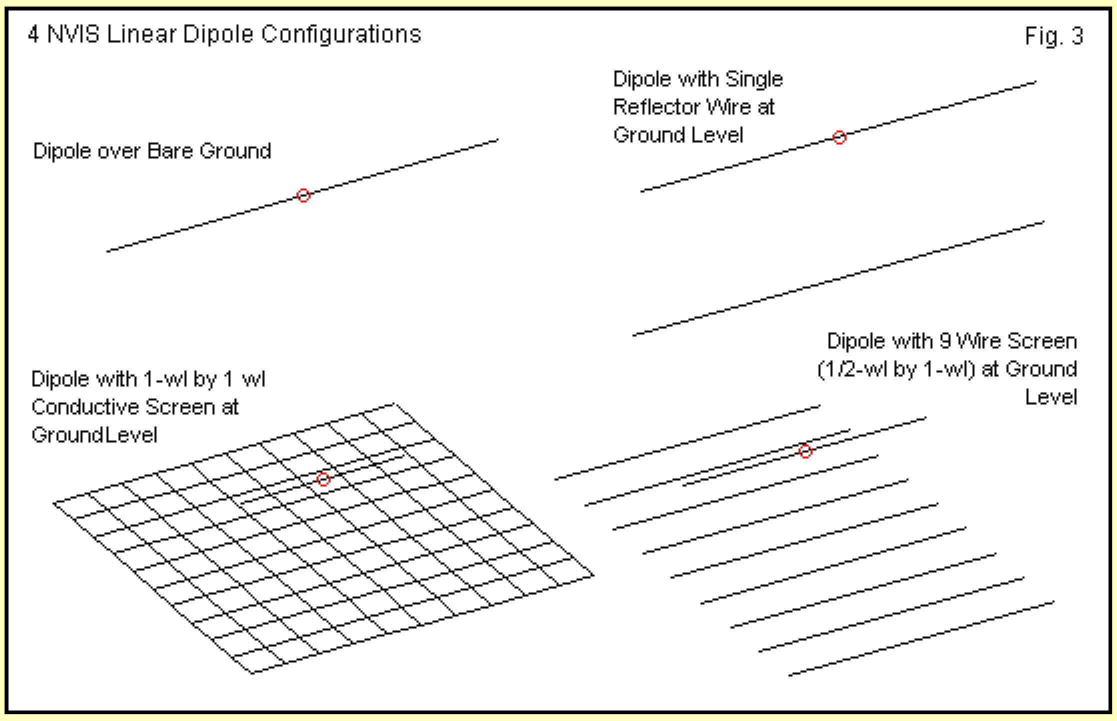

4 NVIS Linear Dipole Configurations

Fig. 3

The first case of a dipole over bare ground has two goals. One aim is to see at what antenna height we obtain maximum upward gain. The second purpose is to put to rest a certain persistent myth about NVIS dipoles, namely, that a super-low height provides a gain advantage. **Table 1** provides expanded information on the performance of a dipole over bare ground at heights ranging from 0.05 wavelength (about 12.5' at 3.9 MHz) up to a quarter wavelength (63'). The table provides gain values from NEC-4 using the Sommerfeld-Norton ground calculation system (referred to as "high accuracy" in EZNEC). It also provides gain numbers reported by the only modeling program readily available during the early days of NVIS antenna analysis in the late 1980s and very early 1990s. That program was MININEC. As early as February, 1991, Roy Lewallen, W7EL, provided warnings to QST readers about the limitations of the MININEC simplified ground calculations system in his article "MININEC: The Other Edge of the Sword." Unfortunately, even today, many beginning modelers do not heed the warning. As the table shows, when we place a horizontal antenna below about 0.2 wavelength, MININEC reports an ever-inflating gain value. At the lowest height used in the table, the actual gain is 8 dB lower than the MININEC report. See the Straw article for the safety concerns and the supposed noise advantage of very low antennas.

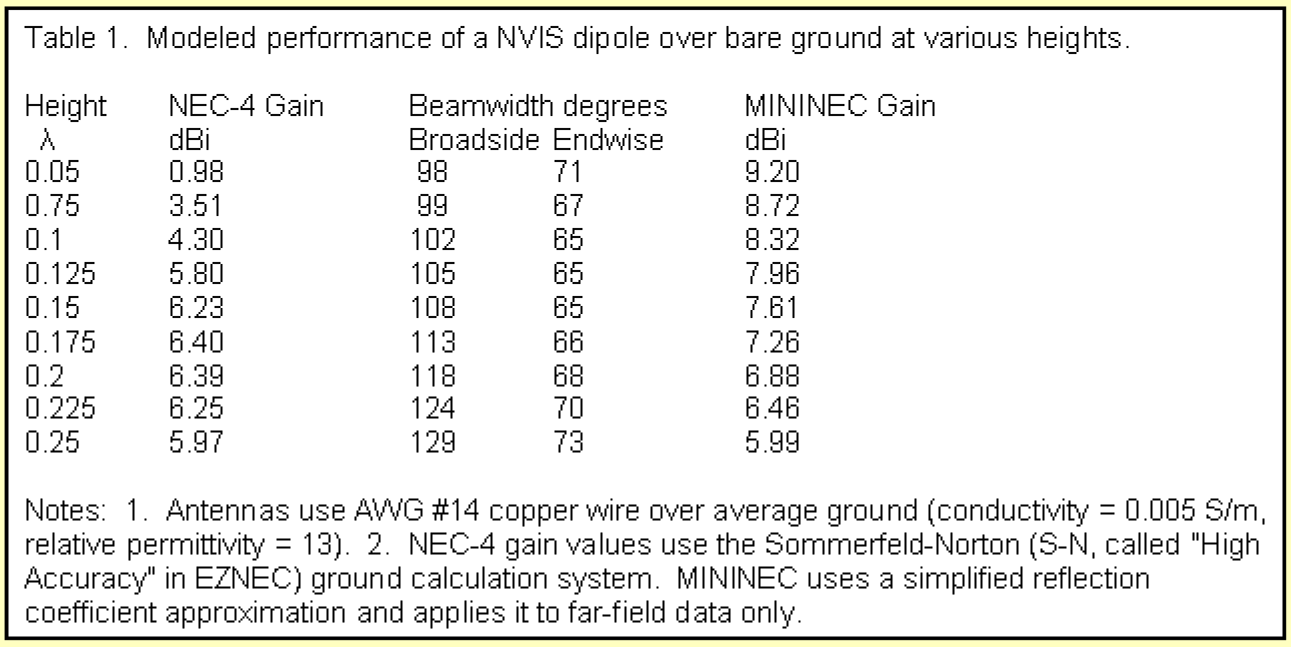


Table 1. Modeled performance of a NVIS dipole over bare ground at various heights.

Height λ	NEC-4 Gain dBi	Beamwidth degrees Broadside	Beamwidth degrees Endwise	MININEC Gain dBi
0.05	0.98	98	71	9.20
0.75	3.51	99	67	8.72
0.1	4.30	102	65	8.32
0.125	5.80	105	65	7.96
0.15	6.23	108	65	7.61
0.175	6.40	113	66	7.26
0.2	6.39	118	68	6.88
0.225	6.25	124	70	6.46
0.25	5.97	129	73	5.99

Notes: 1. Antennas use AWG #14 copper wire over average ground (conductivity = 0.005 S/m, relative permittivity = 13). 2. NEC-4 gain values use the Sommerfeld-Norton (S-N, called "High Accuracy" in EZNEC) ground calculation system. MININEC uses a simplified reflection coefficient approximation and applies it to far-field data only.

The table shows a gain peak with the antenna about 0.175-wavelength above ground. Although this height will be consistently the peak gain height for all of our simple antennas, heights from about 0.125 wavelength up to about 0.225 wavelength are perfectly acceptable. As we raise the antenna in small increments, we notice a slow rise in the endwise beamwidth, but a more rapid rise in the broadside beamwidth. Hence, we can go some way toward tailoring the circularity or elongation of the pattern simply by varying the height without seriously subtracting from the available gain.

The remaining 3 configurations for a NVIS dipole reflect methods that some operators use or should use to improve performance. **Table 2** supplies the corresponding modeling data, but restricts the height range to values from 0.125 wavelength to 0.225 wavelength. The first supplemented dipole uses a single ½-wavelength wire at ground level below the dipole. This wire and all other antenna supplements use modeled heights of 0.001 wavelength above ground so that the models will run on both NEC-2 and NEC-4. The installer's goal is to create a virtual Yagi pointed upward. Contrary to expectations, the table shows a very limited improvement in maximum gain, with the best improvement at the lowest height. Ground reflections do not occur just below the antenna wire, but over a very wide area in all directions from the antenna.

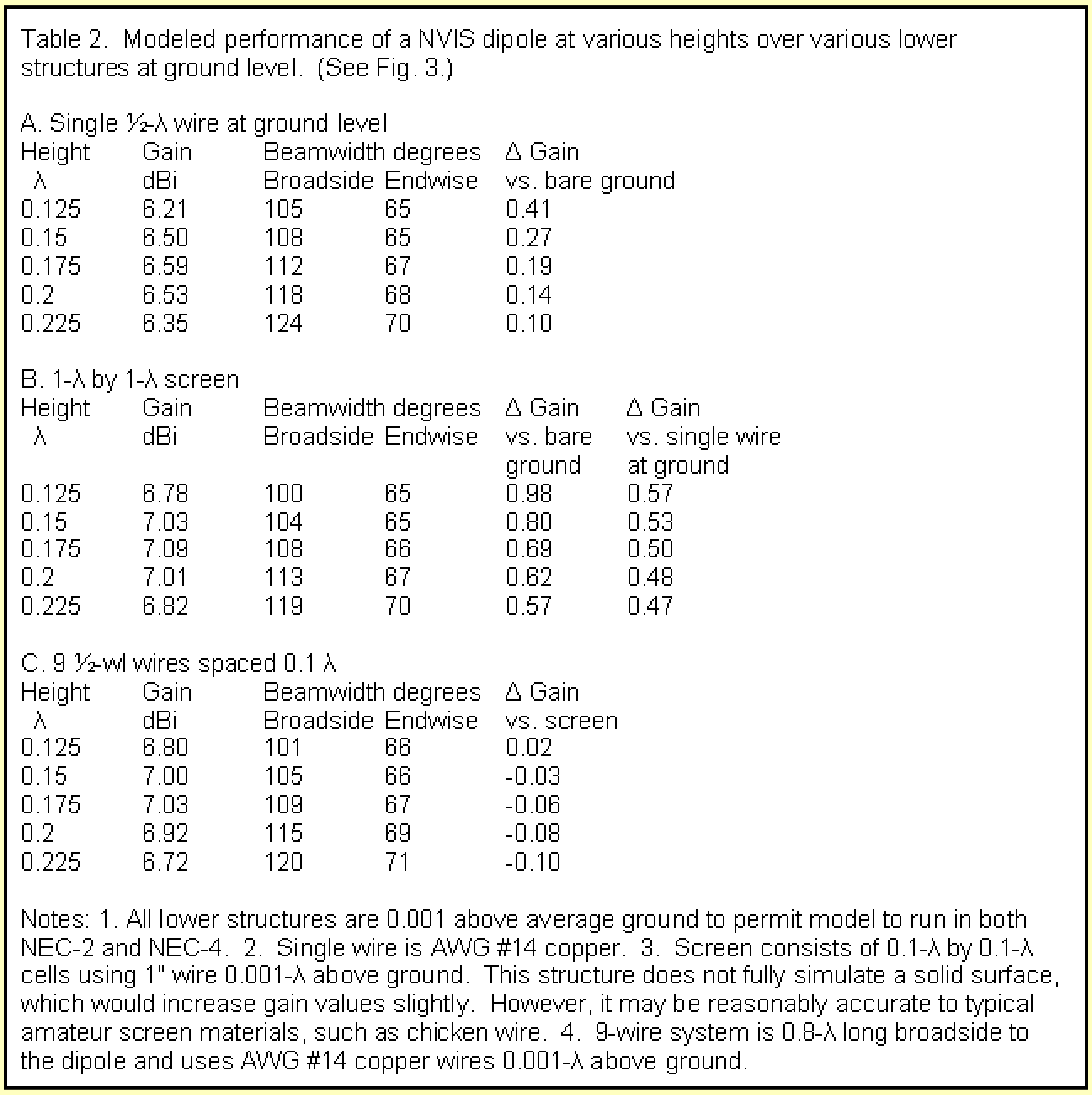


Table 2. Modeled performance of a NVIS dipole at various heights over various lower structures at ground level. (See Fig. 3.)

A. Single ½-λ wire at ground level

Height λ	Gain dBi	Beamwidth degrees Broadside	 Endwise	Δ Gain vs. bare ground
0.125	6.21	105	65	0.41
0.15	6.50	108	65	0.27
0.175	6.59	112	67	0.19
0.2	6.53	118	68	0.14
0.225	6.35	124	70	0.10

B. 1-λ by 1-λ screen

Height λ	Gain dBi	Beamwidth degrees Broadside	 Endwise	Δ Gain vs. bare ground	Δ Gain vs. single wire at ground
0.125	6.78	100	65	0.98	0.57
0.15	7.03	104	65	0.80	0.53
0.175	7.09	108	66	0.69	0.50
0.2	7.01	113	67	0.62	0.48
0.225	6.82	119	70	0.57	0.47

C. 9 ½-wl wires spaced 0.1 λ

Height λ	Gain dBi	Beamwidth degrees Broadside	 Endwise	Δ Gain vs. screen
0.125	6.80	101	66	0.02
0.15	7.00	105	66	-0.03
0.175	7.03	109	67	-0.06
0.2	6.92	115	69	-0.08
0.225	6.72	120	71	-0.10

Notes: 1. All lower structures are 0.001 above average ground to permit model to run in both NEC-2 and NEC-4. 2. Single wire is AWG #14 copper. 3. Screen consists of 0.1-λ by 0.1-λ cells using 1" wire 0.001-λ above ground. This structure does not fully simulate a solid surface, which would increase gain values slightly. However, it may be reasonably accurate to typical amateur screen materials, such as chicken wire. 4. 9-wire system is 0.8-λ long broadside to the dipole and uses AWG #14 copper wires 0.001-λ above ground.

Studies of HF dipole arrays used for short-wave broadcasting and of VHF/UHF planar reflector arrays show that a conductive screen forms a very useful reflecting surface based on principles derived from optics. Such screens perform best when they extend at least ½ wavelength beyond the driven elements in all directions. The model with the screen in **Figure 3** and in **Table 2** uses a screen that is 1 wavelength by 1 wavelength on a side. The cells are 0.1-wavelength on a side. To simulate a solid screen, the wire would have to be very thick and using that wire would prevent the screen from sitting 0.001-wavelength above ground. So I reduced the wire size to a 1" diameter. The reduced wire size leaves the screen "holy" and reduces the reported gain. However, it may also better reflect the likely amateur use of inexpensive materials like chicken wire in which the junctions are not durably connected. The tabulated data shows a nearly constant improvement over the dipole and single-wire reflector. It also shows a decreasing improvement over the dipole above bare average ground. Still, the peak gain height remains at 0.175 wavelength. The broadside beamwidth shows a 4°-5° reduction with the screen in place, but the endwise beamwidth does not change at all.

We can simulate a full screen with a series of wires at ground level if we use enough of them. The final configuration uses 9 AWG #14 copper wires at a height of 0.001 wavelength. The wire spacing is 0.1 wavelength. Each wire is only slightly longer than the dipole itself. With the 9 wires forming a field that is 0.8-wavelength long, the final section of **Table 2** shows performance virtually identical to the performance with a full screen. Smaller numbers of wires or total field sizes produce lesser performance levels. (Since the single reflector proved so ineffective and since the screen is simpler to model than the 9-wires, analyses of other simple antenna will contrast bare-ground and screen performance. However, the 9-wire field is always available as an alternative to a screen and may be easier to install.)

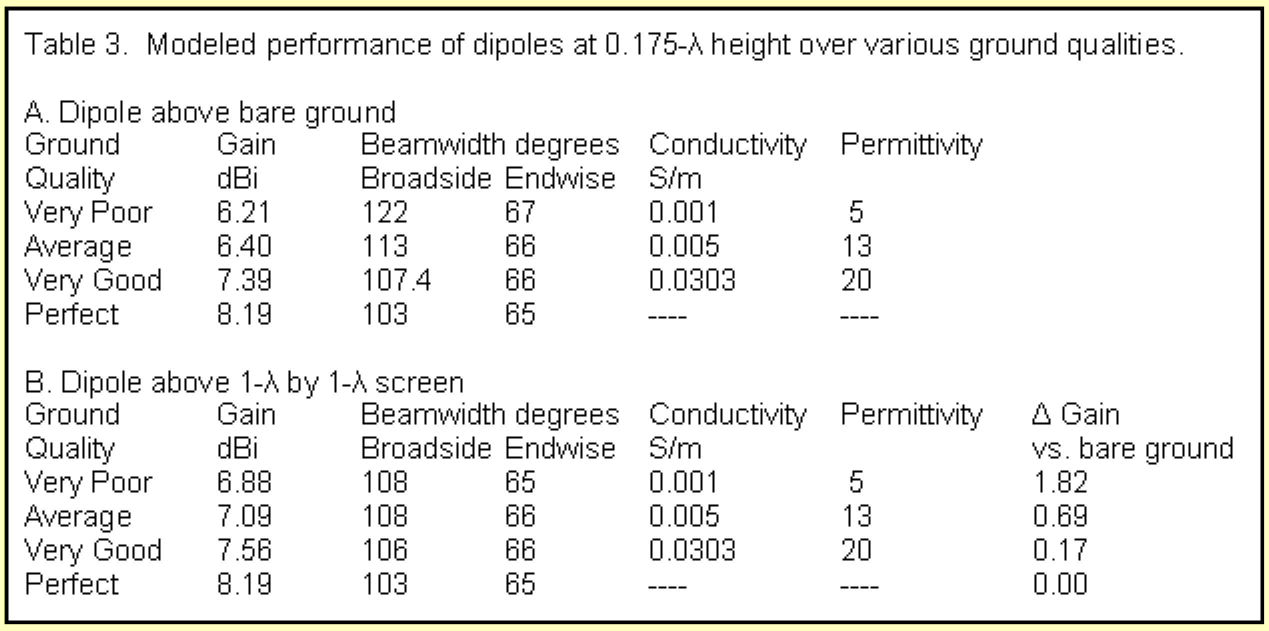


Table 3. Modeled performance of dipoles at 0.175-λ height over various ground qualities.

A. Dipole above bare ground

Ground Quality	Gain dBi	Beamwidth degrees Broadside	 Endwise	Conductivity S/m	Permittivity
Very Poor	6.21	122	67	0.001	5
Average	6.40	113	66	0.005	13
Very Good	7.39	107.4	66	0.0303	20
Perfect	8.19	103	65	----	----

B. Dipole above 1-λ by 1-λ screen

Ground Quality	Gain dBi	Beamwidth degrees Broadside	 Endwise	Conductivity S/m	Permittivity	Δ Gain vs. bare ground
Very Poor	6.88	108	65	0.001	5	1.82
Average	7.09	108	66	0.005	13	0.69
Very Good	7.56	106	66	0.0303	20	0.17
Perfect	8.19	103	65	----	----	0.00

Let's pause here to look at an important side question: how does ground quality affect the improvement level offer by the screen or the 9-wire field? I modeled the dipole at a height of 0.175 wavelength over bare ground and over the screen using several ground quality levels, all of which appear in **Table 3**. The worse the soil quality, the greater the improvement offered by the ground-level screen. Over very poor soil, the gain improvement is nearly 2 dB, but over very good soil, the improvement drops to only 0.2 dB. In no case of solid ground does the use of a screen seriously approach the level of a perfect ground, although at sea, one might come very close. The conclusion is that NVIS antennas over poorer grades of soil may benefit significantly from a screen or a 9-wire reflector. **The Inverted-V**

Testing NVIS inverted-V antennas adds another variable to our modeling efforts. Let's assume that we use a fixed height for the ends of the V. For safety, I placed the ends 0.05-wavelength (about 12.5' at 3.9 MHz) above ground. As I surveyed changing top heights, I restored the antenna to near resonance, which drew the ends in toward the center and increased the angle of the wire relative to the ground. **Figure 4** shows the bare ground and screen configurations. **Table 4** presents the test results, including the wire angle.

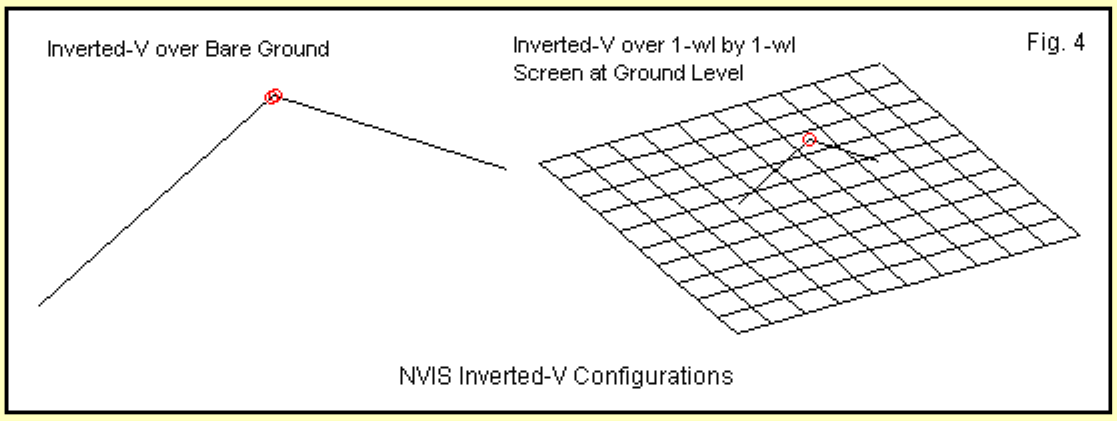


Fig. 4

NVIS Inverted-V Configurations

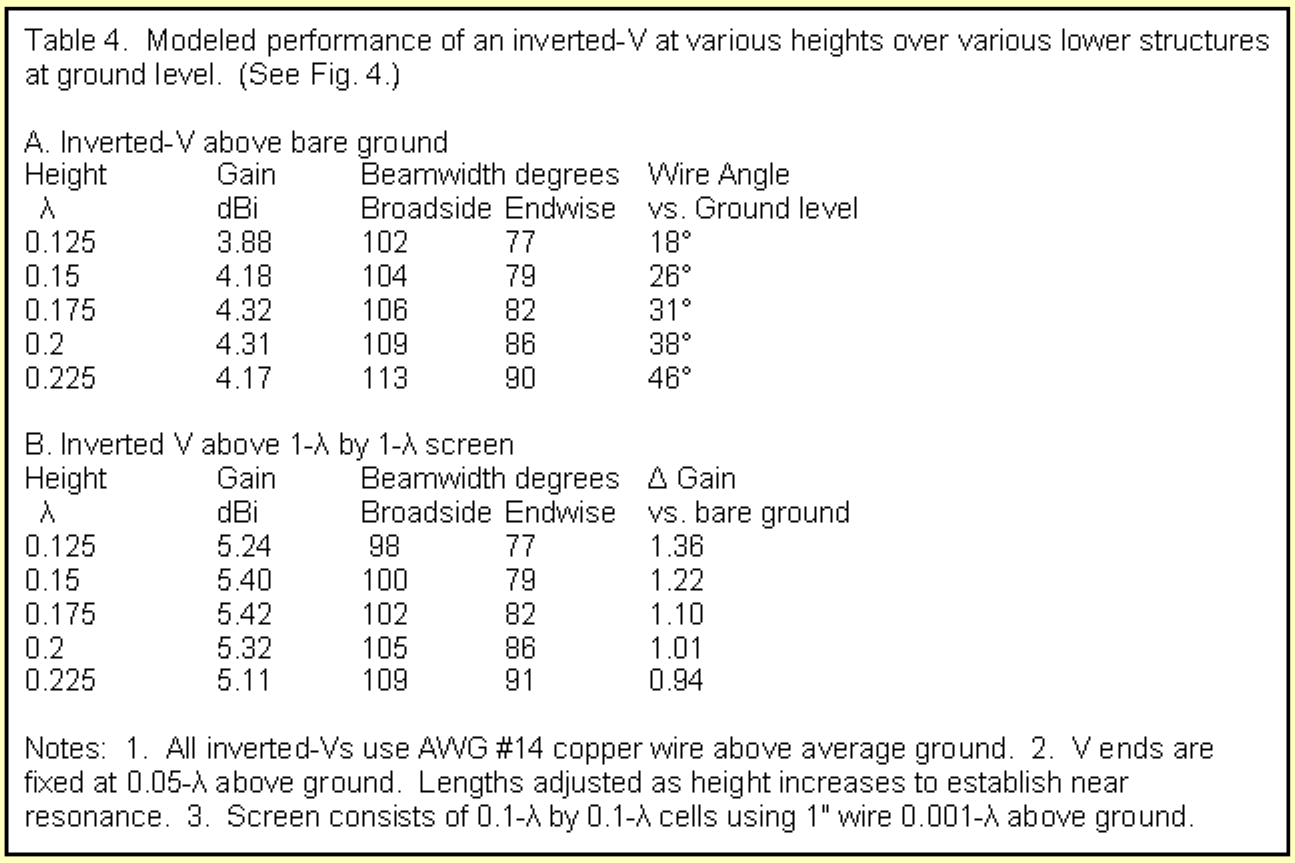


Table 4. Modeled performance of an inverted-V at various heights over various lower structures at ground level. (See Fig. 4.)

A. Inverted-V above bare ground

Height	Gain	Beamwidth degrees		Wire Angle
λ	dBi	Broadside	Endwise	vs. Ground level
0.125	3.88	102	77	18°
0.15	4.18	104	79	26°
0.175	4.32	106	82	31°
0.2	4.31	109	86	38°
0.225	4.17	113	90	46°

B. Inverted V above 1-λ by 1-λ screen

Height	Gain	Beamwidth degrees		Δ Gain
λ	dBi	Broadside	Endwise	vs. bare ground
0.125	5.24	98	77	1.36
0.15	5.40	100	79	1.22
0.175	5.42	102	82	1.10
0.2	5.32	105	86	1.01
0.225	5.11	109	91	0.94

Notes: 1. All inverted-Vs use AWG #14 copper wire above average ground. 2. V ends are fixed at 0.05-λ above ground. Lengths adjusted as height increases to establish near resonance. 3. Screen consists of 0.1-λ by 0.1-λ cells using 1" wire 0.001-λ above ground.

The inverted-V over bare ground shows much less gain than a dipole. The effective height of the entire wire is about 2/3 the distance between the lower and the upper ends. Hence, the peak gain is approximately the same as the dipole over bare ground at a height between 0.1 wavelength and 0.125 wavelength. Consistent with the dipole models, the peak gain for the inverted-V occurs at a top height of 0.175 wavelength.

One advantage of an inverted-V is that the endwise beamwidth increases by from 10° to 20° relative to the dipole. In fact, the higher that we place the V, the more circular the pattern becomes. At a height of 0.225 wavelength, we find only a 23° difference between the broadside and the endwise beamwidth reports. The wire angle at this height is about 46°, a value that we cannot safely achieve at lower top heights. Obviously, the greater the wire angle relative to ground, the more omni-directional the pattern becomes.

For any given top height, an inverted-V's effective height will be lower than a linear dipole at the same height. As a consequence, the inverted-V tends to benefit more from the presence of a ground-level screen (or its 9-wire substitute). The lower part of Table 4 shows a 1-dB or greater improvement in gain. As well, it shows a slight improvement in the circularity of the azimuth coverage due to a small shrinkage in the broadside beamwidth.

One strategy for setting up a NVIS antenna system is to use a pair of inverted-V antennas--one for 80/75 meters, the other for 40 meters--using a common center support and a common feedpoint. If the antennas are at right angles to each other, interactions between the two sets of wires will be minimal. The limitation of such a system is that we end up with both bands using heights that are not optimal. 0.125 wavelength at 3.9 MHz is close to 0.23 wavelength at 7.2 MHz. While both heights fall within the scanned range for our test cases, one or the other may yield a pattern shape that is not ideal. We may use the same center support for both bands, but setting up separate antennas optimized for the best height and wire angle (over a reflector screen) may let us achieve near circularity of coverage or just the degree of pattern elongation that we need for the intended coverage area.

The 1-Wavelength Loop

An overlooked antenna for NVIS work is the 1-wavelength loop. Each side of the loop is only about half the length of a dipole for the same frequency. If we plan to supplement the antenna with a screen or other reflection means, the loop may prove to be more compact than a dipole or a V with a screen below. As well, we can nest loops for each lower HF band that we wish to cover. **Figure 5** shows the bare-ground and the screened configurations, the data for which appear in **Table 5**.

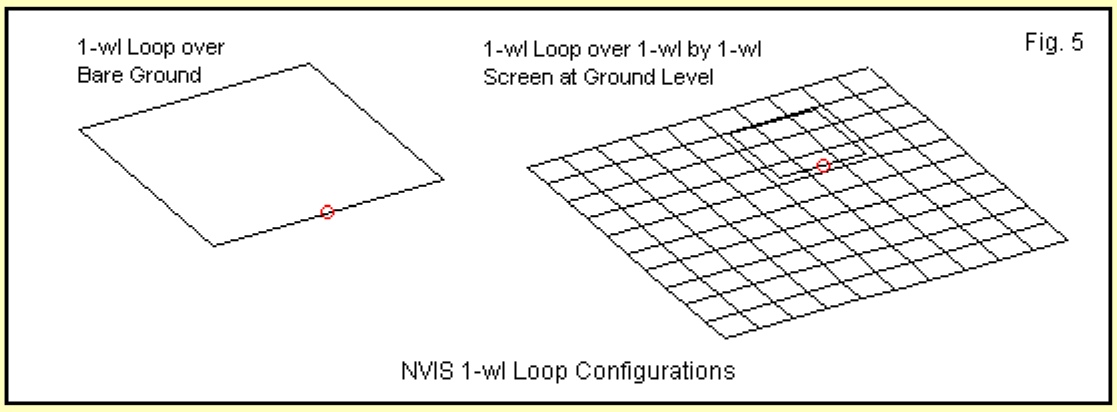


Fig. 5

NVIS 1-wl Loop Configurations

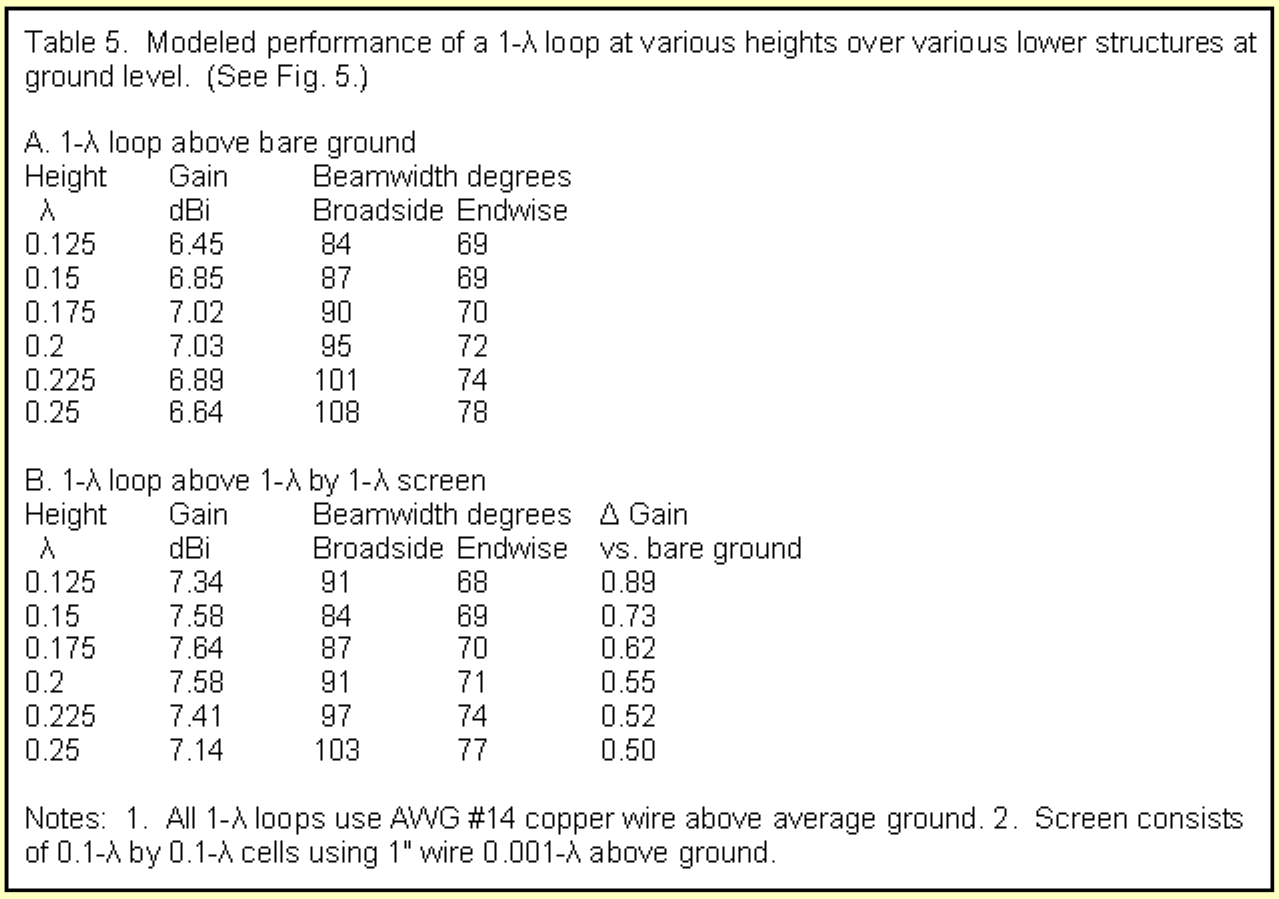


Table 5. Modeled performance of a 1-λ loop at various heights over various lower structures at ground level. (See Fig. 5.)

A. 1-λ loop above bare ground

Height	Gain	Beamwidth degrees	
λ	dBi	Broadside	Endwise
0.125	6.45	84	69
0.15	6.85	87	69
0.175	7.02	90	70
0.2	7.03	95	72
0.225	6.89	101	74
0.25	6.64	108	78

B. 1-λ loop above 1-λ by 1-λ screen

Height	Gain	Beamwidth degrees		Δ Gain
λ	dBi	Broadside	Endwise	vs. bare ground
0.125	7.34	91	68	0.89
0.15	7.58	84	69	0.73
0.175	7.64	87	70	0.62
0.2	7.58	91	71	0.55
0.225	7.41	97	74	0.52
0.25	7.14	103	77	0.50

Notes: 1. All 1-λ loops use AWG #14 copper wire above average ground. 2. Screen consists of 0.1-λ by 0.1-λ cells using 1" wire 0.001-λ above ground.

Compared to a dipole, the 1-wavelength loop provides slightly higher maximum gain levels and slightly more circular patterns. At the height of maximum gain, the loop pattern is about 24° less oval than the dipole pattern, as measured by the difference between the broadside and the endwise beamwidth values. For the loop, the broadside direction passes through the mid-side feedpoint and the midpoint of the opposite side. The endwise pattern passes through the two opposing two sides without a feedpoint. The use of a 1-wavelength by 1-wavelength screen below the loop at ground level provides slightly less added gain than it does for a dipole.

In some respects, the 1-wavelength loop provides the best of the dipole and the inverted-V worlds. It has the dipole's gain and the V's nearly circular pattern. However, it does require 4 corner supports, and the feedpoint is well above the range for a good match to common 50-Ohm coaxial cable. The latter problem disappears if we add a ¼-wavelength section of 70-75-Ohm cable.

High-Gain NVIS Arrays

The simple antennas that we have explored offer a balance between gain and beamwidth. Since we are dealing with nearly circular azimuth patterns with only one main lobe, the only way to increase upward or maximum gain is to decrease the beamwidth in one or both directions. Hence, high-gain arrays are not necessarily for everyone. The operator who needs to use elevation angles down to say 45° may obtain better results with one of the simple antennas. However, a central station that requires only short-distance communication may find an advantage in concentrating his or her signal upward. In fact, by using a common wire array configuration, we may obtain up to 6-dB additional gain.

Perhaps the two most common NVIS arrays used to increase upward gain are the "Jamaica" and the "Shirley" array. Actually, both arrays are forms of the lazy-H facing the sky. Moreover, for raw upward gain, these arrays overlook the best of the lot: the extended (or expanded) lazy-H. Let's quickly sample all 3 antennas both with and without a screen (or multi-wire) supplement. In each case, the antenna itself will use the same AWG #14 copper wire common to the simple antennas. We feed each antenna element in phase with equal length lines to a central feedpoint. The feedpoint impedance will vary according to the element length, the spacing, and the characteristic impedance of the phasing lines. **Table 6** provides the modeled data for all 3 antennas.

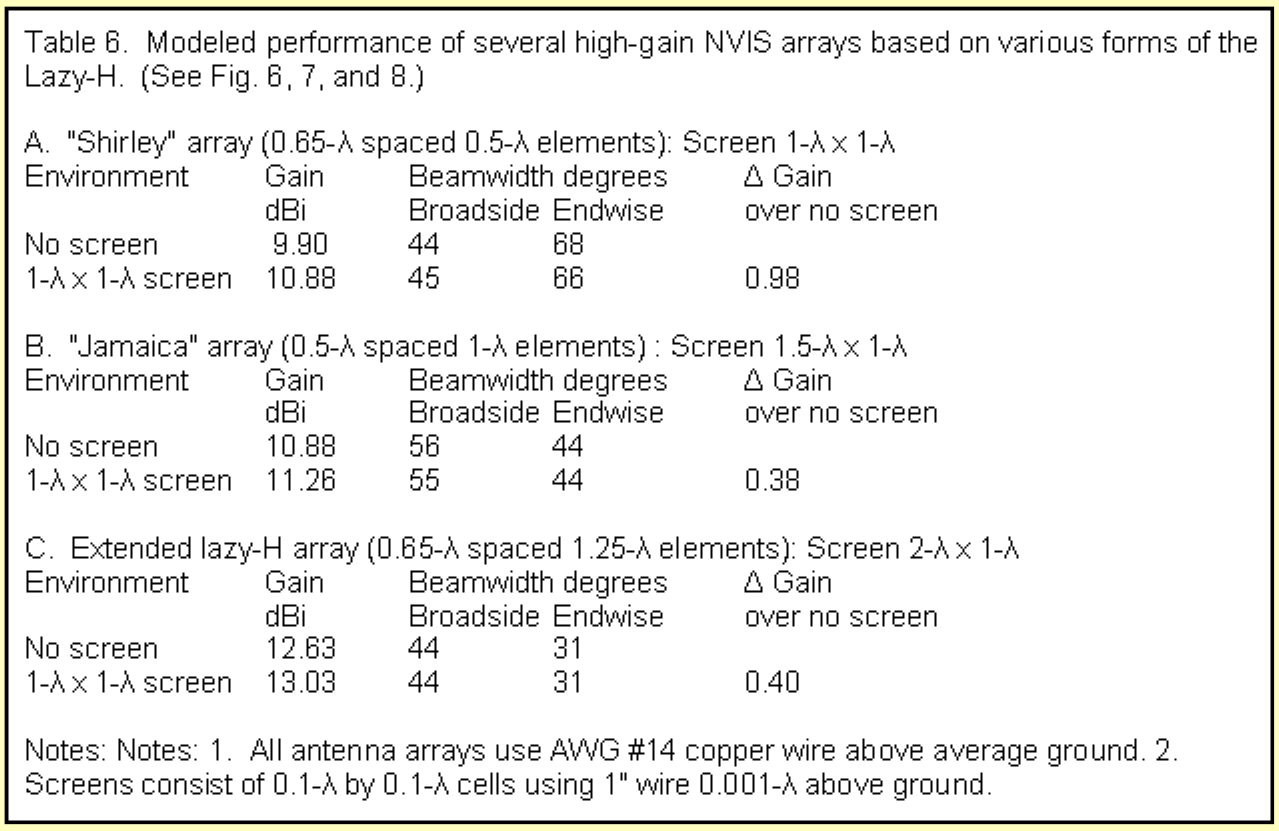


Table 6. Modeled performance of several high-gain NVIS arrays based on various forms of the Lazy-H. (See Fig. 6, 7, and 8.)

A. "Shirley" array (0.65-λ spaced 0.5-λ elements): Screen 1-λ x 1-λ

Environment	Gain	Beamwidth degrees		Δ Gain
	dBi	Broadside	Endwise	over no screen
No screen	9.90	44	68	
1-λ x 1-λ screen	10.88	45	66	0.98

B. "Jamaica" array (0.5-λ spaced 1-λ elements) : Screen 1.5-λ x 1-λ

Environment	Gain	Beamwidth degrees		Δ Gain
	dBi	Broadside	Endwise	over no screen
No screen	10.88	56	44	
1-λ x 1-λ screen	11.26	55	44	0.38

C. Extended lazy-H array (0.65-λ spaced 1.25-λ elements): Screen 2-λ x 1-λ

Environment	Gain	Beamwidth degrees		Δ Gain
	dBi	Broadside	Endwise	over no screen
No screen	12.63	44	31	
1-λ x 1-λ screen	13.03	44	31	0.40

Notes: Notes: 1. All antenna arrays use AWG #14 copper wire above average ground. 2. Screens consist of 0.1-λ by 0.1-λ cells using 1" wire 0.001-λ above ground.

The Shirley array, shown in **Figure 6** uses ½-wavelength elements spaced about 0.65-wavelength apart. Some versions use folded dipole elements for presumed match to the phase lines, but that aspect of the antenna construction plays no role in establishing the basic gain and pattern data. At a height between 0.175-wavelength and 0.2 wavelength, the antenna shows a little over 4-dB gain over a dipole. The price that we pay for the gain is a very significant reduction in the broadside beamwidth (by nearly 70°), but not in the endwise beamwidth. See the lower part of **Figure 6**. The result is a highly elongated oval that favors the directions off the ends of the elements. The use of a 1-wavelength by 1-wavelength screen adds nearly a dB to the gain without altering the beamwidth values.

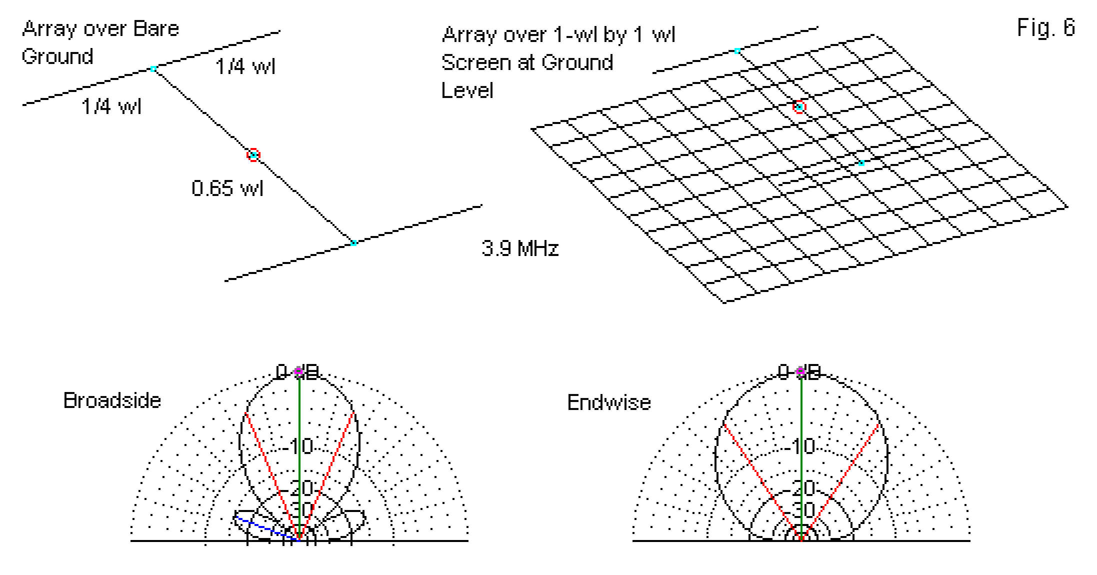


Fig. 6

NVIS Shirley Array (Wide-Spaced Lazy-H) Outline and Elevation Patterns

The Jamaica array, shown in **Figure 7**, uses a standard lazy-H configuration: two 1-wavelength elements with a ½-wavelength space between them. Over bare ground, it improves upward gain by a full dB over the Shirley array, but the addition of a 1.5-wavelength by 1-wavelength screen adds less than a half-dB more. In both cases, the Jamaica height is the same as the Shirley height. One way to view the circularity of the patterns is to take the ratio of the broadside to endwise beamwidth values. The dipole over bare ground shows a broadside-to-endwise ratio of 1.7:1. In contrast, the Jamaica array has a ratio of less than 1.3:1 over bare ground, as illustrated by the patterns in the lower half of **Figure 7**. Both numbers are drawn from the height of maximum gain. (In contrast, the Shirley array showed a broadside-to-endwise ratio of 0.6:1.) Note that the use of collinear half-wavelength elements and half-wavelength spacing yields no sidelobes. The wider spacing of the Shirley elements revealed the emergence of low-angle broadside lobes.

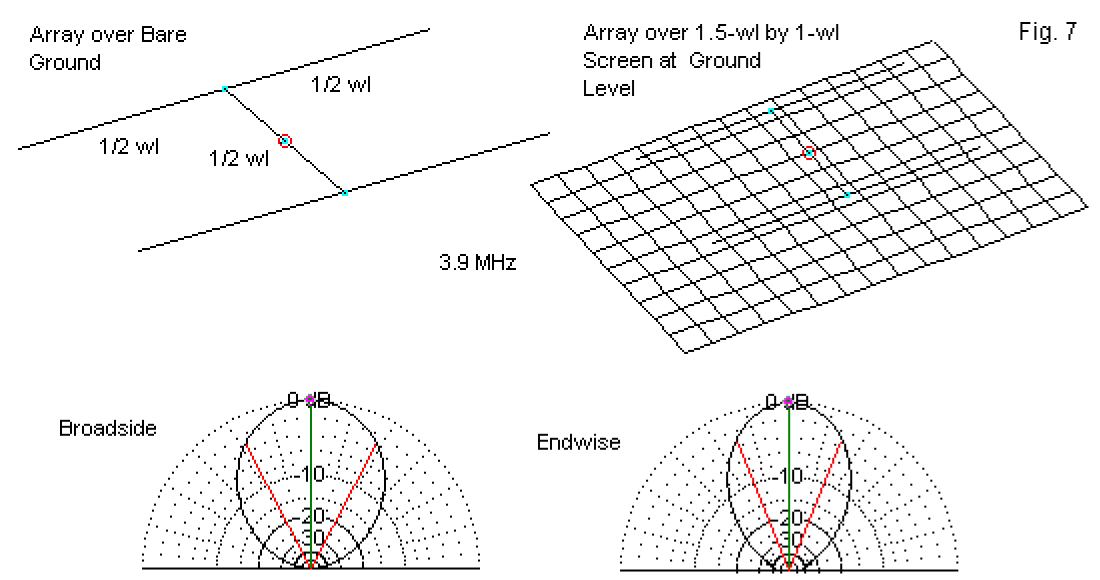


Fig. 7

NVIS Jamaica Array (Lazy-H) Outline and Elevation Patterns

For raw gain, we can do little better than increase the element length to 1.25 wavelength and use a 0.65-wavelength space between the elements. **Figure 8** shows the results, along with patterns that reveal the emergence of sidelobes in both the broadside and endwise directions. The user will have to determine whether the lower-angle sidelobes present a danger of increased noise pick-up based on the level and types of noise sources for the given location.

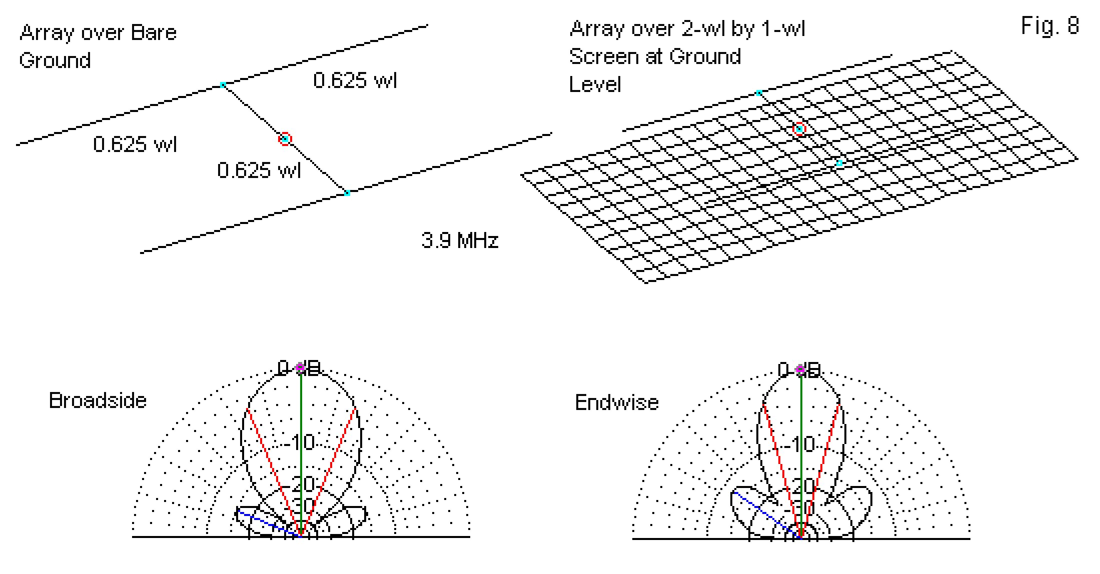


Fig. 8

NVIS Extended Lazy-H Outline and Elevation Patterns

If the sidelobes do not pose a problems, then the extended lazy-H array adds nearly 2 dB to the gain offered by the Jamaica beam, without a screen or with the requisite 2-wavelength by 1-wavelength screen needed by the extended lazy-H. (Of course, a field of wires about 1.5-wavelength long and extending about 0.4-0.5-wavelength beyond the broadside limits of the active array may substitute for the screen.) The screen adds only about 0.4-dB gain to the bare ground version of the antenna. Essentially, the extended lazy-H configuration provides 12.5-13 dBi maximum gain over average ground, compared to 6.4 to 7.1 dB for a dipole at roughly the same height. In exchange, as shown by the lower part of **Figure 8**, we further narrow the beamwidth--down to 44° broadside and 31° endwise. The 1.4:1 ratio shows fairly good azimuth circularity.

Assuming that we can handle the Lazy-H array feedpoint impedance values with an antenna tuner, the extended version of the array offers a further unadvertised benefit that stems from its higher gain level. We can afford to place an extended lazy-H a bit higher than the optimal height and set the element length at 1.25 wavelength on 7.2 MHz, with a 40-meter spacing of about 0.6-wavelength to 0.65-wavelength. The gain deficit relative to an optimal height will be small. At 3.9 MHz, the array will be a little over half as high, and the element lengths and the spacing will be half as much. The array will still perform well, with a gain level intermediate between a dipole and a full extended lazy-H. At the lower frequency, we would find no sidelobes.

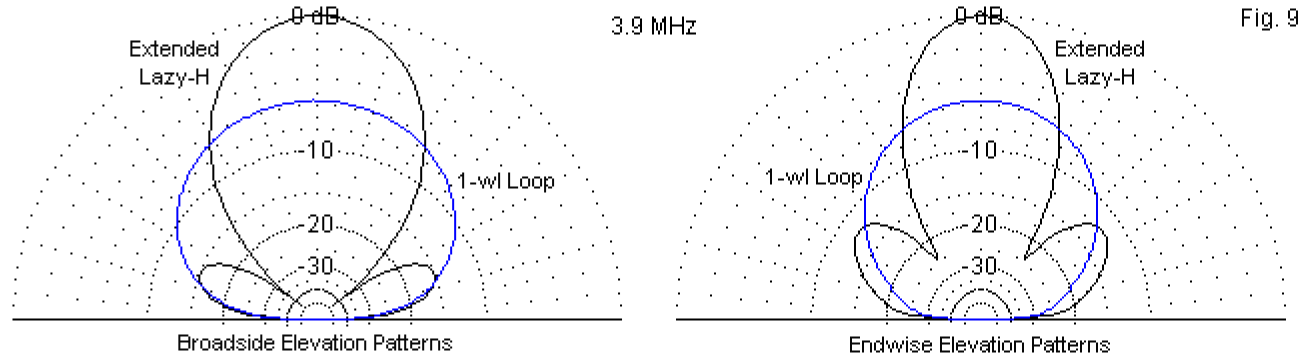


Fig. 9

Comparative Broadside and Endwise Elevation Patterns: 1-WL Loop and Extended Lazy-H Array

The lure of additional gain often blinds us to other considerations that may affect our operation. Throughout these notes, I have tried to give equal strength to gain and beamwidth comparisons. Which factor requires greater weight in deciding on a NVIS antenna requires an operator decision. If operations require more than short range, then the added gain of the lazy-H configurations may not be an advantage. Therefore, **Figure 9** may be of interest. It shows overlaid patterns for a 1-wavelength loop and for the extended lazy-H array, both over bare ground. The increased gain potential of the lazy-H captures our initial attention. However, if we count upward to the 45° elevation angle, we discover that the loop has a significantly higher gain in that elevation direction. In fact, at that angle, the lazy-H has almost no gain, since it is the angle for the null between the main lobe and the sidelobe in both the broadside and the endwise patterns.

Conclusion

We have looked at a variety of central-station NVIS antennas for amateur use with an eye toward finding the optimal height of maximum gain (between 0.175 wavelength and 0.2 wavelength). We also examined the level of pattern circularity achieved by these simple designs. We also explored a few high-gain NVIS arrays, as well as the level of benefit offered by ground screens or multi-wire substitutes. Which antenna might be correct for you depends on your available space, your access to supports, and also the type of operating that you do. For casual chats with a neighbor who lives beyond yon hill (or even beyond the hill beyond yon hill), a high gain array may be a nearly ideal NVIS antenna.

For the emergency operator, high gain alone may not solve all challenges, especially if there is a need to reach beyond short range into the intermediate range that still falls within the skip zone. One of the simpler antennas may better serve the requirement. In his article, Straw noted the need for multiple relays to route important messages outward and then back inward toward targets, many of which required NVIS-type propagation. Under these conditions, the right antenna--abetted by high operator skill and experience--proved invaluable. In fact, it gave a contemporary rationale for continuing to call our national organization the American Radio Relay League. Indeed, an operator who copies precisely and relays accurately is as important as the antenna that he or she uses.

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