The Linear and Sloping Lazy-H Wide-Band NVIS Antenna Systems

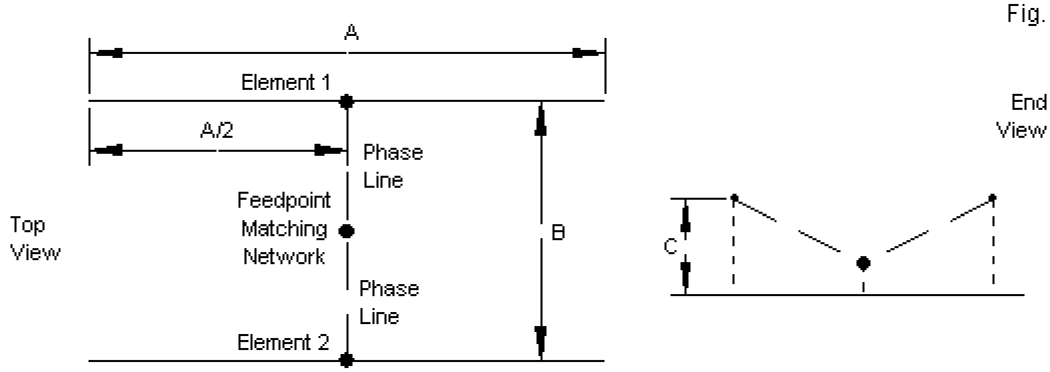
L. B. Cebik, W4RNL
1434 High Mesa Drive
Knoxville, TN 37938-4443
e-mail: cebik@cebik.com

For non-ALE wide-band NVIS antenna systems, the requirement for high-speed switching from one to another frequency is much reduced. As well, the frequency list is normally short, and the frequency range generally extends no higher than 10 MHz. These reduced requirements allow the use of a remote wide-range antenna tuner (matching network) under computer control. Remote computer-controlled tuners generally have memories so that a change of frequency recalls settings established under a periodic search and lock protocol.

For such systems, the Lazy-H antenna provides a 2.5:1 frequency range. The Lazy-H antenna consists of 2 wire elements, each 1.25 λ long at the highest frequency in the range. At the lowest frequency, the wires are 0.5 λ long. The distance between wire elements is 0.625 λ at the highest frequency and 0.125 λ at the lowest. Equal lengths of parallel feedline constitute the phasing lines and reach a central point between the 2 wires, but may be at any height at the junction. The parallel transmission lines join in parallel so that the 2 wires are fed in phase. Because the element wires change in length from 0.5 to 1.25 λ across the operating range, the impedance at the center changes considerably with frequency. However, in-phase feeding via parallel transmission lines reduces the excursion limits for the impedance with normal line lengths and characteristic impedance values.

1. *The Standard Lazy-H Array.* These notes compare the size and performance of standard Lazy-H configurations with linear elements to Lazy-H installations using inverted-V elements. The initial comparison will use 600-Ω phase lines for which sturdy construction is possible using AWG #10 copperweld wire or similar, along with UV-protected periodic spacers of materials rated for the operating environment. Initial comparisons will employ average ground (conductivity 0.005 S/m, permittivity 13) with no ground screen.

Fig. 1



Standard NVIS Lazy-H: Dimensional Guide

Fig. 1 outlines the standard Lazy-H configuration using linear elements. Note that the phase lines slope downward to a short center support that is 10' tall for the low-range version and 5' tall for the high-range version of the array. **Table 1** provides the dimensions for the arrays in both ranges.

Table 1. Standard NVIS Lazy-H Dimensions
All dimensions are in feet.

Dimension	Low-Range	High Range
A	240	120
B	123	61.5
C	42	21

Because the phase lines slope downward to their junction support, they are slightly longer than half the distance labeled as B. The actual junction impedance will vary slightly with small changes in the length of the phase lines. Therefore, tabulated values for feedpoint junction impedances are indicative of actual values but not identical to them.

Table 2 provides the modeled performance of the 2 versions of the antenna system. The low-range covers 2 through 5 MHz. The high-range version covers 4 through 10 MHz. Hence, the antennas are direct scalings of each other, except for the wire diameter, which is AWG #10 throughout.

Table 2. Modeled Performance of the Standard Lazy-H Array over Average Ground with No Ground Screen.

Low-Range

Frequency MHz	Maximum Gain dBi	Broadside Beamwidth Degrees	End-wise Beamwidth degrees	Beamwidth Ratio	Feedpoint Z R +/- jX Ω
2	6.34	80	65	1.23	85 + j390
3	8.69	67	56	1.20	60 - j235
4	10.77	56	45	1.24	30 + j 70
5	12.55	47	33	1.42	130 + j630

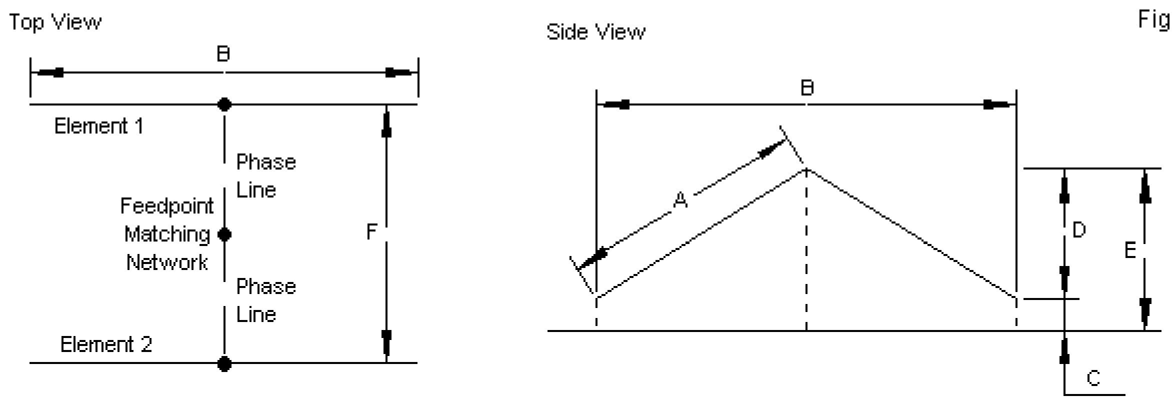
High-Range

Frequency MHz	Maximum Gain dBi	Broadside Beamwidth Degrees	End-wise Beamwidth degrees	Beamwidth Ratio	Feedpoint Z R +/- jX Ω
4	5.64	81	66	1.23	95 + j382
5	7.07	75	61	1.23	655 - j860
6	8.25	68	56	1.21	75 - j250
7	9.36	62	51	1.22	40 - j 60
8	10.48	56	45	1.24	35 + j 70
9	11.57	51	39	1.31	45 + j240
10	12.31	47	33	1.42	170 + j695

The gain values for scaled frequencies of the upper range relative to the lower range are slightly lower due to increased ground losses at the high frequencies. The standard Lazy-H configuration shows a rising gain value with rising frequency, due to the increasing length of the elements as a function of a wavelength. As well, the more optimal spacing at higher frequencies contributes to the increased gain.

Rising gain exacts a cost in terms of the narrowing beamwidth with increased frequency in each range. *It is extremely important to establish that the narrow beamwidths associated with the higher frequencies in each range still permit effective communications within the total skip zone* *at each frequency to be used.* Although the beamwidth values grow narrow, the ratio of broadside to end-wise beamwidth indicates a reasonable approximation of a circle, that is, nearly omni-directional coverage.

Fig. 2



NVIS Inverted-V Lazy-H: Dimensional Guide

2. *The Inverted-V Lazy-H Array with No Screen.* **Fig. 2** outlines a Lazy-H array composed of inverted-V elements. Mechanically, the inverted-V elements are simpler, since each element requires only one tall center support, with lower end support masts (suitably guyed). However, the center of each V elements is nearly 1.8 times the height of the required end supports for the standard Lazy-H. **Table 3** provides the dimensions indicated in the sketch for the low-range and the high-range versions of the antenna.

Table 3. Inverted-V NVIS Lazy-H Dimensions
All dimensions are in feet.

Dimension	Low-Range	High Range
A	120	60
B	200	100
C	10	5
D	65	32.5
E	75	37.5
F	123	61.5

The overall inverted-V array length (wire-end to wire-end) is 20% shorter than the corresponding linear-element version, although the center height is considerably greater. The array width or distance between the two wires remains unchanged. For initial study purposes, the low-range and the high-range versions of the array are direct scalings of each other. However, the wire diameter remains AWG #10.

Table 4 provides the modeled performance of the inverted-V Lazy-H arrays over average ground with no ground screen. Therefore, the values in this table are directly comparable to those in **Table 2**, which covers the linear versions of the array.

Table 4. Modeled Performance of the Inverted-V Lazy-H Array over Average Ground with No Ground Screen.

Low-Range

Frequency MHz	Maximum Gain dBi	Broadside Beamwidth Degrees	End-wise Beamwidth degrees	Beamwidth Ratio	Feedpoint Z R +/- jX Ω
2	4.94	82	93	1.13	310 + j725
3	6.34	70	88	1.26	50 - j 80
4	7.54	57	72	1.26	70 + j280
5	9.25	45	46	1.02	510 - j1130

High-Range

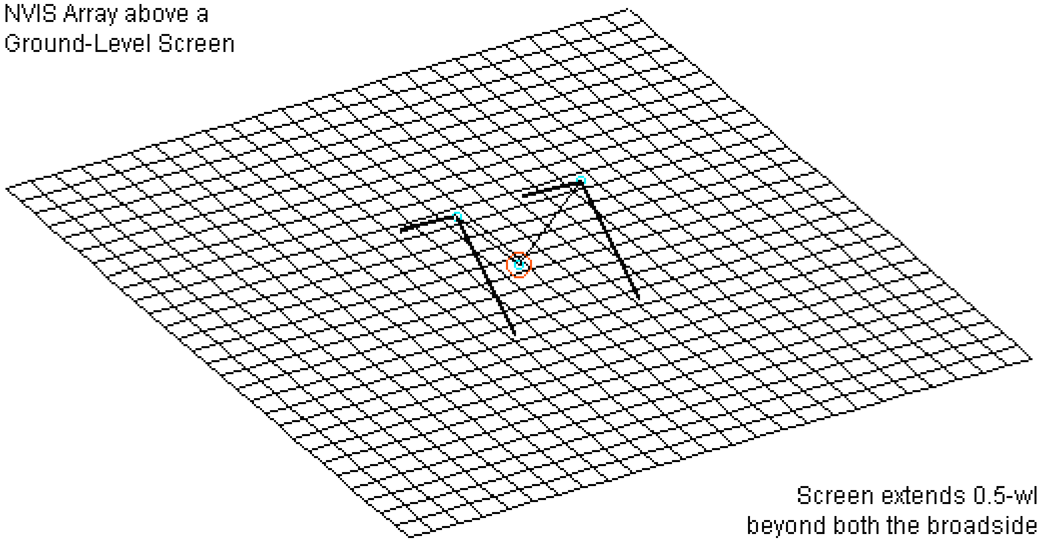
Frequency MHz	Maximum Gain dBi	Broadside Beamwidth Degrees	End-wise Beamwidth degrees	Beamwidth Ratio	Feedpoint Z R +/- jX Ω
4	4.31	84	91	1.08	320 + j690
5	5.27	78	89	1.14	180 - j410
6	5.99	71	86	1.21	60 - j 90
7	6.63	64	81	1.26	50 + j 80
8	7.28	57	71	1.25	75 + j280
9	8.00	51	58	1.14	375 + j865
10	8.83	45	46	1.02	405 - j965

The inverted-V version of the array achieves a greater overall circularity of pattern as indicated by the beamwidth ratios. Note that the beamwidth ratios use the end-wise values as the numerator, reversing the ratios used for the linear versions of the array. Nevertheless, the maximum beamwidth values for any test frequency do not differ much between the two array configurations. Hence, the caution concerning skip-zone coverage applies equally to the inverted-V arrays.

The increased circularity of the patterns of the inverted-V Lazy-H array comes at the expense of maximum gain. The inverted-V versions show gain values that are from 1.5 to 3 dB lower than the linear versions, averaging a gain deficit of about 2.5 dB overall. The pattern of increasing gain with rising frequency within each range is common to both versions of the Lazy-H.

3. *The Inverted-V Lazy-H Array with a Ground Screen.* The function of a ground screen is largely to equalize NVIS array performance over a wide range of ground qualities ranging from very poor (conductivity 0.001, permittivity 5) to very good (conductivity 0.0303, permittivity 20). An effective screen operates in the manner of a planar reflector (common in UHF arrays). Research shows that for maximum effectiveness, the screen must exceed the array dimensions by at least 0.5 λ in all directions.

Modeling such a screen is somewhat less than perfectly precise due to conflicting requirements. A screen that simulates a solid surface or tightly woven grid must use cells that are no larger than 0.1-λ per side with a wire diameter that is the length of the cell side divided by π. As well, the grid must be at or as close as possible to ground level. In the MF and lower HF ranges, the required wire diameter would place the screen several feet above ground to prevent an intersection of the wire's volume with the ground, a limitation of NEC software. Therefore, as a compromise, I created grids with 0.1-λ cells at 4 and 8 MHz (for the 2 scaled array sizes), and used 2" and 1" diameter wires respectively. The grid therefore falls short of fully approximating a solid or tightly woven surface. However, it is tight enough to produce gain values within a few tenths of a dB of precise, with about a 1% error in beamwidth values. **Fig. 3** shows the outline of the array and its screen, as used in these tests.



The inverted-V Lazy-H arrays for the 2 frequency ranges retain all of the dimensions shown earlier in **Table 3**. As well, the ground used is average in order to show the net change of performance using a ground screen. Over very good ground, there would be almost no change of performance with and without the screen. Over very poor ground, the improvement in gain performance with the screen relative to the performance without it would be very dramatic. A slight difference in performance between very good and very poor soil would remain, because there is a small component of the radiation pattern affected by the ground beyond the screen. However, overcoming that small remnant difference (a fraction of a dB in gain) would require a screen several wavelengths larger in each dimension.

Table 5 provides the modeled performance data in a form that is exactly parallel to the form used in **Table 4**, where the array used no ground screen.

Table 5. Modeled Performance of the Inverted-V Lazy-H Array over Average Ground with a Ground Screen.

Low-Range Frequency MHz	Maximum Gain dBi	Broadside Beamwidth Degrees	End-wise Beamwidth degrees	Beamwidth Ratio	Feedpoint Z R +/- jX Ω
2	6.29	82	104	1.27	275 + j795
3	7.20	68	88	1.29	45 - j 75
4	8.64	54	52	0.96	70 + j285
5	9.94	46	46	1.00	485 - j1105

Δ Gain 2-5 MHz: 3.65 dB

High-Range Frequency MHz	Maximum Gain dBi	Broadside Beamwidth Degrees	End-wise Beamwidth degrees	Beamwidth Ratio	Feedpoint Z R +/- jX Ω
4	6.26	82	104	1.27	300 + j800
5	6.37	78	106	1.35	140 - j400
6	7.15	68	88	1.29	50 - j 80
7	8.04	58	56	0.97	50 + j 90
8	8.70	54	46	0.85	80 + j290
9	9.18	52	48	0.92	400 + j890
10	9.90	46	46	1.00	380 - j940
Δ Gain 2-5 MHz: 3.64 dB					

The Δ-Gain value is virtually identical for both ranges and indicates the changing gain related to the element lengths and spacing as measured in terms of a wavelength at the operating frequency. As well, the impedance values are parallel between the 2 ranges, differing only due to the differential effects of ground at a 2:1 ratio in frequency. There are only minor differences in the impedances with and without the ground screen, which confirms the general adequacy of the models used. Impedance values are rounded, since they are only roughly indicative of actual values but subject to construction variables that may change the phase-line lengths.

Table 6 summarizes the improvement in gain over average ground using a ground screen of the prescribed size.

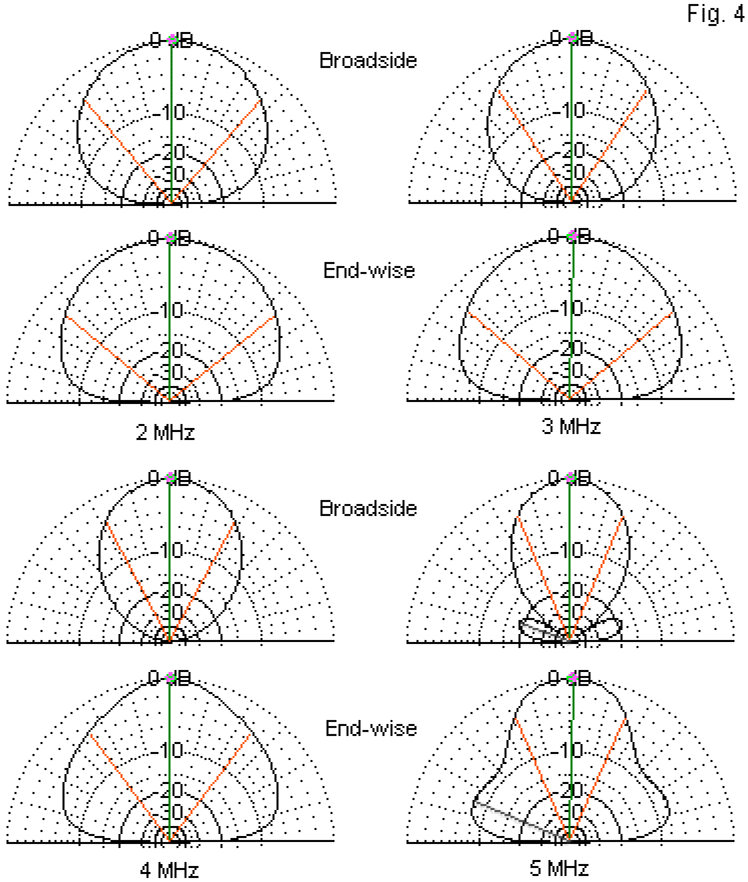
Table 6. Gain Improvement Using a Ground Screen

Range: Low Freq. MHz	Gain dBi No-Scr.	Gain dBi Screen	Δ Gain dB	High Freq. MHz	Gain dBi No-Scr.	Gain dBi Screen	Δ Gain dB
2	4.94	6.29	1.35	4	4.31	6.26	1.95
3	6.34	7.20	0.86	5	5.27	6.37	1.10
4	7.54	8.64	1.10	6	5.99	7.15	1.16
5	9.25	9.94	0.69	7	6.63	8.04	1.41
				8	7.28	8.70	1.42
				9	8.00	9.18	1.18
				10	8.83	9.90	1.07
Average Gain Improvement			1.00 dB				1.33 dB

The higher gain improvement in the upper-range version of the array shows the degree to which a ground screen tends to overcome the differential effects of ground, not only with respect to basic ground quality, but also with respect to changes in ground effects with rising frequency. Note that for comparable frequencies--where the high-range array uses twice the frequency of the low-range array--there is a far smaller differential in gain with a screen than without a screen.

The use of a ground screen is not necessarily wholly advantageous. The beamwidth ratios in **Table 5** show an interesting fluctuation above and below 1.00 (the indicator of a circular pattern at NVIS elevations). This pattern is not consistent with all implementations of NEC-4, due to variations in software handling of the grid used to simulate the ground screen. **Fig. 4** shows the patterns for the low-range version of the inverted-V Lazy-H array using a ground screen.

Fig. 4



Elevation Patterns of the Low-Range Inverted-V Lazy-H
NVIS Array with a Ground Screen at 1-MHz Intervals

The lower half of the operating range shows normal patterns on all software. As well, the patterns for the highest frequency are consistent on all software. However, note the small side lobes on the broadside 5 MHz pattern (equivalent to the 10-MHz pattern for the high-range version of the array). The "gum-drop" end-wise 5-MHz pattern shape is a stable version of the evolving end-wise pattern for 4 MHz. At 4 MHz, different implementations of NEC-4 show small differences in the sharpness of the end-wise triangular pattern. Slight changes in the slope of the pattern create large differences in the calculated beamwidth. Hence, the tabular end-wise beamwidth figure from one software source is smaller than the beamwidth derived in the figure from an alternate software source. The end-wise beamwidth in the upper mid-range of both versions of the array may vary by up to 15°, depending upon the exact implementation used.

The variation is allowable for this preliminary study. However, any design for a specific antenna will employ more exacting criteria for the wire grid to reduce beamwidth vagaries to an absolute minimum.

Despite the uncertainty about the exact beamwidth at certain modeling points, the patterns show clearly the evolution of the array pattern with increasing frequency. Under these conditions and considering the narrowness of the beamwidth at the higher end of each operating range, the cautionary note given earlier bears repeating. *It is extremely important to* *establish that the narrow beamwidths associated with the higher frequencies in each range still permit effective communications within the total skip zone at each frequency to be used.*

These notes have provided a preliminary overview of the performance capabilities of the linear and the inverted-V Lazy-H wide-band NVIS arrays for possible use in non-ALE communications systems.

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