Basic NVIS Antennas: Dipoles, Loops, and Vs

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The most fundamental NVIS antennas for fixed station operations are the linear dipole, the inverted-V dipole, and the 1-λ closed loop. Each has its own set of mechanical advantages and disadvantages in terms of the complexity of installation. Despite the very commonness of these antennas, their properties when installed at heights appropriate to NVIS operations remain somewhat murky to many radio amateurs. Advice ranges from the idea of placing the antenna as close to the ground as possible to placing it as high as may be feasible.

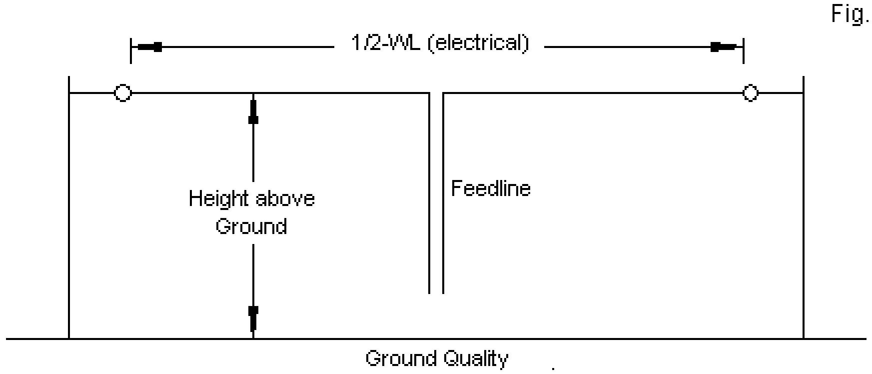
There is a range of heights that optimizes the performance of each of these basic antennas in the zenith direction, that is, straight upward. The idea of straight upward in this context means a cone of radiation offset from the true zenith by enough to allow contact with stations up to 200 to 300 miles away. All HF antennas have rather broad patterns in this regard, so using the concept of zenith gain will capture the properties of the antenna within the required cone.

In this set of notes, we shall use the antennas alone, without supplementary wires or ground improvement screens. Our goal is to find out what we may obtain from the antenna relative to its height and the quality of the ground beneath it. Performance supplements will arise in later sets of notes. Our working tool will be NEC-4 with the SN ground calculation system. We shall examine each antenna over three of the soil quality values from standard charts. At the extremes are very good soil (conductivity 0.0303 S/m, permittivity 20) and very poor soil (conductivity 0.001 S/m, permittivity 5), while the middle ground will be average soil (conductivity 0.005 S/m, permittivity 13). As well, we shall explore each antenna on three bands: 40 meters (7.2 MHz), 75 meters (3.9 MHZ), and 160 meters (1.85 MHz) to uncover any possible differences in performance for equivalent heights above ground (as measured for each antenna in fractions of a wavelength). The results will create a considerable body of data and some fairly definite conclusions.

The Linear Dipole

Of all NVIS antennas, the linear dipole is the most basic. **Fig. 1** outlines the dipole and the critical properties necessary to examine its performance at possible eights above ground. We shall start with a 40-meter dipole and then proceed to lower frequencies. We shall evaluate each dipole at heights from 0.075-λ up to 0.255-λ in 0.01-λ increments.

Fig. 1

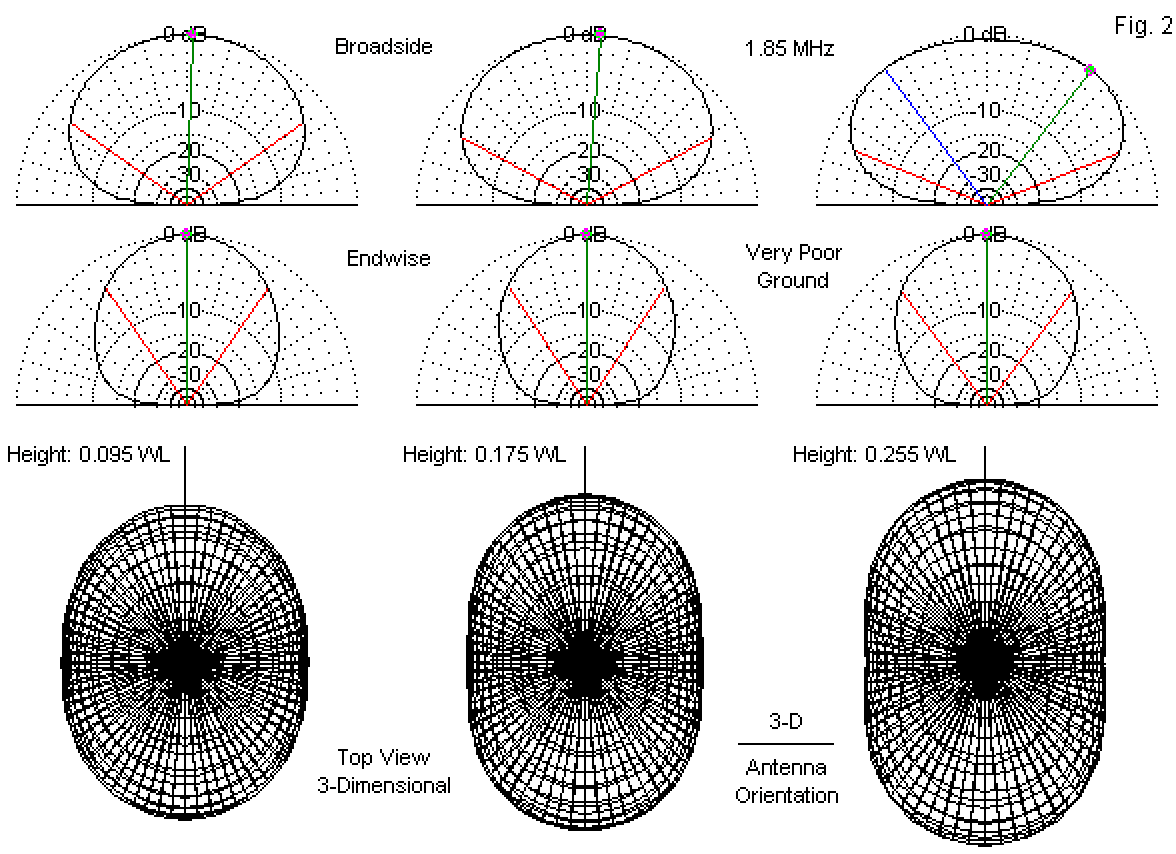


Key Properties of a Linear NVIS Dipole

The 40-meter dipole is cut for near resonance at 7.2 MHz at a height of about 0.175-λ above average ground. The length remains constant for all tests: 0.4806-λ using AWG #14 copper wire. (The length of dipoles for the lower bands will be the same. On 75 meters, we shall also use AWG #14 wire, but for 160 meters, we shall increase the diameter to AWG #12 wire.)

The basic data collected for the 40-meter dipole appears in **Table 1**. The table has separate sections for each soil quality. The left-most columns list the antenna height in wavelengths and in feet. The uppermost height used is 0.255-λ, just over ¼-λ, which is only about 35' above ground. Hence, on 40, at most installation sites, the antenna height falls wholly within the operator's range of choice. On lower bands, not all heights may be feasible.

The gain columns record zenith or straight-up gain on the left. The maximum gain column only has entries where the value differs from the zenith gain value. Both values are in dBi. The need for the second column results from the standard evolution of the NVIS pattern with increasing antenna height. **Fig. 2** shows a sample set of patterns for a 160-meter NVIS dipole at several heights above very poor ground. Patterns for 75 and 40 meters and for other soil qualities will be similar, although the final step of showing different zenith and maximum gain values varies in height with different soil qualities. As the antenna height increases, the broadside beamwidth grows continuously, while the endwise beamwidth varies by slightly.



Typical NVIS Antenna Radiation Pattern Evolution with Increasing Height above Ground
(Sample Uses a 1.85-MHz Dipole above Very Poor Soil)

At a height near the upper limit of our sampling range, the elevation pattern begins to split into broadside lobes, resulting in two maximum gain directions with a slightly depressed zenith gain value. The broadside elevation patterns and the 3-dimensional "top-down" plots provide alternative views of the phenomenon. The broadside axis line has a constant total length from the 3-D plot center to provide a visual estimate of the growth of the broadside beamwidth with increasing dipole height.

The elevation plots contain lines showing the half-power or 3-dB beamwidth in both the broadside and endwise directions relative to the dipole. **Table 1** and subsequent tables record these values as BS BW and as EW BW. In addition, the tables contain a column recording the ratio of the broadside to the endwise beamwidths as a rough measure of the circularity of the pattern. A ratio of 1:1 would indicate a perfectly circular pattern. Values greater than 1:1 indicate an elongation of the pattern in the broadside direction. An antenna builder may productively use this information if the antenna requires an orientation favoring certain directions—and if there is available space to satisfy this need.

The final columns of the table list the feedpoint resistance and reactance at each height. Horizontal antennas close to ground undergo considerable swings of feedpoint impedance values, a fact recorded by the data in the tables. As we change the quality of the ground beneath the antenna, we also encounter some interesting variations in feedpoint impedance values for each height in the survey.

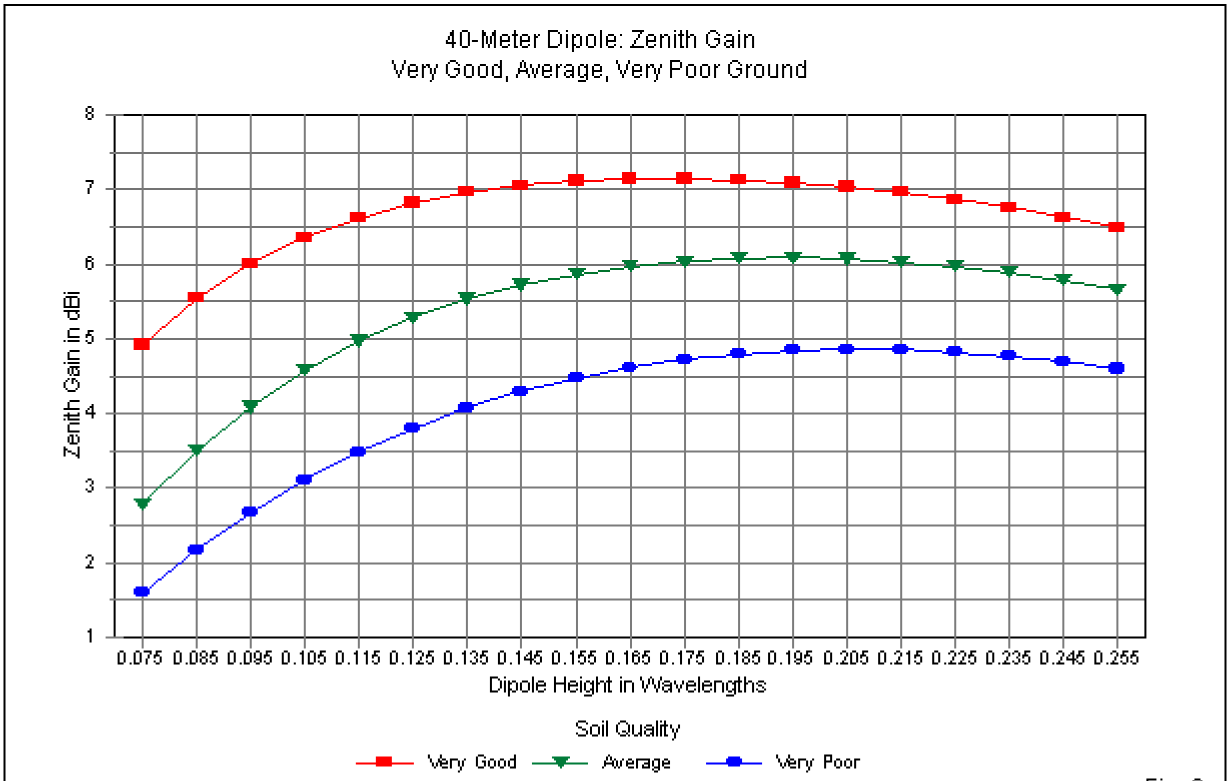


Fig. 3

Because the tables do not allow rapid scanning of certain critical information, I have graphed two significant data items. **Fig. 3** shows the zenith gain values for the entire span of heights, with separate lines for each soil quality. The fact that better soil quality yields higher gain is self-evident. As well, it is also clear that as we reduce the soil quality, we also increase the optimal height range for maximum gain from the dipole.

40-Meter Dipole AWG #14 Copper Wire: Length = 0.4806 WL							7.2 MHz		Table 1
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	10.25	4.92		90	96.0	64.6	1.49	33.62	-2.97
0.085	11.61	5.54		90	96.8	64.3	1.51	35.38	-0.51
0.095	12.98	6.01		90	97.6	64.1	1.52	37.65	1.92
0.105	14.34	6.36		90	98.6	64.0	1.54	40.32	4.19
0.115	15.71	6.62		90	99.8	64.2	1.55	43.31	6.22
0.125	17.08	6.82		90	101.0	64.2	1.57	46.54	7.96
0.135	18.44	6.96		90	102.2	64.4	1.59	49.95	9.37
0.145	19.81	7.06		90	103.8	64.8	1.60	53.47	10.42
0.155	21.17	7.12		90	105.2	65.2	1.61	57.04	11.10
0.165	22.54	*7.15*		90	107.0	65.6	1.63	60.62	11.42
0.175	23.91	*7.15*		90	109.0	66.2	1.65	64.16	11.37
0.185	25.27	7.13		90	111.0	66.8	1.66	67.61	10.96
0.195	26.64	7.09		90	113.0	67.6	1.67	70.93	10.20
0.205	28.00	7.04		90	115.2	68.4	1.68	74.08	9.13
0.215	29.37	6.96		90	117.6	69.4	1.69	77.04	7.76
0.225	30.74	6.87		90	120.0	70.4	1.70	79.77	6.13
0.235	32.10	6.76		90	122.4	71.6	1.71	82.25	4.25
0.245	33.47	6.63	6.67	68	124.8	72.8	1.71	84.46	2.17
0.255	34.83	6.49	6.59	64	126.8	74.4	1.70	86.39	-0.08
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	10.25	2.78		90	101.0	67.4	1.50	51.85	-6.23
0.085	11.61	3.50		90	102.0	66.4	1.54	51.63	-5.08
0.095	12.98	4.09		90	103.0	65.6	1.57	52.13	-3.75
0.105	14.34	4.58		90	104.0	65.2	1.60	53.13	-2.36
0.115	15.71	4.97		90	105.2	64.8	1.62	54.58	-1.02
0.125	17.08	5.28		90	106.5	64.8	1.64	56.33	0.16
0.135	18.44	5.53		90	107.8	64.8	1.66	58.33	1.14
0.145	19.81	5.72		90	109.5	65.0	1.68	60.50	1.89
0.155	21.17	5.87		90	111.0	65.2	1.70	62.80	2.39
0.165	22.54	5.97		90	113.0	65.4	1.73	65.17	2.63
0.175	23.91	6.04		90	114.8	65.8	1.74	67.55	2.60
0.185	25.27	6.08		90	116.8	66.4	1.76	69.91	2.30
0.195	26.64	*6.09*		90	118.8	67.0	1.77	72.21	1.76
0.205	28.00	6.07		90	121.1	67.8	1.79	74.40	0.97
0.215	29.37	6.03		90	123.4	68.6	1.80	76.48	-0.03
0.225	30.74	5.97	5.98	70	125.8	69.4	1.81	78.40	-1.24
0.235	32.10	5.89	5.94	65	127.8	70.6	1.81	80.14	-2.63
0.245	33.47	5.78	5.91	62	129.6	71.8	1.81	81.70	-4.17
0.255	34.83	5.66	5.88	58	131.4	73.0	1.80	83.05	-5.84
Very Poor Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	10.25	1.59		90	109.8	73.0	1.50	67.33	-10.07
0.085	11.61	2.17		90	110.8	71.2	1.56	65.88	-10.19
0.095	12.98	2.67		90	111.8	69.8	1.60	65.10	-9.95
0.105	14.34	3.11		90	112.8	68.6	1.64	64.79	-9.48
0.115	15.71	3.48		90	114.0	67.8	1.68	64.90	-8.93
0.125	17.08	3.80		90	115.2	67.2	1.71	65.32	-8.36
0.135	18.44	4.07		90	116.6	66.8	1.75	66.00	-7.84
0.145	19.81	4.29		90	118.2	66.6	1.77	66.89	-7.42
0.155	21.17	4.47		90	119.8	66.6	1.80	67.92	-7.11
0.165	22.54	4.61		90	121.4	66.6	1.82	69.04	-6.94
0.175	23.91	4.72		90	123.2	66.6	1.85	70.24	-6.91
0.185	25.27	4.79		90	125.2	67.0	1.87	71.46	-7.04
0.195	26.64	4.84		90	127.2	67.4	1.89	72.70	-7.33
0.205	28.00	*4.86*		90	129.0	67.8	1.90	73.90	-7.76
0.215	29.37	4.85	4.88	64	131.0	68.6	1.91	75.05	-8.33
0.225	30.74	4.82	4.91	63	132.6	69.2	1.92	76.13	-9.03
0.235	32.10	4.76	4.93	59	134.2	70.2	1.91	77.12	-9.84
0.245	33.47	4.69	4.95	55	135.6	71.0	1.91	78.01	-10.76
0.255	34.83	4.59	4.98	53	137.0	72.2	1.90	78.78	-11.76

On 40 meters, the maximum zenith gain occurs at heights between 0.165-λ and 0.175-λ over very good soil. Reducing the soil quality to average raises the maximum gain height to about 0.195-λ. A further reduction in soil quality to the very poor level results in a maximum gain height of about 0.205-λ. As the graph lines in **Fig. 3** show, the gain goes not change very rapidly near the optimal height. For practical purposes, there is a window of heights perhaps 0.04-λ wide in which the gain changes over an operationally undetectable range (including changes in the broadside beamwidth). This range amounts to a spread of about 5.5' of height on 40 meters, or +/-3' or so relative to the optimal height for maximum gain. If one does not know the local ground quality, placing the antenna at the optimal height for average ground will let it fall close to the best height for other soil values.

The differences in ground quality values from very good to very poor not only affects the peak-gain antenna height, but also have perhaps even more profound effects on the feedpoint impedance. **Fig. 4** graphs the feedpoint resistance values of the dipole across the range of heights, with separate lines for each ground quality surveyed. At very low heights, the resistance values very widely for the different soils. They gradually converge so that at a height of 0.205-λ, they meete, only to separate again above that height. The convergence height coincides with the maximum gain height for very poor soil. In general, selecting an antenna height that is near the level for best gain will yield an impedance value over any soil that will produce few, if any, surprises when it comes to matching the antenna to the feedline. The convergence resistance is close to 75 Ω, with up to about +/-j10 Ω reactance.

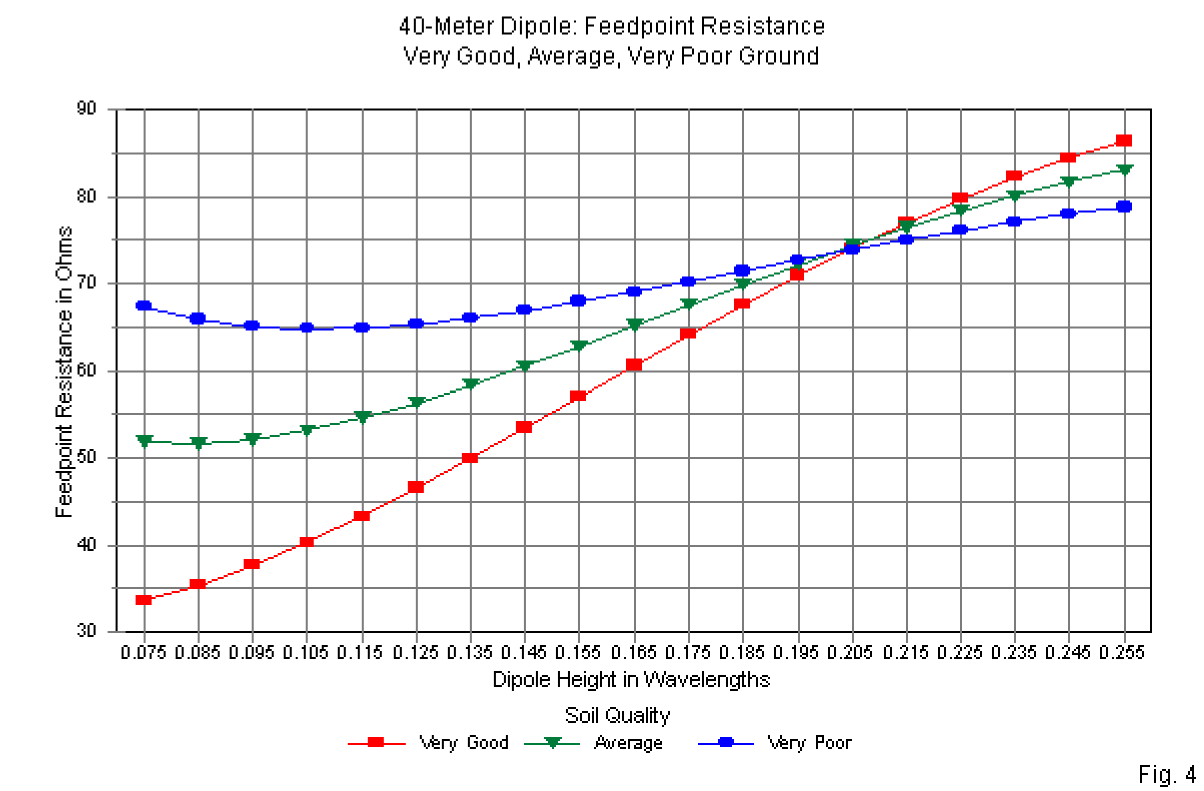


Fig. 4

The table reveals another facet of NVIS dipole behavior worth noting. If we decrease soil quality levels for any given height near the optimal range, the beamwidth ratio systematically increases. As the soil quality grows worse, the broadside beamwidth increases more rapidly relative to the slowly changing endwise beamwidth. At a height of 0.195-λ, for example, the broadside beamwidth changes by about 14° across the rage of soils. In other terms, each half-power point is about 7° lower over very poor soil than over very good soil. Since antenna gain drops very rapidly beyond the half-power points, the difference may make a difference in the performance of antennas designed for both NVIS and medium-range communications. In such cases, one may wish to place a 40-meter NVIS dipole above rather than below the maximum gain height with average or better soils. However, the height should in all cases be below the level at which the zenith gain suffers significantly.

On 75 meters, if we continue to count height in increments that are a fraction of a wavelength, we may not have the option of placing an antenna above the maximum gain height. Indeed, many sites will have difficulty raising the antenna to its best-gain height. Still, the behavior of the dipole on 75 meters over the same three soil qualities differs enough from the 40-meter properties to warrant a separate table and graph set. **Table 2** provides the parallel set of data to the 40-meter information in **Table 1**. **Fig. 5** graphs the zenith gain across the span of heights, which are, in feet, almost double those on 40 meters. At first glance, the graph lines appear to be the same as those for 40, but there are some interesting differences in the 75-meter set. Most significantly, the maximum gain values occur at lower heights: 0.165-λ for very good soil, 0.185-λ for average soil, and between 0.195-λ and 0.205λ for very poor soil. Although the individual changes from 40 meters are small (about 1% of a wavelength), they indicate a trend that we should anticipate to continue when we examine 160-meter dipoles. In addition, the peak zenith gain values that we may obtain on 75 meters are all higher than those we can obtain on 40 meters. For horizontal antennas over ground, especially at the low NVIS heights, the ground absorption increases with rising frequency for any given soil quality. We normally notice this effect only in lower HF surface-wave communications, but the phenomenon also affects the maximum obtainable NVIS gain.

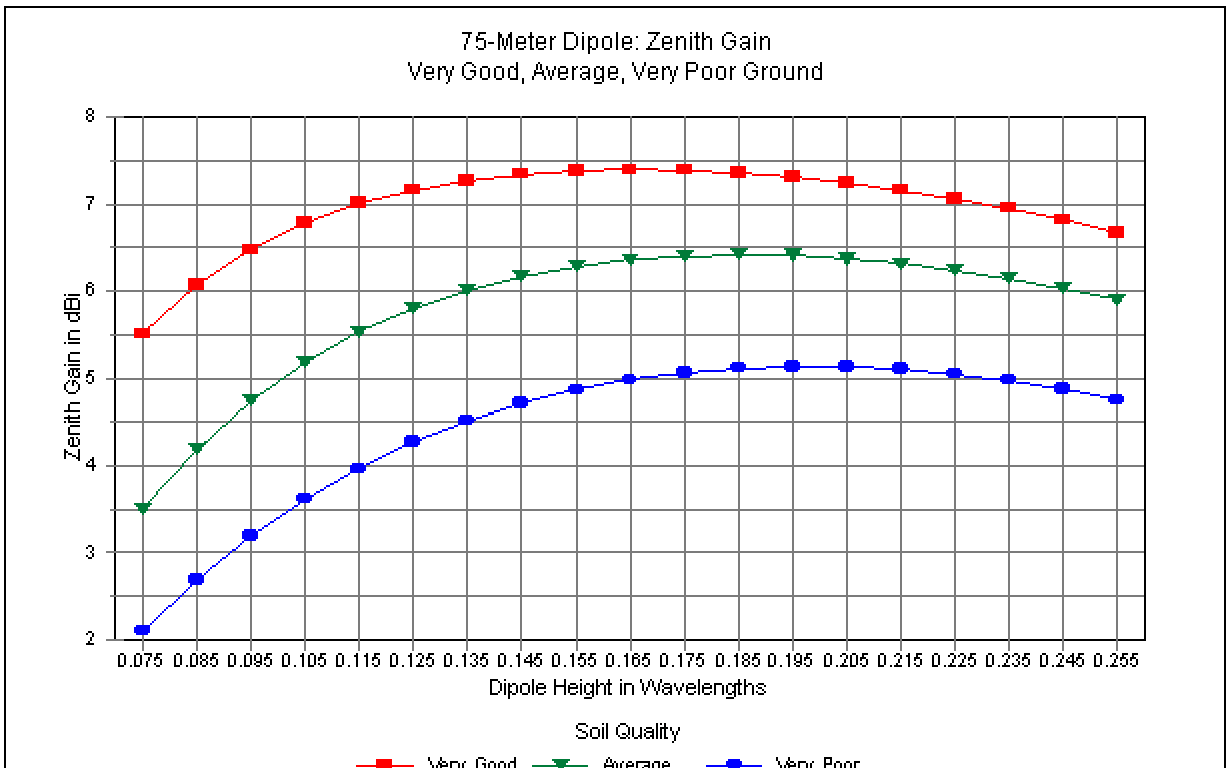


Fig. 5

75-Meter Dipole AWG #14 Copper Wire: Length = 0.4806 WL							3.9 MHz		Table 2
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	18.91	5.51		90	94.8	63.8	1.49	28.92	-8.11
0.085	21.44	6.07		90	95.6	63.6	1.50	31.11	-5.48
0.095	23.96	6.48		90	96.5	63.6	1.52	33.75	-2.36
0.105	26.48	6.78		90	97.4	63.6	1.53	36.77	0.25
0.115	29.00	7.01		90	98.5	63.6	1.55	40.08	2.57
0.125	31.52	7.16		90	99.8	64.0	1.56	43.61	4.57
0.135	34.05	7.27		90	101.0	64.3	1.57	47.30	6.20
0.145	36.57	7.34		90	102.5	64.6	1.59	51.10	7.44
0.155	39.09	7.38		90	104.0	65.0	1.60	54.95	8.29
0.165	41.61	*7.40*		90	105.6	65.4	1.61	58.80	8.74
0.175	44.13	7.39		90	107.4	66.1	1.62	62.60	8.80
0.185	46.66	7.36		90	109.2	66.8	1.63	66.30	8.47
0.195	49.18	7.31		90	111.4	67.4	1.65	69.88	7.78
0.205	51.70	7.24		90	113.6	68.4	1.66	73.28	6.74
0.215	54.22	7.16		90	116.0	69.2	1.68	76.48	5.39
0.225	56.74	7.06		90	118.4	70.4	1.68	79.44	3.74
0.235	59.27	6.95		90	120.8	71.4	1.69	82.14	1.84
0.245	61.79	6.82	6.84	73	123.2	72.8	1.69	84.56	-0.29
0.255	64.31	6.67	6.74	65	125.6	74.4	1.69	86.68	-2.61
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	18.91	3.51		90	99.2	66.8	1.49	46.61	-7.27
0.085	21.44	4.19		90	100.2	66.0	1.52	47.15	-5.92
0.095	23.96	4.74		90	101.2	65.6	1.54	48.33	-4.43
0.105	26.48	5.18		90	102.2	65.2	1.57	49.95	-2.95
0.115	29.00	5.53		90	103.4	65.0	1.59	51.95	-1.58
0.125	31.52	5.80		90	104.6	65.0	1.61	54.24	-0.39
0.135	34.05	6.01		90	106.2	65.0	1.63	56.74	0.56
0.145	36.57	6.17		90	107.6	65.2	1.65	59.39	1.26
0.155	39.09	6.28		90	109.2	65.6	1.66	62.12	1.67
0.165	41.61	6.36		90	111.0	65.8	1.69	64.89	1.79
0.175	44.13	6.40		90	113.0	66.4	1.70	67.64	1.62
0.185	46.66	*6.42*		90	115.0	67.0	1.72	70.34	1.16
0.195	49.18	6.41		90	117.2	67.6	1.73	72.94	0.43
0.205	51.70	6.37		90	119.4	68.4	1.75	75.42	-0.55
0.215	54.22	6.32		90	121.8	69.2	1.76	77.73	-1.78
0.225	56.74	6.24	6.25	72	124.2	70.4	1.76	79.87	-3.22
0.235	59.27	6.15	6.19	67	126.4	71.4	1.77	81.80	-4.84
0.245	61.79	6.03	6.14	63	128.4	72.6	1.77	83.51	-6.63
0.255	64.31	5.90	6.10	60	130.2	74.0	1.76	84.98	-8.56
Very Poor Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	18.91	2.10		90	107.8	71.8	1.50	65.60	-10.75
0.085	21.44	2.69		90	108.8	70.4	1.55	64.50	-10.82
0.095	23.96	3.19		90	110.0	69.2	1.59	64.08	-10.58
0.105	26.48	3.61		90	111.2	68.4	1.63	64.13	-10.13
0.115	29.00	3.97		90	112.4	67.6	1.66	64.60	-9.65
0.125	31.52	4.27		90	113.8	67.2	1.69	65.37	-9.17
0.135	34.05	4.51		90	115.2	67.0	1.72	66.39	-8.79
0.145	36.57	4.71		90	116.8	66.8	1.75	67.59	-8.52
0.155	39.09	4.86		90	118.6	66.8	1.78	68.90	-8.39
0.165	41.61	4.98		90	120.4	67.0	1.80	70.29	-8.42
0.175	44.13	5.06		90	122.4	67.2	1.82	71.73	-8.62
0.185	46.66	5.11		90	124.4	67.6	1.84	73.16	-9.00
0.195	49.18	*5.13*		90	126.4	68.2	1.85	74.57	-9.53
0.205	51.70	*5.13*	5.14	69	128.4	68.6	1.87	75.92	-10.22
0.215	54.22	5.10	5.15	65	130.4	69.4	1.88	77.18	-11.06
0.225	56.74	5.04	5.16	61	132.0	70.4	1.87	78.35	-12.02
0.235	59.27	4.97	5.17	57	133.6	71.2	1.88	79.39	-13.11
0.245	61.79	4.87	5.19	55	135.2	72.4	1.87	80.31	-14.28
0.255	64.31	4.75	5.21	52	136.5	73.6	1.85	81.07	-15.54

Apart from the difference in maximum possible gain from an un-supplemented dipole and the modeled height of occurrence, virtually every other comment on the 40-meter dipole applies equally to the 75-meter dipole. Heights in the range of 40' (for very good soil) up to about 50' (for very poor soil) yield maximum gain. If we select an arbitrary but common amateur dipole height of 35' above ground, then the gain deficit relative to maximum possible gain varies with the soil quality. It ranges from about 0.1 dB over very good soil to more than 0.6 dB over very poor soil. At 75 meters, the maximum value of the beamwidth ratio also decreases slightly relative to the values at 40 meters.

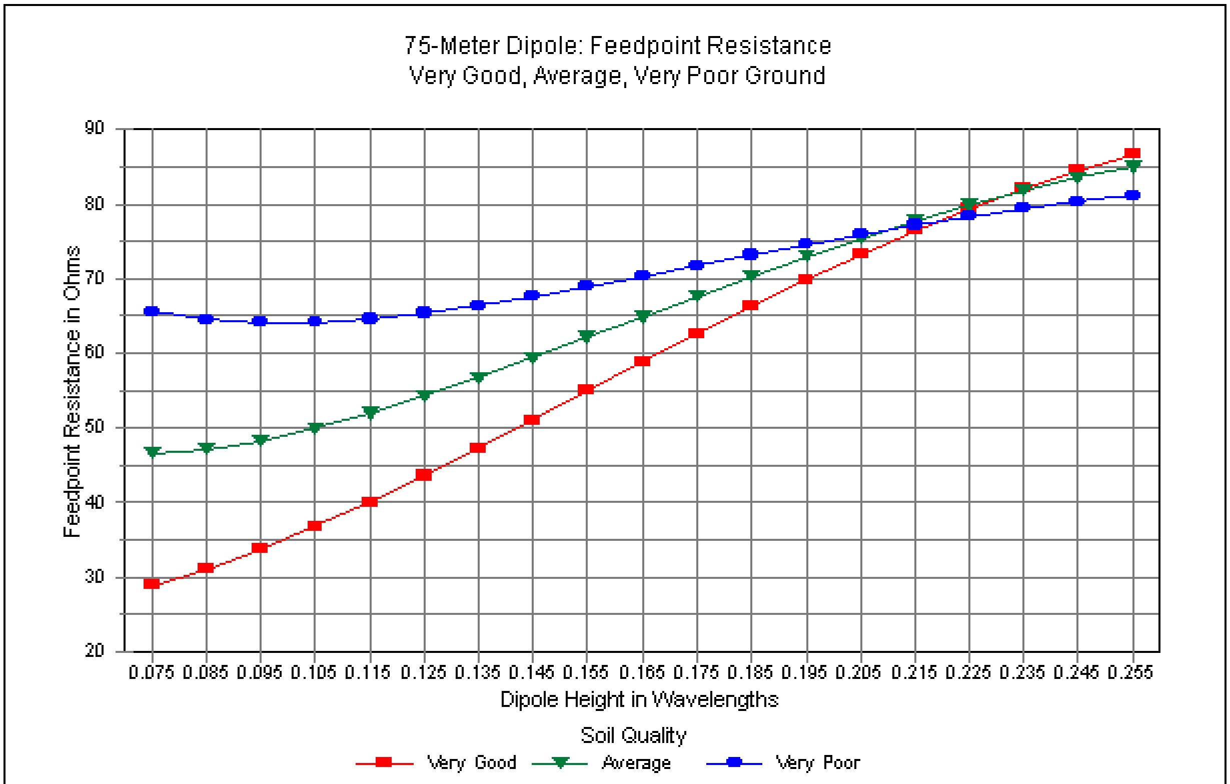


Fig. 6

The feedpoint resistance curves for 75 meters, shown in **Fig. 6**, resemble those in **Fig. 4** with a small but significant difference. The convergence region is slightly higher on 75 meters: between antenna heights of 0.205-λ and 0.215-λ. Since the optimal gain region shows lower heights on 75 meters, we can expect a wider variation in the feedpoint impedance values as we move from very good to very poor soil. In fact, if we return to the arbitrary but common amateur dipole height of 35' above ground, the impedance range runs from close to 50 ° over the worst soil to nearly 70 Ω over the best.

The trends that we have noted relative to the 40-meter and 75-meter dipoles continue unabated when we examine a 160-meter dipole (set for 1.85 MHz in this sample). If the patterns hold true, we should expect higher maximum gain values, lower optimal gain heights (in wavelengths), lower maximum beamwidth ratio values, and a greater height of feedpoint resistance convergence. **Table 3** provides the numerical data to confirm each of these trends, while **Fig. 7** and **Fig. 8** supply visual references for the gain and feedpoint resistance curves. Indeed, with only a few exceptions, we may bypass extensive commentary on the 160-meter dipole's behavior, although we can hardly avoid a note on the usual amateur 160-meter horizontal antenna installation.

160-Meter Dipole AWG #12 Copper Wire: Length = 0.4806 WL							1.95 MHz		Table 3
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	39.87	6.10		90	94.0	63.0	1.49	24.58	-13.27
0.085	45.19	6.59		90	94.6	63.0	1.50	27.10	-9.86
0.095	50.51	6.94		90	95.6	63.0	1.52	30.04	-6.63
0.105	55.82	7.19		90	96.5	63.2	1.53	33.33	-3.67
0.115	61.14	7.37		90	97.4	63.3	1.54	36.89	-1.04
0.125	66.46	7.49		90	98.6	63.6	1.55	40.66	1.23
0.135	71.77	7.57		90	99.8	63.9	1.56	44.58	3.11
0.145	77.09	7.62		90	101.2	64.3	1.57	48.61	4.57
0.155	82.41	*7.63*		90	102.8	64.8	1.59	52.69	5.61
0.165	87.72	*7.63*		90	104.4	65.2	1.60	56.76	6.22
0.175	93.04	7.61		90	106.2	65.8	1.61	60.79	6.42
0.185	98.36	7.56		90	108.2	66.6	1.62	64.72	6.22
0.195	103.67	7.51		90	110.0	67.2	1.64	68.52	5.62
0.205	108.99	7.43		90	112.2	68.2	1.65	72.15	4.66
0.215	114.31	7.34		90	114.6	69.2	1.66	75.57	3.35
0.225	119.62	7.24		90	117.0	70.2	1.67	78.74	1.73
0.235	124.94	7.13		90	119.4	71.4	1.67	81.65	-0.17
0.245	130.26	6.84	6.99	74	122.0	72.8	1.68	84.27	-2.31
0.255	135.57	6.85	6.89	68	124.2	74.2	1.67	86.58	-4.66
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	39.87	4.41		90	97.0	65.6	1.48	38.46	-9.76
0.085	45.19	5.05		90	97.8	65.2	1.50	39.87	-7.85
0.095	50.51	5.55		90	98.8	64.8	1.52	41.81	-5.88
0.105	55.82	5.93		90	99.8	64.6	1.54	44.17	-3.99
0.115	61.14	6.22		90	101.0	64.6	1.56	46.86	-2.29
0.125	66.46	6.44		90	102.0	64.8	1.57	49.79	-0.83
0.135	71.77	6.61		90	103.5	64.8	1.60	52.90	0.33
0.145	77.09	6.72		90	105.2	65.2	1.61	56.12	1.18
0.155	82.41	6.80		90	106.8	65.6	1.63	59.41	1.70
0.165	87.72	6.85		90	108.4	66.0	1.64	62.70	1.88
0.175	93.04	*6.87*		90	110.4	66.5	1.66	65.95	1.73
0.185	98.36	6.86		90	112.4	67.2	1.67	69.12	1.25
0.195	103.67	6.83		90	114.6	67.8	1.69	72.18	0.46
0.205	108.99	6.78		90	116.8	68.6	1.70	75.07	-0.63
0.215	114.31	6.71		90	119.1	69.6	1.71	77.79	-1.98
0.225	119.62	6.63		90	121.5	70.6	1.72	80.29	-3.58
0.235	124.94	6.52	6.53	69	124.0	71.8	1.73	82.55	-5.40
0.245	130.26	6.40	6.46	67	126.0	73.0	1.73	84.56	-7.40
0.255	135.57	6.26	6.39	61	128.2	74.4	1.72	86.30	-9.56
Very Poor Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	39.87	2.87		90	103.8	70.2	1.48	59.18	-9.15
0.085	45.19	3.49		90	104.8	69.0	1.52	58.87	-9.01
0.095	50.51	3.99		90	105.8	68.2	1.55	59.22	-8.63
0.105	55.82	4.41		90	107.0	67.6	1.58	60.05	-8.07
0.115	61.14	4.75		90	108.4	67.2	1.61	61.24	-7.54
0.125	66.46	5.02		90	109.8	66.8	1.64	62.72	-7.06
0.135	71.77	5.24		90	111.4	66.8	1.67	64.41	-6.73
0.145	77.09	5.41		90	113.0	66.8	1.69	66.26	-6.56
0.155	82.41	5.54		90	114.8	66.8	1.72	68.19	-6.58
0.165	87.72	5.63		90	116.6	67.2	1.74	70.16	-6.80
0.175	93.04	5.68		90	118.8	67.6	1.76	72.12	-7.24
0.185	98.36	*5.71*		90	120.8	68.2	1.77	74.05	-7.88
0.195	103.67	*5.71*		90	123.0	68.6	1.79	75.91	-8.72
0.205	108.99	5.68		90	125.2	69.4	1.80	77.66	-9.74
0.215	114.31	5.63	5.66	68	127.4	70.2	1.81	79.29	-10.93
0.225	119.62	5.56	5.64	63	129.4	71.2	1.82	80.77	-12.28
0.235	124.94	5.46	5.63	60	131.0	72.2	1.81	82.07	-13.75
0.245	130.26	5.35	5.62	56	132.6	73.4	1.81	83.20	-15.33
0.255	135.57	5.21	5.62	54	134.2	74.8	1.79	84.14	-17.00

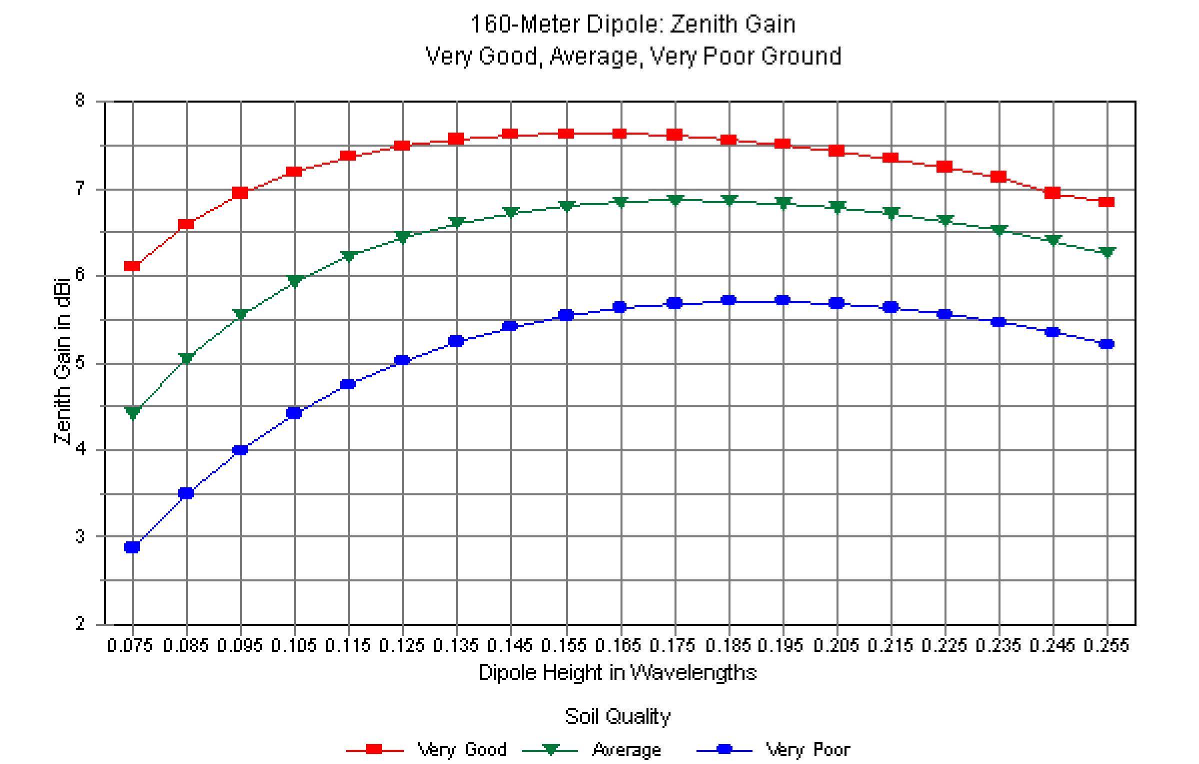

160-Meter Dipole: Zenith Gain
Very Good, Average, Very Poor Ground
Zenith Gain in dBi
8
7
6
5
4
3
2
0.075 0.085 0.095 0.105 0.115 0.125 0.135 0.145 0.155 0.165 0.175 0.185 0.195 0.205 0.215 0.225 0.235 0.245 0.255
Dipole Height in Wavelengths
Soil Quality
Very Good
Average
Very Poor

Fig. 7

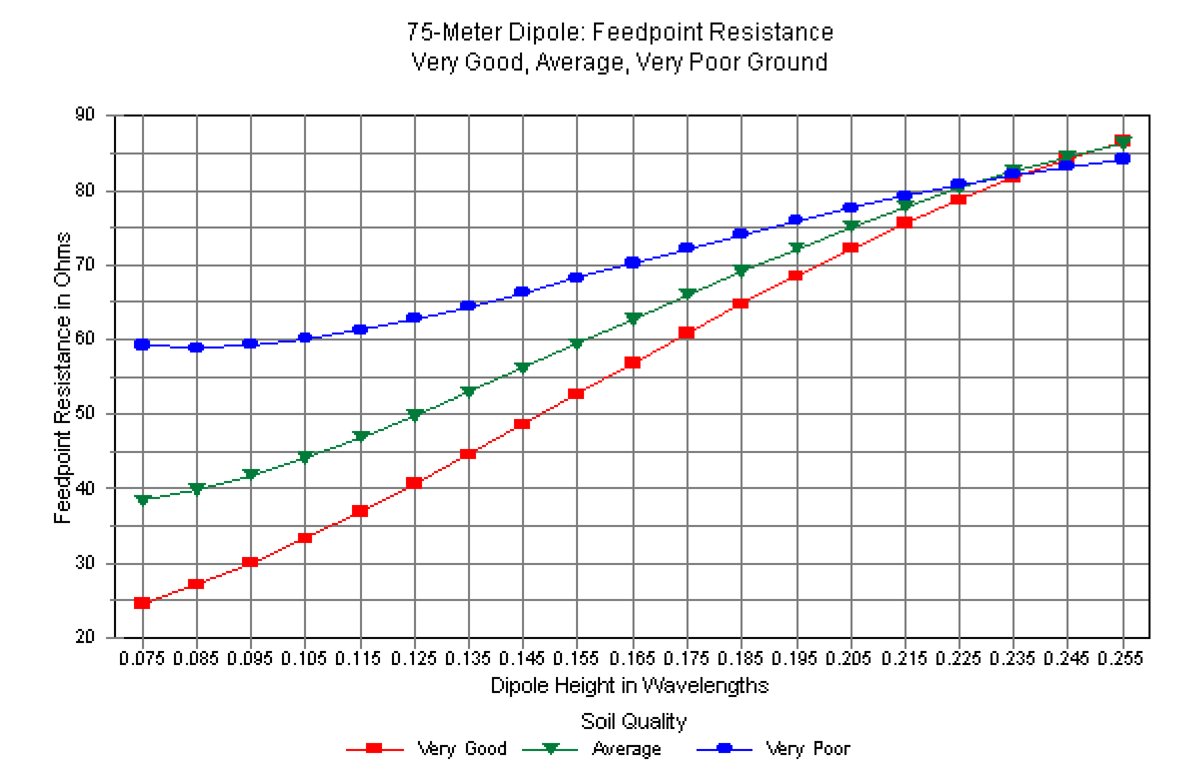

75-Meter Dipole: Feedpoint Resistance
Very Good, Average, Very Poor Ground
Feedpoint Resistance in Ohms
90
80
70
60
50
40
30
20
0.075 0.085 0.095 0.105 0.115 0.125 0.135 0.145 0.155 0.165 0.175 0.185 0.195 0.205 0.215 0.225 0.235 0.245 0.255
Dipole Height in Wavelengths
Soil Quality
Very Good
Average
Very Poor

Fig. 8

For the most typical amateur installations, a height of 35' falls below the lowest height in the survey. In fact, at 35' above ground, a 160-meter dipole will lose between 1.5 dB (over very good soil) to 2.8 dB over very poor soil relative to placing the antenna at an optimal NVIS height. Since the gain of the antenna at 160 meters is higher for a given height (in wavelengths) above any given soil quality, the deficit is not quite as severe as the internal 160-meter numbers suggest, but the installation at a low height has far less performance potential than it might have. As well, at the low height, the feedpoint impedance may range from 25 Ω up to 50 Ω, depending upon soil quality.

We may better gauge the relative gain for the three bands covered by this survey by graphically sampling at least one set of antennas. **Fig. 9** compares the gain values over average ground for 160-, 75-, and 40-meter dipoles across the surveyed heights as measured in wavelengths. Just the change in operating frequency produces nearly a full dB difference in maximum gain when we take the values that coincide with the maximum zenith gain for each band. As we increase the height of the antenna above ground, the differentials decrease, but remain notable even at a height greater than ¼-λ above ground. Curves for other soil qualities will be similar. The idea that ground quality has very little effect on horizontal antenna performance may be true for antenna that are 1 λ up or higher, but in the range of NVIS heights in the upper MF and lower HF region, horizontal antennas show considerable effects from both height changes and from ground quality changes.

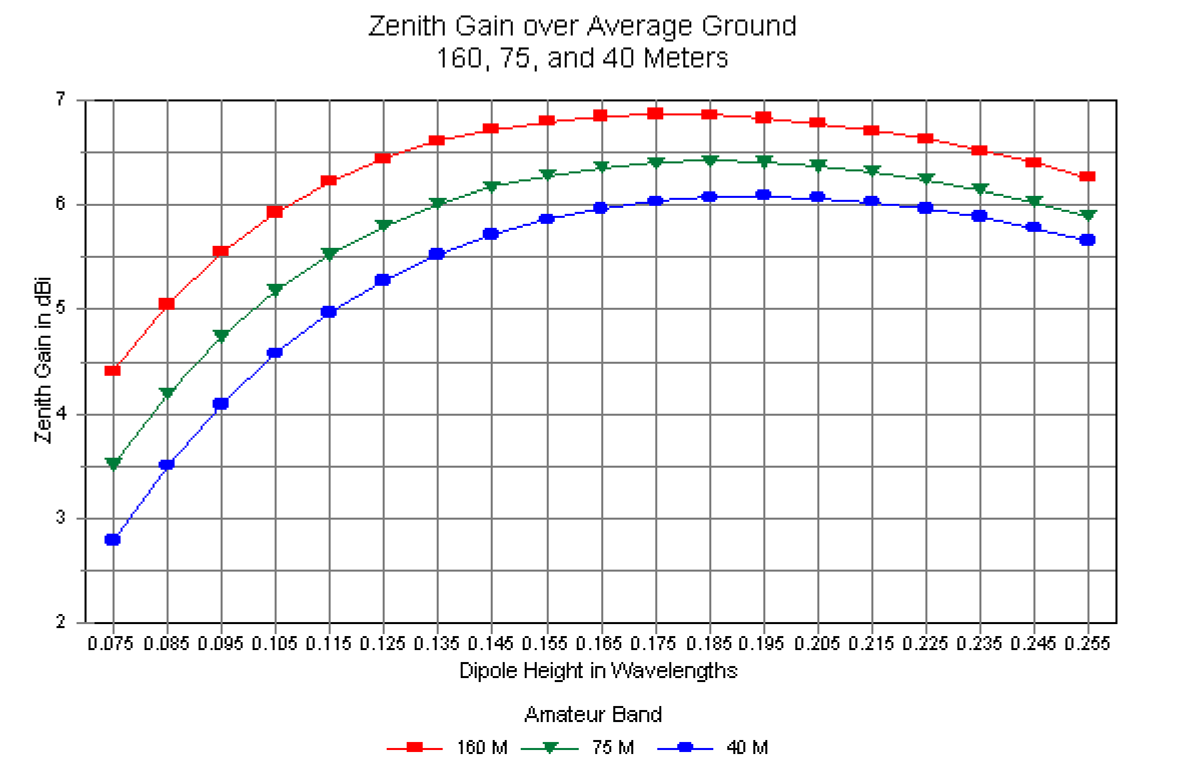


Fig. 9

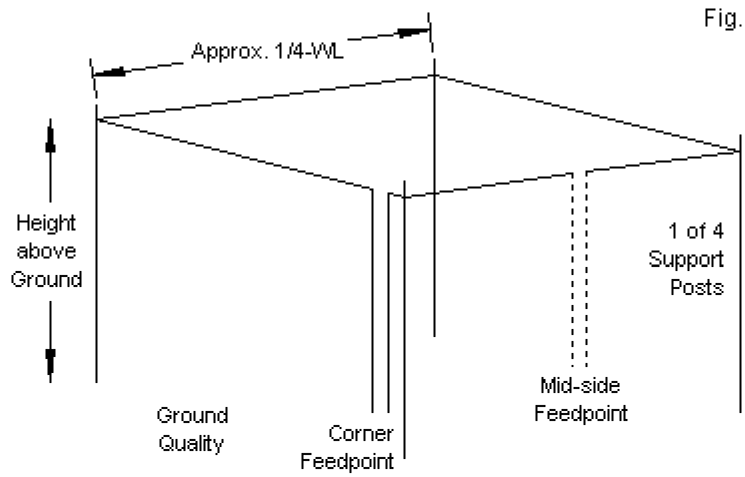
We may summarize the findings—to a degree, at least—by encapsulating some of the key data from the individual data tables in a single place. **Table 4** uses a cross-matrix of the 3 bands vs. the soil quality levels. It lists the peak zenith gain for each band and the height in wavelengths at which that gain occurs. In addition, it lists the height in wavelengths at which the feedpoint resistance values converge. Wherever individual values occur at two adjacent heights, the table lists the average of the pair. Although highly incomplete, the table provides at a glance a view of some of the trends that we have noted along the way. It may also allow a fairly quick interpolation of probable values for NVIS dipoles at other frequencies, for example, 60 meters. It may also serve to make comparisons easier with other antennas in our collection.

Tri-Band Summary of Significant NVIS Dipole Values							Table 4
Ground	Very Good		Average		Very Poor		
	Max Gain	Height	Max Gain	Height	Max Gain	Height	Z Cross
Band	Zenith	WL	Zenith	WL	Zenith	WL	WL
160 m	7.63	0.160	6.87	0.175	5.71	0.190	0.240
75 m	7.40	0.165	6.42	0.185	5.13	0.200	0.210
40 m	7.15	0.170	6.09	0.195	4.86	0.205	0.205
Delta	0.48	0.010	0.78	0.020	0.85	0.015	0.035
Notes:	Max Gain Zenith = maximum zenith gain in dBi						
	Height WL = maximum zenith gain height in wavelengths						
	Z Cross WL = height at which feedpoint resistance values converge						
	(Where 2 heights have the same value, the average appears here.)						
	Delta = maximum change between 160 and 40 meters						

The 1-λ Closed Loop

In basic antenna theory, the inverted-V is a dipole form and perhaps ought to come next in our survey. However, the inverted-V has some special limitations that divorce it from its close family ties to the dipole. More akin to the dipole by virtue of using a level plane for installation is the 1-λ closed loop. In these notes, we shall deal only with a square loop, although we might in principle approximate any polygon ranging from a triangle to an almost perfect circle. Performance differences among the closed loops will be minimal.

Fig. 10



Key Properties of a Square 1-WL Closed NVIS Loop

As shown in **Fig. 10**, we may feed the square either at mid-side or at a corner with no change in the loop dimensions, the feedpoint impedance, or the performance. Corner feeding may be more convenient, since the post at that location can support the vertical run of feedline. We define the broadside direction of the loop as running between the feedpoint and a point directly opposite. The endwise direction is at 90° to this line. For modeling convenience, these notes use a mid-side feedpoint. The patterns do not differ significantly from those produced by selecting the more convenient corner feed position.

The 1-λ loop is subject to the same constraints as the dipole. The height above ground and the quality of the ground both below the antenna and in the region of far-field reflections largely determine the pattern shape and strength. Mechanically, the side dimension of the loop is about half that of a dipole, but the loop does require 4 support posts and occupies an area at the installation site. As well, the loop feedpoint impedance is higher than the impedance of a dipole, resulting in the need for a matching section if the main feedline is a standard 50-Ω coaxial cable.

At 40 meters (7.2 MHz), total circumference of the 1-λ loop is actually close to 1.03 λ at NVIS heights. **Table 5** provides the numerical data derived from surveying the loop over the same height range as the dipole and over the three selected ground qualities. The range of reactance variation may seem striking compared to the values for the dipole. However, its affect upon the SWR relative to resonance is about the same, given the ratio of reactance to resistance at the feedpoint.

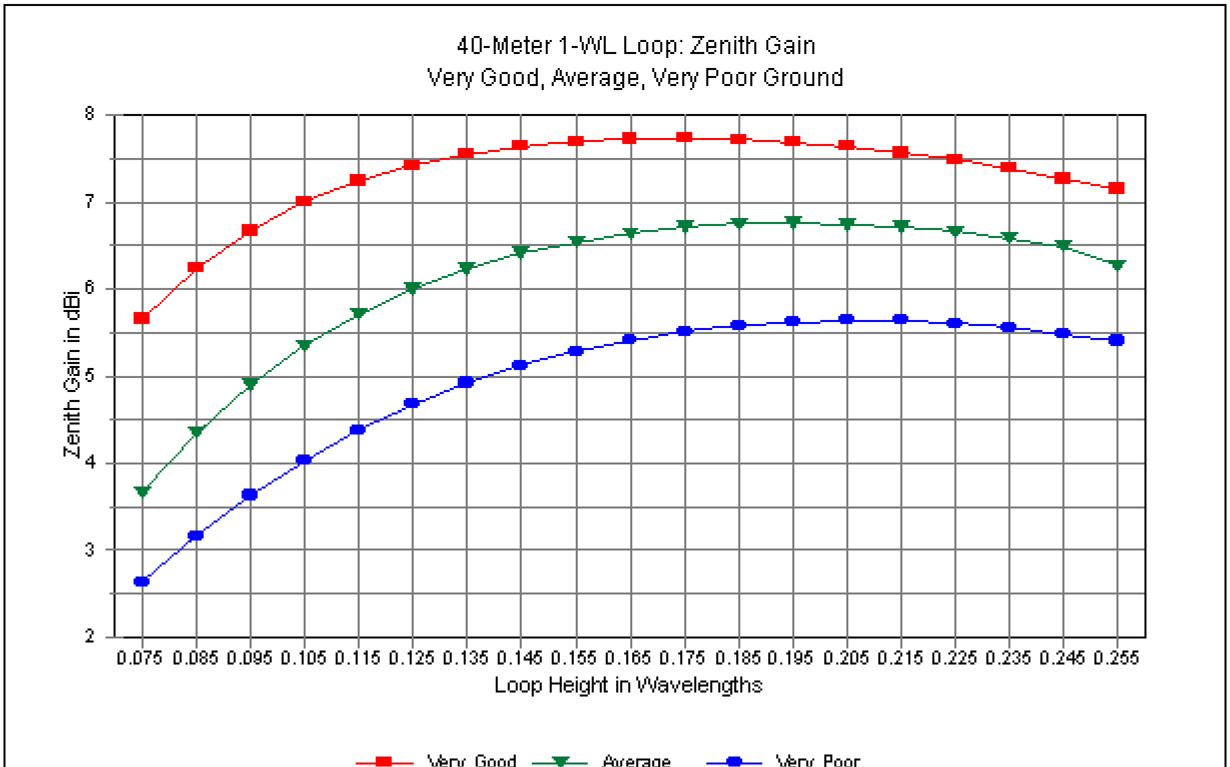


Fig. 11

The gain curves in **Fig. 11** are very similar to those for the dipole, with two major exceptions. First, the values at all heights are higher for the loop. (Whether the added gain justifies the more complex construction is a user judgment.) Second, the loop has a narrower broadside beamwidth and a very slightly wider endwise beamwidth at all heights. Hence, the column for maximum gain in the table is blank, since the broadside beamwidth never reaches a value that creates a dual line for the maximum gain direction. In essence, the loop more closely approximates the circular pattern that represents the theoretical ideal (although that ideal may be less applicable to given installations).

40-Meter 1-WL Loop AWG #14 Copper Wire: Circumference = 1.0296 WL							7.2 MHz		Table 5
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	10.25	5.66		90	77.7	68.2	1.14	63.78	38.74
0.085	11.61	6.24		90	78.2	67.6	1.16	67.48	35.27
0.095	12.98	6.67		90	78.9	67.6	1.17	72.11	32.93
0.105	14.34	7.00		90	79.4	67.4	1.18	77.47	31.27
0.115	15.71	7.24		90	80.3	67.4	1.19	83.37	29.98
0.125	17.08	7.42		90	81.2	67.6	1.20	89.68	28.80
0.135	18.44	7.55		90	82.1	68.0	1.21	96.25	27.56
0.145	19.81	7.64		90	83.2	68.4	1.22	103.00	26.10
0.155	21.17	7.70		90	84.3	68.8	1.23	109.80	24.33
0.165	22.54	7.73		90	85.6	69.2	1.24	116.50	22.19
0.175	23.91	*7.74*		90	87.0	69.8	1.25	123.10	19.63
0.185	25.27	7.72		90	88.6	70.6	1.25	129.50	16.62
0.195	26.64	7.69		90	90.5	71.4	1.27	135.50	13.17
0.205	28.00	7.64		90	92.4	72.4	1.28	141.30	9.29
0.215	29.37	7.57		90	94.5	73.4	1.29	146.60	5.00
0.225	30.74	7.49		90	96.8	74.4	1.30	151.40	0.35
0.235	32.10	7.39		90	99.2	75.8	1.31	155.70	-4.64
0.245	33.47	7.27		90	101.9	77.2	1.32	159.40	-9.89
0.255	34.83	7.15		90	104.9	78.8	1.33	162.60	-15.37
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	10.25	3.67		90	80.9	71.6	1.13	94.53	25.16
0.085	11.61	4.35		90	81.6	70.4	1.16	94.81	20.06
0.095	12.98	4.90		90	82.3	69.4	1.19	96.37	16.41
0.105	14.34	5.35		90	83.0	68.8	1.21	98.79	13.75
0.115	15.71	5.71		90	83.8	68.6	1.22	101.90	11.71
0.125	17.08	6.00		90	84.7	68.4	1.24	105.60	10.01
0.135	18.44	6.23		90	85.9	68.4	1.26	109.60	8.41
0.145	19.81	6.41		90	87.0	68.6	1.27	113.90	6.79
0.155	21.17	6.54		90	88.4	68.8	1.28	118.30	5.02
0.165	22.54	6.64		90	89.8	69.2	1.30	122.80	3.06
0.175	23.91	6.71		90	91.4	69.6	1.31	127.30	0.84
0.185	25.27	6.75		90	93.1	70.2	1.33	131.60	-1.68
0.195	26.64	*6.76*		90	95.0	70.8	1.34	135.80	-4.48
0.205	28.00	6.74		90	97.2	71.6	1.36	139.70	-7.58
0.215	29.37	6.71		90	99.4	72.4	1.37	143.40	-10.96
0.225	30.74	6.66		90	101.8	73.6	1.38	146.70	-14.60
0.235	32.10	6.58		90	104.6	74.6	1.40	149.70	-18.46
0.245	33.47	6.49		90	107.3	76.0	1.41	152.20	-22.51
0.255	34.83	6.27		90	110.5	77.4	1.43	154.40	-26.71
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	10.25	2.63		90	86.5	78.6	1.10	118.00	0.91
0.085	11.61	3.16		90	87.2	76.2	1.14	116.40	-4.00
0.095	12.98	3.63		90	87.9	74.4	1.18	115.80	-7.57
0.105	14.34	4.03		90	88.7	73.2	1.21	115.90	-10.17
0.115	15.71	4.38		90	89.7	72.0	1.25	116.70	-12.18
0.125	17.08	4.67		90	90.7	71.2	1.27	118.00	-13.79
0.135	18.44	4.92		90	91.8	70.8	1.30	119.70	-15.19
0.145	19.81	5.12		90	93.1	70.4	1.32	121.70	-16.51
0.155	21.17	5.28		90	94.6	70.4	1.34	123.90	-17.85
0.165	22.54	5.41		90	96.0	70.4	1.36	126.20	-19.22
0.175	23.91	5.51		90	97.9	70.6	1.39	128.50	-20.72
0.185	25.27	5.58		90	99.7	70.8	1.41	130.90	-22.38
0.195	26.64	5.62		90	101.8	71.4	1.43	133.10	-24.20
0.205	28.00	*5.64*		90	104.0	71.8	1.45	135.30	-26.20
0.215	29.37	*5.64*		90	106.3	72.6	1.46	137.40	-28.36
0.225	30.74	5.60		90	108.8	73.4	1.48	139.20	-30.67
0.235	32.10	5.56		90	111.6	74.4	1.50	140.90	-33.12
0.245	33.47	5.48		90	114.4	75.4	1.52	142.30	-35.68
0.255	34.83	5.40		90	117.4	76.6	1.53	143.40	-38.34

If you compare **Table 5** with **Table 1**, you will discover that the maximum gain occurs at the same heights over each type of ground quality for both loops and dipoles. As well, the feedpoint resistance tends to converge in the same manner as we found for the dipole, although the convergence is less complete in the case of the loop. The loop's convergence region is considerably wider as a span of heights, so we may bypass a graph. However, the tabular data will show the spread. Of special note are the beamwidth numbers, especially the ratio of broadside to endwise beamwidth. Note that the loop and the dipole both use the same wire: for 40 meters, AWG #14 copper wire.

In the case of the dipole, we found that as we lowered the operating frequency from 40 meters to 75 meters, the maximum gain value rose, while height of maximum gain decreased. These facts applied to all three ground qualities. We encounter the same phenomena in the case of the 75-meters 1-λ loop. The numbers appear in **Table 6** (for comparison with the corresponding dipole values in **Table 2**). **Fig. 12** compares the loop gain values for the three qualities of ground.

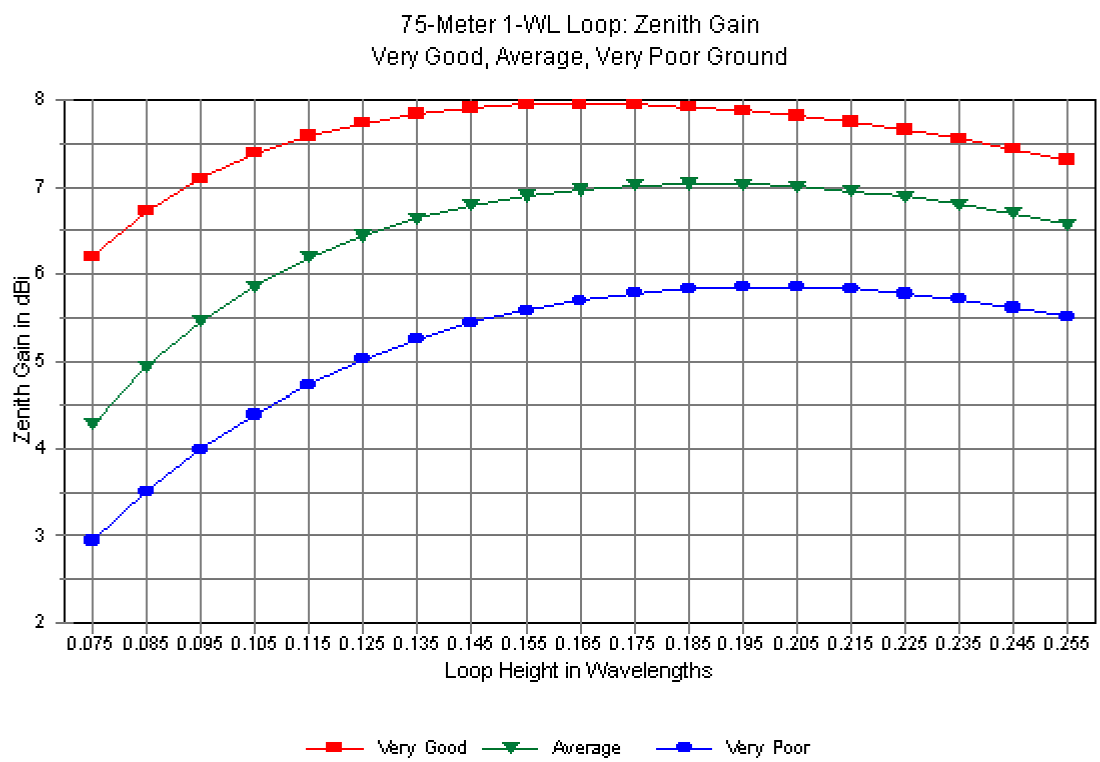


Fig. 12

As both the graphs and the tables make clear, the heights of maximum gain on 75 meters are virtually identical for both the loop and the dipole. Unlike either antenna at 40 meters, where we may easily construct the antenna at the optimal height, on 75 meters, we may need to be satisfied with a slightly lesser height. The loop is like the dipole in the fact that gain does not fall off sharply over any of the soil types as we lower the antenna by modest amounts. However, the effect may be more noticeable over the worst soils where the maximum gain height in wavelengths is greatest, while the antenna construction project may have a strict physical limit. For example, compare the gain values at 35' (about 0.14-λ) with the maximum gain possible for each of the individual ground quality values.

75-Meter 1-WL Loop AWG #14 Copper Wire: Circumference = 1.0248 WL							3.9 MHz		Table 6
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	18.91	6.20		90	77.1	67.2	1.15	55.06	29.84
0.085	21.44	6.72		90	77.6	67.0	1.16	59.52	27.14
0.095	23.96	7.10		90	78.2	67.0	1.17	64.82	25.43
0.105	26.48	7.39		90	78.7	66.8	1.18	70.78	24.33
0.115	29.00	7.59		90	79.6	67.0	1.19	77.24	23.53
0.125	31.52	7.74		90	80.4	67.2	1.20	84.08	22.78
0.135	34.05	7.84		90	81.3	67.6	1.20	91.17	21.91
0.145	36.57	7.91		90	82.3	68.0	1.21	98.40	20.79
0.155	39.09	7.95		90	83.4	68.6	1.22	105.70	19.31
0.165	41.61	*7.96*		90	84.7	69.0	1.23	112.90	17.41
0.175	44.13	7.95		90	86.1	69.8	1.23	120.00	15.05
0.185	46.66	7.92		90	87.6	70.6	1.24	126.90	12.20
0.195	49.18	7.88		90	89.4	71.4	1.25	133.40	8.87
0.205	51.70	7.82		90	91.4	72.4	1.26	139.60	5.06
0.215	54.22	7.75		90	93.3	73.2	1.27	145.40	0.80
0.225	56.74	7.66		90	95.6	74.4	1.28	150.60	-3.87
0.235	59.27	7.56		90	98.0	75.8	1.29	155.40	-8.90
0.245	61.79	7.44		90	100.8	77.2	1.31	159.50	-14.25
0.255	64.31	7.31		90	103.6	79.0	1.31	163.10	-19.85
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	18.91	4.28		90	79.9	70.8	1.13	86.79	25.53
0.085	21.44	4.93		90	80.5	69.8	1.15	88.26	20.43
0.095	23.96	5.45		90	81.2	69.2	1.17	90.87	16.76
0.105	26.48	5.86		90	82.0	68.8	1.19	94.26	14.02
0.115	29.00	6.19		90	82.8	68.6	1.21	98.31	11.83
0.125	31.52	6.44		90	83.8	68.6	1.22	102.80	9.94
0.135	34.05	6.64		90	84.8	68.6	1.24	107.70	8.13
0.145	36.57	6.79		90	85.9	68.8	1.25	112.80	6.26
0.155	39.09	6.90		90	87.2	69.2	1.26	117.90	4.22
0.165	41.61	6.97		90	88.8	69.6	1.28	123.10	1.94
0.175	44.13	7.02		90	90.3	70.2	1.29	128.20	-0.64
0.185	46.66	*7.04*		90	92.0	70.8	1.30	133.10	-3.53
0.195	49.18	7.03		90	93.9	71.4	1.32	137.80	-6.75
0.205	51.70	7.00		90	96.0	72.4	1.33	142.20	-10.28
0.215	54.22	6.95		90	98.3	73.4	1.34	146.30	-14.12
0.225	56.74	6.89		90	100.8	74.4	1.35	150.00	-18.23
0.235	59.27	6.80		90	103.5	75.6	1.37	153.30	-22.58
0.245	61.79	6.70		90	106.4	77.0	1.38	156.10	-27.14
0.255	64.31	6.57		90	109.4	78.6	1.39	158.40	-31.84
Very Poor Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	18.91	2.94		90	85.6	77.2	1.11	119.50	3.32
0.085	21.44	3.51		90	86.2	75.2	1.15	118.00	2.25
0.095	23.96	3.99		90	87.0	73.6	1.18	117.50	-6.42
0.105	26.48	4.39		90	88.0	72.6	1.21	118.00	-9.57
0.115	29.00	4.73		90	88.9	71.8	1.24	119.10	-12.11
0.125	31.52	5.02		90	90.0	71.2	1.26	120.80	-14.24
0.135	34.05	5.25		90	91.3	71.0	1.29	122.80	-16.17
0.145	36.57	5.44		90	92.6	70.8	1.31	125.10	-18.01
0.155	39.09	5.58		90	94.2	70.8	1.33	127.60	-19.87
0.165	41.61	5.69		90	95.7	71.0	1.35	130.20	-21.80
0.175	44.13	5.78		90	97.6	71.2	1.37	132.80	-23.87
0.185	46.66	5.83		90	99.6	71.6	1.39	135.40	-26.09
0.195	49.18	*5.85*		90	101.8	72.2	1.41	137.90	-28.48
0.205	51.70	*5.85*		90	104.1	72.8	1.43	140.20	-31.05
0.215	54.22	5.83		90	106.5	73.6	1.45	142.30	-33.77
0.225	56.74	5.77		90	109.3	74.6	1.47	144.30	-36.64
0.235	59.27	5.71		90	112.2	75.4	1.49	145.90	-39.64
0.245	61.79	5.61		90	115.2	76.8	1.50	147.30	-42.74
0.255	64.31	5.51		90	118.3	78.2	1.51	148.30	-45.90

The 75-meter loop continues the trends that we encountered with the 40-meter loop. The broadside beamwidth never reaches a value that creates a difference between the antenna's maximum gain and the zenith gain. (The exact broadside beamwidth at which the maximum gain splits into to vectors with a slight depression in the zenith gain varies from one antenna and ground quality to the next. The general region of the split is a broadside beamwidth above 125°, a value that the 1-λ loop never reaches with the survey height limit of 0.255-λ.) The 75-meter beamwidth ratios parallel those for 40 meters, as do the progressions of feedpoint resistance and reactance.

If we followed the band-by-band progressions for the dipole and have digested the values for the 40- and 75-meter 1-λ loops, we can almost predict the values that we meet for the 160-meter loop. We expect increased gain and slightly lower heights for maximum zenith gain, and the 160-meter loop does not disappoint us. **Fig. 13** graphs the gain curves to supplement the numerical information in **Table 7**.

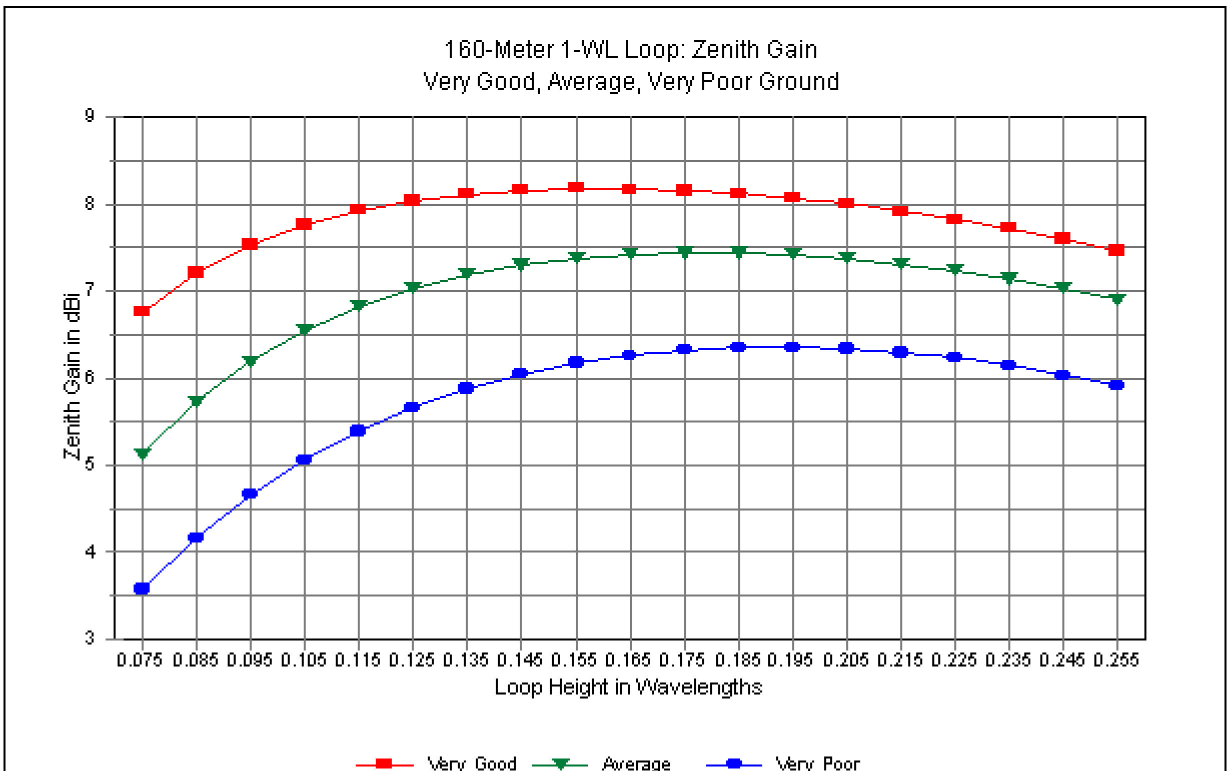


Fig. 13

Perhaps the most limiting factor for the 160-meter loop, which also applies to the 160-meter dipole, is the physical height limit to which most horizontal antennas are subject on that band. The lowest height on the survey is almost 40' (for 0.075-λ), which is very much below the height of maximum gain, even over the best of soil qualities. This height present deficits of gain, as well as considerably different feedpoint resistance values. Moreover, the feedpoint resistance values (assuming one field adjusts the antenna to resonance) vary considerably with soil quality at the very low height. Almost inevitably, then, any 160-meter NVIS installation will suffer relative to performance values that are possible for 75-meter and 40-meter NVIS antennas. However, if the antenna height may reach between 80' and 100' (depending on soil quality), the 160-meter loop is capable of excellent performance.

160-Meter 1-WL Loop AWG #12 Copper Wire: Circumference = 1.0212 WL							1.85 MHz		Table 7
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	39.87	6.75		90	76.7	66.4	1.16	47.01	20.45
0.085	45.19	7.21		90	77.0	66.2	1.16	52.06	18.55
0.095	50.51	7.53		90	77.7	66.2	1.17	57.88	17.53
0.105	55.82	7.76		90	78.4	66.4	1.18	64.30	17.03
0.115	61.14	7.93		90	78.9	66.6	1.18	71.20	16.75
0.125	66.46	8.04		90	79.8	66.8	1.19	78.45	16.48
0.135	71.77	8.11		90	80.7	67.2	1.20	85.95	16.05
0.145	77.09	8.16		90	81.6	67.6	1.21	93.60	15.32
0.155	82.41	*8.18*		90	82.8	68.2	1.21	101.30	14.18
0.165	87.72	8.17		90	84.1	68.8	1.22	108.90	12.59
0.175	93.04	8.15		90	85.4	69.6	1.23	116.40	10.49
0.185	98.36	8.12		90	86.8	70.2	1.24	123.70	7.86
0.195	103.67	8.07		90	88.4	71.2	1.24	130.70	4.71
0.205	108.99	8.00		90	90.3	72.2	1.25	137.30	1.03
0.215	114.31	7.92		90	92.2	73.2	1.26	143.50	-3.13
0.225	119.62	7.82		90	94.4	74.4	1.27	149.20	-7.74
0.235	124.94	7.72		90	96.8	75.6	1.28	154.30	-12.76
0.245	130.26	7.60		90	99.4	77.2	1.29	158.90	-18.14
0.255	135.57	7.46		90	102.3	78.8	1.30	162.80	-23.80
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	39.87	5.13		90	78.5	69.2	1.13	72.39	23.33
0.085	45.19	5.73		90	79.1	68.6	1.15	75.41	18.95
0.095	50.51	6.19		90	79.8	68.4	1.17	79.40	15.87
0.105	55.82	6.55		90	80.5	68.2	1.18	84.12	13.62
0.115	61.14	6.82		90	81.3	68.2	1.19	89.40	11.83
0.125	66.46	7.03		90	82.2	68.2	1.21	95.09	10.24
0.135	71.77	7.19		90	83.2	68.4	1.22	101.00	8.66
0.145	77.09	7.30		90	84.3	68.8	1.23	107.20	6.94
0.155	82.41	7.38		90	85.5	69.2	1.24	113.30	4.97
0.165	87.72	7.42		90	87.0	69.6	1.25	119.50	2.70
0.175	93.04	*7.44*		90	88.4	70.2	1.26	125.50	0.06
0.185	98.36	*7.44*		90	90.1	70.8	1.27	131.30	-2.96
0.195	103.67	7.42		90	91.9	71.6	1.28	136.90	-6.37
0.205	108.99	7.38		90	93.9	72.6	1.29	142.10	-10.16
0.215	114.31	7.31		90	96.1	73.6	1.31	146.90	-14.31
0.225	119.62	7.24		90	98.6	74.8	1.32	151.30	-18.79
0.235	124.94	7.14		90	101.2	76.0	1.33	155.10	-23.56
0.245	130.26	7.03		90	104.0	77.4	1.34	158.50	-28.57
0.255	135.57	6.90		90	106.9	79.2	1.35	161.30	-33.77
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.075	39.87	3.57		90	83.0	75.0	1.11	111.40	13.42
0.085	45.19	4.16		90	83.8	73.5	1.14	110.90	7.01
0.095	50.51	4.66		90	84.4	72.4	1.17	111.70	2.14
0.105	55.82	5.06		90	85.4	71.6	1.19	113.30	-1.65
0.115	61.14	5.39		90	86.4	71.2	1.21	115.60	-4.79
0.125	66.46	5.66		90	87.5	70.8	1.24	118.40	-7.50
0.135	71.77	5.87		90	88.8	70.8	1.25	121.50	-10.01
0.145	77.09	6.04		90	90.1	70.8	1.27	124.90	-12.46
0.155	82.41	6.17		90	91.5	70.8	1.29	128.50	-14.95
0.165	87.72	6.26		90	93.2	71.2	1.31	132.00	-17.56
0.175	93.04	6.32		90	95.0	71.6	1.33	135.50	-20.34
0.185	98.36	*6.35*		90	96.9	72.0	1.35	138.90	-23.31
0.195	103.67	*6.35*		90	99.2	72.8	1.36	142.10	-26.48
0.205	108.99	6.33		90	101.6	73.6	1.38	145.10	-29.85
0.215	114.31	6.29		90	104.1	74.4	1.40	147.80	-33.41
0.225	119.62	6.23		90	106.7	75.4	1.42	150.20	-37.14
0.235	124.94	6.14		90	109.7	76.6	1.43	152.30	-41.01
0.245	130.26	6.03		90	112.7	78.0	1.44	154.00	-44.99
0.255	135.57	5.91		90	115.8	79.4	1.46	155.30	-49.04

Some Preliminary Dipole and Loop Comparisons

The dipole and the loop have numerous similarities in their performance curves relative to height and ground quality. They also display a number of differences worth noting. The differences are real, but their import for a given NVIS operation will vary from one installation to the next. We can here only note the differences, but the user must assign them weight in the overall decision on what sort of antenna to construct for a given fixed station system.

Mechanically, the dipole requires only two end-support posts (towers, trees, etc.) but the linear space is about ½-λ at the operating frequency. In contrast, the loop requires 4 supports, but at a spacing just over ¼-λ per side. The dipole's feedline has only the antenna wire for support, but a corner-fed loop may use the support post to minimize feedline stress on the antenna wire.

Electrically, one of the most interesting differences between the dipole and the loop is the beamwidth ratio, that is, the broadside beamwidth divided by the endwise beamwidth. **Fig. 14** graphs the beamwidth ratios for to 75-meter dipole and loop for all ground qualities in order to clarify the difference. In the region of higher gain, the dipole values range from 1.6:1 up to nearly 1.9:1. Values increase as we lessen the quality of the soil beneath the antenna. In contrast, the loop ratios for the same region vary from 1.2:1 to 1.4:1. Again, the values increase with worse soils in the antenna region.

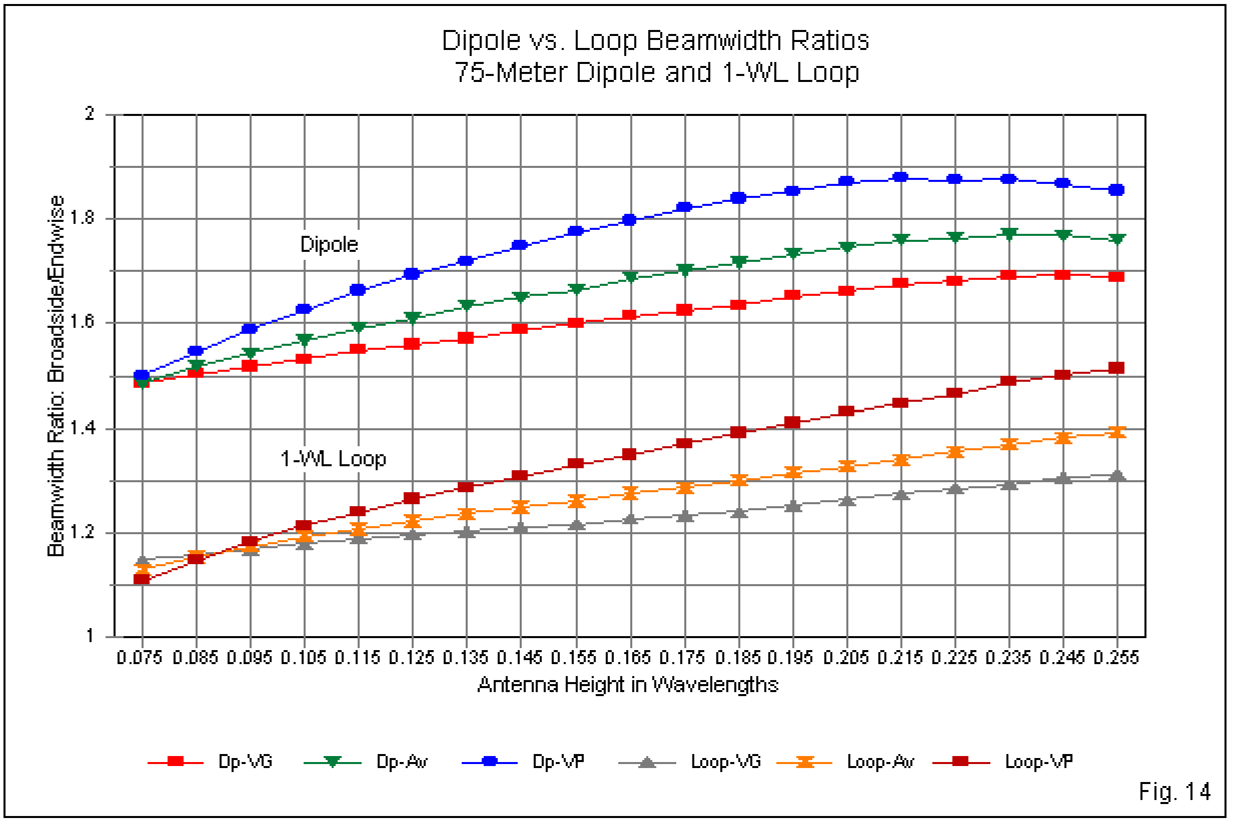
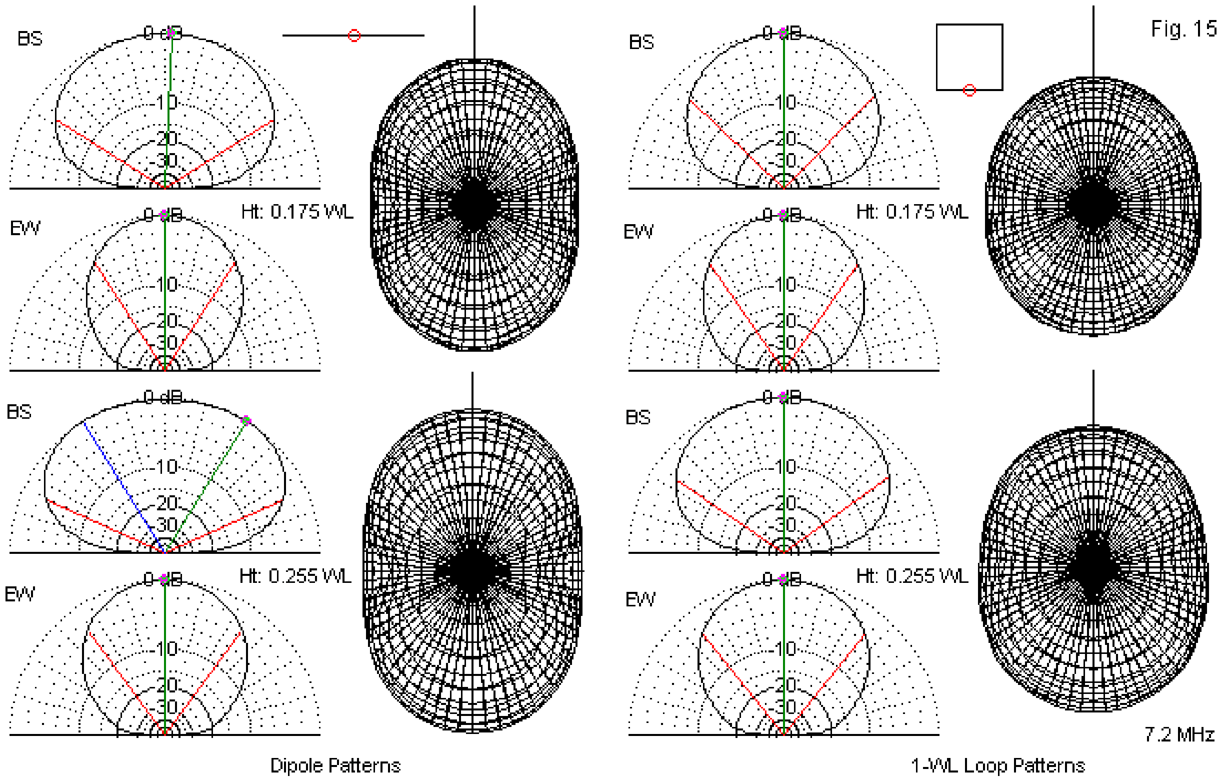


Fig. 14

The significance of the numerical values shows more clearly if we present the information in the form of far-field antenna patterns. **Fig. 15** provides a sample of elevation and 3-dimensional (top-view) patterns for the same dipole and loop. The sample uses average soil and 2 heights: 0.175-λ and 0.255-λ. The heights correspond to near-maximum zenith gain and the upper limit of the survey. For reference, the 3-dimensional patterns show the same length of broadside axis line in all cases.



A Comparison of Elevation and 3-Dimensional Patterns of Two NVIS Antennas at Two Heights: a Dipole and a 1-WL Loop for 40 Meters

At both heights, the dipole shows a greater broadside elongation of its patterns. In fact, at 0.255-λ, the broadside elevation pattern displays the dual maximum gain lines, although the zenith gain depression is operationally insignificant. In contrast, the loop patterns are more nearly circular, even at the maximum height surveyed. (Close inspection of the 3-dimensional loop pattern at 0.255-λ reveals a slight asymmetry or egg-shape, with the broad end at the antenna feedpoint side of the mid-side fed loop used in the sample.) In operation, either pattern may prove to be the more desirable, depending upon the mission specifications for a given station. Nevertheless, the differences are real and may play a role in operations under difficult physical or ionospheric conditions.

We have noted in passing that the loop provides a gain improvement over the dipole. Conventionally, we tend to compare dipoles and loops in free space. In that environment, the loop has a gain advantage of about 1.1 dB over the dipole. When we place horizontal antennas close to ground, as is necessary for NVIS operations, we must set aside conventional numbers and examine the effects of the ground upon the two antennas.

Table 8 summarizes some of the key features of the 1-λ loop in NVIS operation. (See **Table 4** for a parallel treatment of NVIS dipoles.) Just as was the case with the dipole, lowering the operating frequency shows a greater increase in gain over very poor soil than over better soils. The table also shows the increase in the height of maximum zenith gain as we raise the operating frequency over each of the soil types.

Tri-Band Summary of Significant NVIS 1-WL Loop Values									Table 8
Ground	Very Good			Average			Very Poor		
	Max Gain	Height	Gain over	Max Gain	Height	Gain over	Max Gain	Height	Gain over
Band	Zenith	WL	Dipole dB	Zenith	WL	Dipole dB	Zenith	WL	Dipole dB
160 m	8.18	0.155	0.55	7.44	0.180	0.57	6.35	0.190	0.64
75 m	7.96	0.165	0.56	7.04	0.185	0.62	5.85	0.200	0.72
40 m	7.74	0.175	0.59	6.76	0.195	0.67	5.64	0.210	0.78
Delta	0.44	0.020		0.68	0.015		0.71	0.02	
Notes:	Max Gain Zenith = maximum zenith gain in dBi								
	Height WL = maximum zenith gain height in wavelengths								
	(Where 2 heights have the same value, the average appears here.)								
	Gain over Dipole dB = gain of 1-WL loop over dipole at maximum gain; same frequency and height								
	Delta = maximum loop-only change between 160 and 40 meters								

The table also contains an extra set of columns showing the zenith gain advantage of the loop over the dipole when we set each antenna at the height of maximum gain (a height that is the same for each antenna type over each soil type). The gain advantage of the loop increases as we reduce the quality of the ground in the antenna region. **Fig. 16** graphs all 6 of the relevant gain curves (3 for the dipole and 3 for the loop) to shows the variation in the loop's advantage over the full spectrum of surveyed heights. The curves appear in pairs for each of the soil quality value sets. For each pair, the loop is always the higher curve. One interesting facet of comparing the curves is the more rapid drop in gain of the dipole above the height of maximum zenith gain. The loop curves are shallower above the maximum gain height. Below the height of maximum gain, the dipole and loop curves show a highly parallel shape. You may correlate this data to the beamwidth ratio information in the following way. At the maximum surveyed height, the dipole has already passed the beamwidth at which the broadside pattern begins to split into two lobes, but the loop beamwidth remains short of that value.

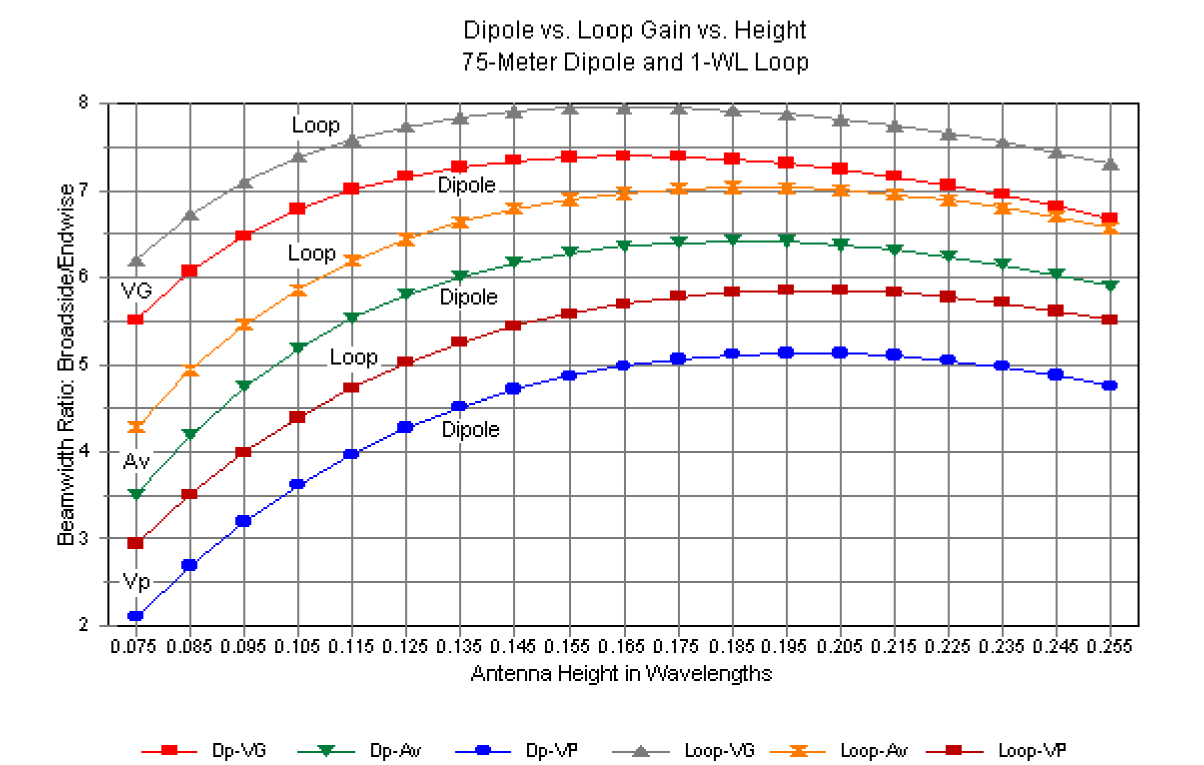
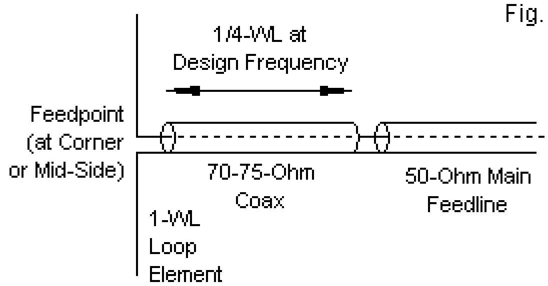


Fig. 16

The feedpoint impedance levels for NVIS dipoles are generally suitable for use with 50-Ω coaxial cable feedlines, although at the heights of maximum zenith gain, 70-Ω coax may yield better SWR values. Loop impedance values at the heights of maximum zenith gain range between 100 Ω and 130 Ω, depending upon the quality of the soil. In most cases, the simple ¼-λ 70-Ω series matching section shown in **Fig. 17** will transform the impedance to a level compatible with a 50-Ω main feedline. Since the matching-section line is in series with the main feedline and counts toward the total feedline length from the antenna to the equipment, it does not measurably increase line losses.

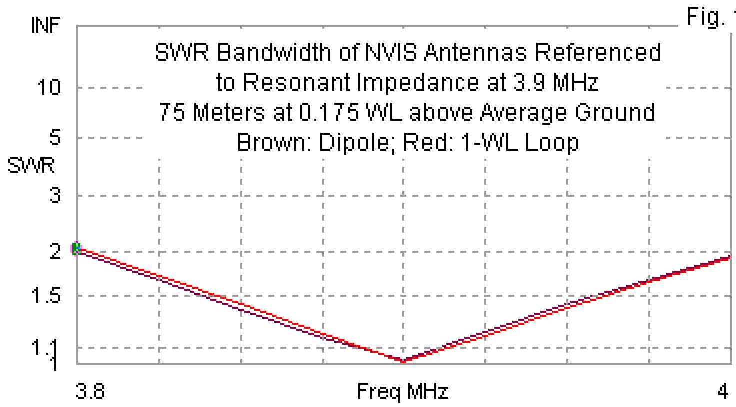
Fig. 17



Conventional Method for Converting the 1-WL Loop Impedance to a 50-Ohm Value for Coaxial Feedlines

Neither antenna shows an advantage with respect to the SWR bandwidth once well matched. **Fig. 18** overlays the SWR curves for both antennas, with each referenced to the resonant impedance, on 75 meters at 0.175-λ above ground over average soil. The curves are virtually indistinguishable.

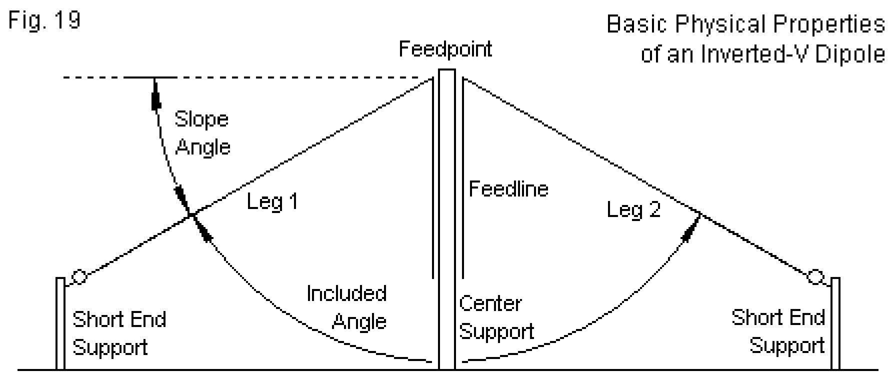
Fig. 18



These comparative notes on the dipole and the 1-λ loop as NVIS antennas make no decisions about which one (or which height) may be best for a given installation. That decision rests on the total span of considerations that go into planning and building an antenna with a certain set of mission specifications. The whole point of the extensive notes, graphs, and tables is to provide sufficient background information on the anticipated electrical performance of the antennas to make the decision as well informed as possible. However, among our basic antennas, we still have one more to consider. The inverted-V dipole is a form of dipole, but has a special property when placed close to ground in a NVIS environment: the V-shape.

The Inverted-V Dipole

When we consider the inverted-V with a modest slope (or a large included angle) in a free-space environment or placed higher than ½-λ above ground, we consider it to be a slightly modified dipole with almost as much broadside gain and with a smaller gain null off the ends of the wire. In those contexts, we tend to truncate the discussion of the V and its performance. As a NVIS antenna, the inverted-V requires close attention to details of its performance. **Fig. 19** provides some of the reasons for special focus.

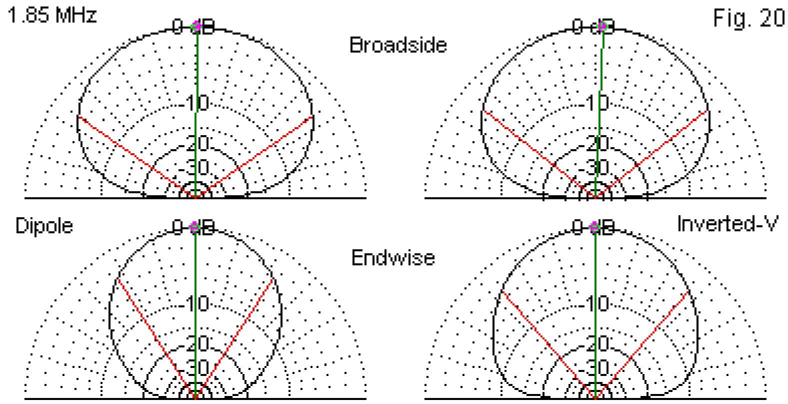


We ordinarily define an inverted-V in one of two ways: by reference to the slope of the line from the horizontal or by reference to the included angle between the wires. For our work, we shall select a slope angle of 30°, which yields an included angle of 120°. Larger slope angles are generally impractical for NVIS work on the lowest three amateur bands. Shallower angles will have performance reports between the 30° V we have selected and a linear dipole, so you may interpolate the probable values.

The chief mechanical advantage of the V is that it needs only one central tall, study support. The wire-end supports can be shorter and therefore lighter. In addition, the V version of the dipole has a lower feedpoint impedance value than a linear dipole. If the standard dipole has a NVIS feedpoint impedance close to 70 Ω, then the anticipated V impedance value should approach 50 Ω, a good match for the ubiquitous coaxial cables used in most amateur installations. Of course, we shall allow the data to eventually tell us what the most likely values are for each soil type in our survey.

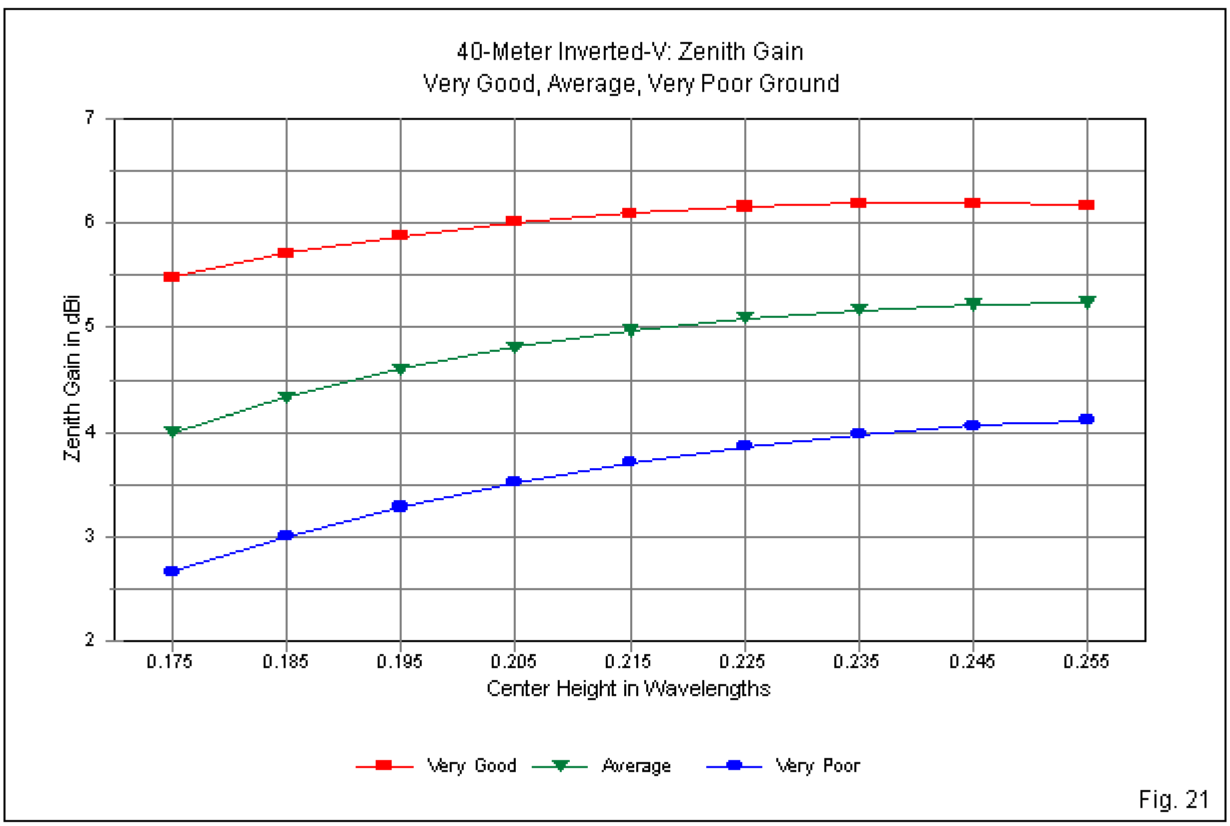
The 30° inverted-V sets some limits to the lowest height at which we can set the center point. The ends must not only clear the ground, but as well leave a safety margin to prevent human or animal contact with the high-voltage end of the wires. A reasonable standard is probably about 10'. However, we shall show results for one step below this level. On 40 meters, the minimum center height will be 0.175-λ, which results in an end height of about 7.4' above ground. On 75 meters, the center minimum is 1.55-λ, for an end height of 8.7'. The 160-meter center height of 0.135-λ results in an end height of 7.7' above ground. For each band, we shall use the center-height as a reference and increase that value in 0.1-λ increments to the survey limit of 0.255-λ, regardless of whether that value is practical on any particular band.

One of the most interesting aspects of the inverted-V configuration is the difference in the endwise patterns relative to either the dipole or the 1-λ loop. **Fig. 20** compares elevation patterns for a dipole and a V for 160 meters, both with center heights of 0.175-λ. The broadside patterns show very little difference. However, the endwise patterns have quite different general shapes as well as beamwidth values. The sloping elements, even with only a 30° droop, show considerable radiation off the ends. The end radiation is not sufficient to dominate the pattern, but it is enough to widen the endwise beamwidth and to retain more than expected levels of radiation at lower angles. The patterns are similar on all three of our surveyed bands.



Broadside and Endwise Elevation Patterns: 160-Meter Dipole and Inverted-V at 0.175-WL Center Height over Average Ground

Because the V enforces a minimum height for the antenna center, our data tables will be smaller than for the other two antennas. The 40-meter V has the smallest data set of all, as evidenced by **Table 9**. However, the span of values is large enough for use to see some interesting differences in V behavior relative to the behavior of the two level antennas.



40-Meter Inverted-V AWG #14 Copper Wire: Length = 0.482 WL									Table 9
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.175	23.91	5.48		90	102.8	81.8	1.26	49.46	14.32
0.185	25.27	5.71		90	104.2	80.4	1.30	51.47	11.65
0.195	26.64	5.88		90	105.8	79.6	1.33	53.62	9.14
0.205	28.00	6.01		90	107.5	79.0	1.36	55.85	7.42
0.215	29.37	6.10		90	109.2	78.6	1.39	58.10	5.56
0.225	30.74	6.16		90	111.2	78.2	1.42	60.33	3.73
0.235	32.10	*6.19*		90	113.2	78.2	1.45	62.51	1.88
0.245	33.47	*6.19*		90	115.4	78.4	1.47	64.59	-0.02
0.255	34.83	6.17		90	117.6	78.8	1.49	66.54	-1.99
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.175	23.91	4.00		90	108.4	80.2	1.35	58.61	4.12
0.185	25.27	4.33		90	110.0	78.8	1.40	59.00	1.56
0.195	26.64	4.60		90	111.6	77.8	1.43	59.68	-0.51
0.205	28.00	4.81		90	113.2	77.2	1.47	60.58	-2.28
0.215	29.37	4.97		90	115.2	76.8	1.50	61.61	-3.88
0.225	30.74	5.09		90	117.2	76.5	1.53	62.72	-5.38
0.235	32.10	5.17		90	119.2	76.5	1.56	63.88	-6.86
0.245	33.47	5.22		90	121.3	76.6	1.58	65.02	-8.33
0.255	34.83	*5.24*		90	123.4	76.8	1.61	66.13	-9.84
Very Poor Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.175	23.91	2.66		90	117.2	79.8	1.47	64.92	-8.01
0.185	25.27	3.00		90	118.6	78.6	1.51	64.05	-10.09
0.195	26.64	3.28		90	120.4	77.6	1.55	63.54	-11.71
0.205	28.00	3.52		90	122.0	76.6	1.59	63.32	-13.05
0.215	29.37	3.71		90	123.6	76.2	1.62	63.30	-14.20
0.225	30.74	3.86		90	125.5	75.8	1.66	63.44	-15.24
0.235	32.10	3.98		90	127.4	75.5	1.69	63.67	-16.20
0.245	33.47	4.06		90	129.4	75.5	1.71	63.98	-17.13
0.255	34.83	*4.11*	4.14	65	131.0	75.6	1.73	64.32	-18.05

. The gain tracks in **Fig. 21** show two important V idiosyncrasies. First, the center height for maximum gain is uniformly high. Only over very good soil do we find a distinct gain maximum followed by at least one lesser value. For average and very poor soil, maximum zenith gain occurs either at or above the 0.255-λ survey-height limitation. Ground coupling to the lower wire ends and the sloping elements combine to reduce the effective height of the V if we take the maximum gain heights of the level antennas as standards. Second, with a center height only at the level of the dip[ole or loop maximum-gain heights, the V shows a much lower gain. Despite this apparent disadvantage, the anticipated lower feedpoint impedance values—close to the to characteristic impedance of common coaxial cable—do show up in the data set.

The trends established by the 40-meter inverted-V reappear in the 75-meter version. As we move downward in frequency, we can add two more steps of data to the collection and maintain the minimum wire-end height. Only over very good ground does the progression of values in **Table 10** show a distinct peak zenith gain value, although the doubled value at the highest limit over average ground indicates a clear peak at that level. The required center height for peak zenith gain over very poor soil remains outside the table limits. We may also note that the inverted-V, unlike the dipole, only shows a difference between maximum gain and maximum zenith gain at the highest levels and only over very poor soil. The oddity of this phenomenon relative to the dipole and the 1-λ loop is that the differential occurs before the V over the worst ground quality has reached its peak zenith gain value.

75-Meter Inverted-V AWG #14 Copper Wire: Length = 0.482 WL									Table 10
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.155	39.09	5.26		90	99.2	86.2	1.15	42.01	19.02
0.165	41.61	5.59		90	100.2	83.8	1.20	43.99	14.13
0.175	44.13	5.85		90	101.4	82.0	1.24	46.25	11.46
0.185	46.66	6.04		90	102.8	80.8	1.27	48.67	8.98
0.195	49.18	6.19		90	104.4	79.8	1.31	51.20	6.90
0.205	51.70	6.29		90	106.0	79.2	1.34	53.78	5.04
0.215	54.22	6.36		90	107.8	78.8	1.37	56.36	3.26
0.225	56.74	6.41		90	109.6	78.4	1.40	58.90	1.50
0.235	59.27	6.42		90	111.6	78.5	1.42	61.36	-0.30
0.245	61.79	6.41		90	113.8	78.6	1.45	63.71	-2.18
0.255	64.31	6.38		90	116.1	79.0	1.47	65.91	-4.15
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.155	39.09	3.65		90	104.0	86.0	1.21	56.52	13.17
0.165	41.61	4.11		90	105.2	82.8	1.27	56.59	8.26
0.175	44.13	4.47		90	106.6	81.0	1.32	57.15	4.65
0.185	46.66	4.77		90	108.2	79.8	1.36	58.05	1.85
0.195	49.18	5.00		90	109.8	78.8	1.39	59.19	-0.46
0.205	51.70	5.19		90	111.4	78.0	1.43	60.49	-2.47
0.215	54.22	5.32		90	113.4	77.8	1.46	61.88	-4.31
0.225	56.74	5.42		90	115.4	77.4	1.49	63.32	-6.06
0.235	59.27	5.49		90	117.4	77.2	1.52	64.76	-7.78
0.245	61.79	5.52		90	119.6	77.4	1.55	66.15	-9.52
0.255	64.31	5.52		90	121.9	77.8	1.57	67.48	-11.27
Very Poor Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.155	39.09	2.14		90	113.0	84.0	1.35	70.02	-0.87
0.165	41.61	2.61		90	114.4	82.0	1.40	68.01	5.19
0.175	44.13	3.01		90	115.8	80.2	1.44	66.72	-8.34
0.185	46.66	3.34		90	117.4	79.0	1.49	65.92	-10.75
0.195	49.18	3.62		90	119.0	77.8	1.53	65.51	-12.69
0.205	51.70	3.84		90	120.8	77.2	1.56	65.38	-14.32
0.215	54.22	4.01		90	122.7	76.6	1.60	65.45	-15.76
0.225	56.74	4.14		90	124.6	76.4	1.63	65.67	-17.08
0.235	59.27	4.24		90	126.6	76.2	1.66	65.97	-18.32
0.245	61.79	4.30	4.32	73	128.6	76.2	1.69	66.32	-19.52
0.255	64.31	4.33	4.38	63	130.4	76.4	1.71	66.69	-20.71

The gain curves in **Fig. 22** add two lower-level steps to the chart and thereby reveal the rapidly decreasing gain level that occurs as the V wire ends approach ground. Even though the overall gain level for any height (in wavelengths) is higher on 75 meters than on 40 meters, the gain of a V with its ends at about the same height on both bands will be lower on the lower band. In addition, as we lower the inverted-V, the feedpoint resistance shows more parallels to the impedance of the dipole at very low levels, with a strong divergence of values as we change the quality of soil. However, in the case of the V, the divergence occurs largely as a result of the average height of the antenna, not the center height. The divergence shown by the 75-meter V at its minimum height of 0.155-λ corresponds to the divergence displayed by dipoles closer to the lower survey limit of 0.075-λ.

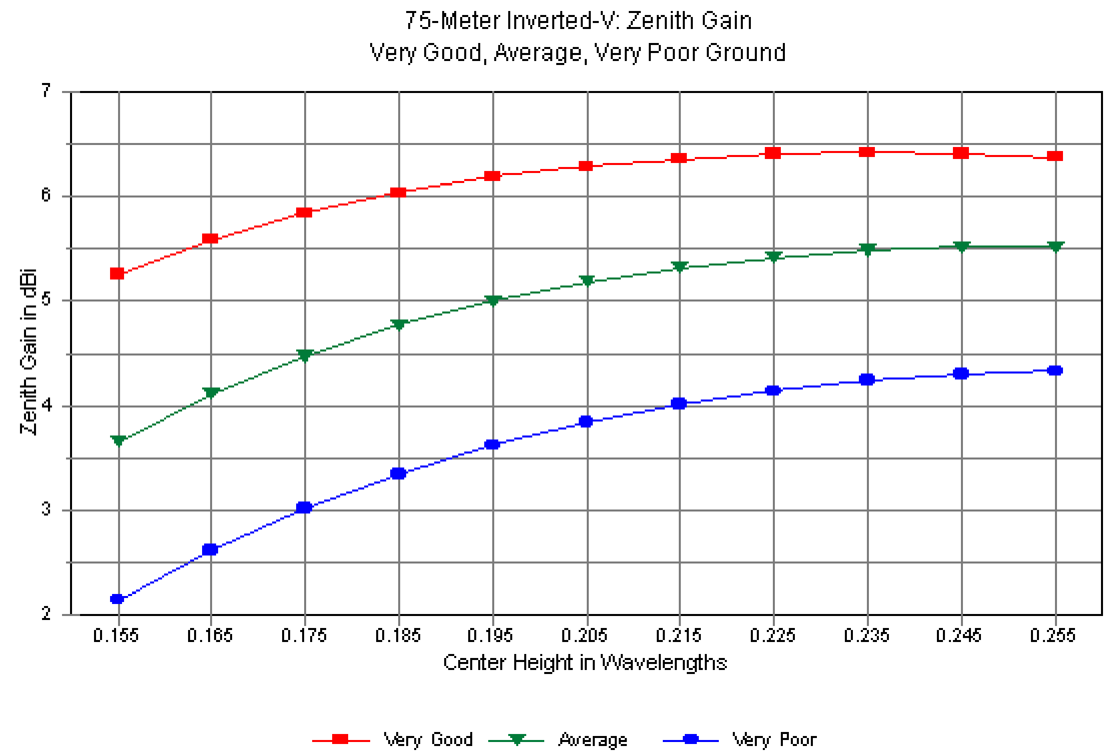

75-Meter Inverted-V: Zenith Gain
Very Good, Average, Very Poor Ground
Zenith Gain in dBi
Center Height in Wavelengths
0.155
0.165
0.175
0.185
0.195
0.205
0.215
0.225
0.235
0.245
0.255
Very Good
Average
Very Poor

Fig. 22

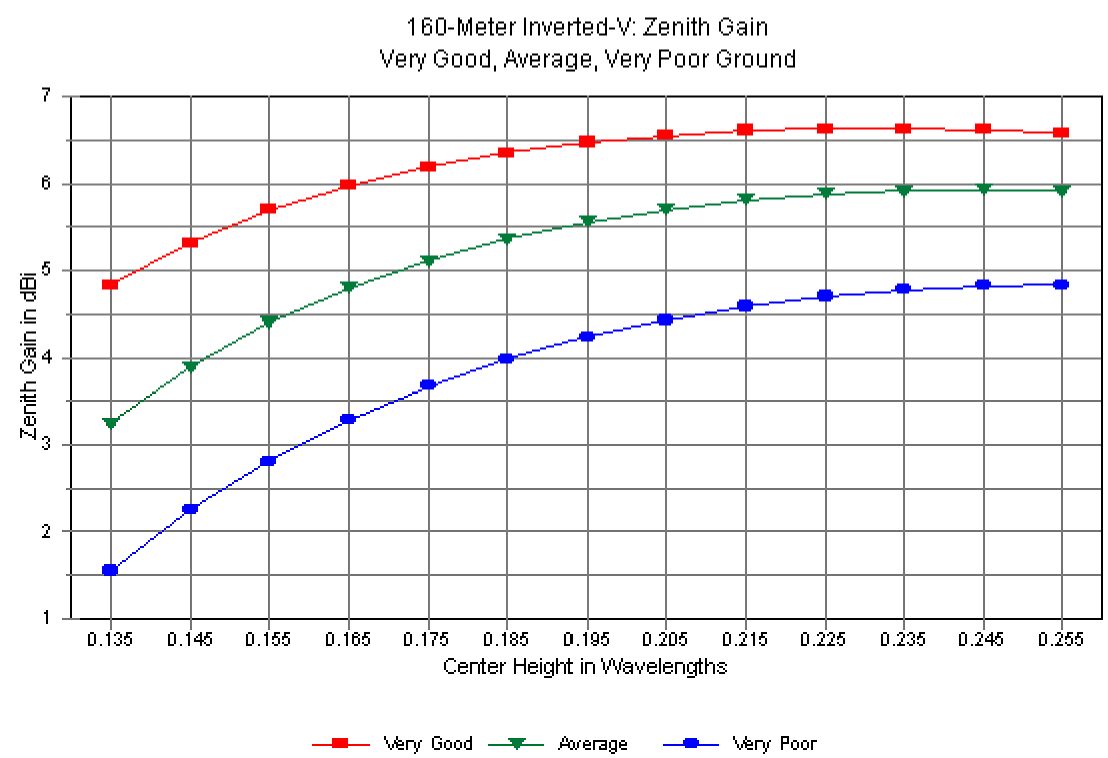

160-Meter Inverted-V: Zenith Gain
Very Good, Average, Very Poor Ground
Zenith Gain in dBi
Center Height in Wavelengths
0.135
0.145
0.155
0.165
0.175
0.185
0.195
0.205
0.215
0.225
0.235
0.245
0.255
Very Good
Average
Very Poor

Fig. 23

160-Meter Inverted-V AWG #12 Copper Wire: Length = 0.482 WL									Table 11
Very Good Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.135	71.77	4.83		90	96.2	94.6	1.02	34.24	31.83
0.145	77.09	5.32		90	97.0	89.6	1.08	35.88	21.64
0.155	82.41	5.70		90	98.0	86.2	1.14	38.01	15.55
0.165	87.72	5.98		90	99.0	83.6	1.18	40.44	11.50
0.175	93.04	6.19		90	100.4	82.0	1.22	43.08	8.60
0.185	98.36	6.35		90	101.8	80.8	1.26	45.85	6.35
0.195	103.67	6.47		90	103.2	79.8	1.29	48.70	4.46
0.205	108.99	6.55		90	104.8	79.2	1.32	51.58	2.75
0.215	114.31	6.61		90	106.4	78.8	1.35	54.44	1.11
0.225	119.62	6.63		90	108.4	78.6	1.38	57.24	-0.55
0.235	124.94	6.63		90	110.4	78.6	1.40	59.95	-2.28
0.245	130.26	6.62		90	112.4	78.8	1.43	62.53	-4.10
0.255	135.57	6.58		90	114.6	79.2	1.45	64.97	-6.03
Average Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.135	71.77	3.25		90	99.4	93.6	1.06	50.15	32.29
0.145	77.09	3.89		90	100.4	89.0	1.13	49.78	20.91
0.155	82.41	4.40		90	101.4	85.6	1.18	50.28	13.84
0.165	87.72	4.80		90	102.6	83.4	1.23	51.32	9.00
0.175	93.04	5.11		90	104.2	81.8	1.27	52.72	5.43
0.185	98.36	5.36		90	105.6	80.4	1.31	54.37	2.64
0.195	103.67	5.56		90	107.0	79.4	1.35	56.19	0.31
0.205	108.99	5.70		90	108.8	78.8	1.38	58.10	-1.75
0.215	114.31	5.81		90	110.6	78.4	1.41	60.06	-3.67
0.225	119.62	5.88		90	112.6	78.2	1.44	62.01	-5.53
0.235	124.94	5.92		90	114.6	78.2	1.47	63.92	-7.38
0.245	130.26	5.93		90	117.0	78.2	1.50	65.74	-9.27
0.255	135.57	5.92		90	119.2	78.6	1.52	67.46	-11.20
Very Poor Soil									
Height wl	Height ft	Zen Gain	Max Gain	TO Ang	BS BW	EW BW	BW Ratio	Feed R	Feed X
0.135	71.77	1.55		90	106.5	91.6	1.16	74.36	23.41
0.145	77.09	2.25		90	107.6	87.6	1.23	70.35	12.01
0.155	82.41	2.81		90	109.0	85.0	1.28	67.98	4.71
0.165	87.72	3.28		90	110.4	82.8	1.33	66.61	-0.41
0.175	93.04	3.67		90	111.8	81.0	1.38	65.90	-4.22
0.185	98.36	3.98		90	113.6	79.8	1.42	65.65	-7.19
0.195	103.67	4.23		90	115.2	78.8	1.46	65.74	-9.63
0.205	108.99	4.43		90	117.2	78.2	1.50	66.08	-11.74
0.215	114.31	4.59		90	119.0	77.6	1.53	66.58	-13.64
0.225	119.62	4.70		90	121.0	77.4	1.56	67.18	-15.41
0.235	124.94	4.78		90	123.2	77.2	1.60	67.82	-17.48
0.245	130.26	4.82		90	125.4	77.4	1.62	68.48	-18.72
0.255	135.57	4.83	4.86	67	127.4	77.6	1.64	69.11	-20.33

160 meters creates an additional two steps to the tabulated data and shows how low that zenith gain values may go when the V ends are close to ground. Both **Table 11** and **Fig. 23** show that lowering the operating frequency also lowers the heights of maximum zenith gain, although only slightly. Still, over very poor soil, we cannot from the existing data certify that the highest listed gain value is in fact the peak value. Once more the V over very poor ground begins to split its broadside elevation lobes prior to reaching the peak zenith gain value. The trends among all three sample inverted-V NVIS antennas are consistent with prior trends.

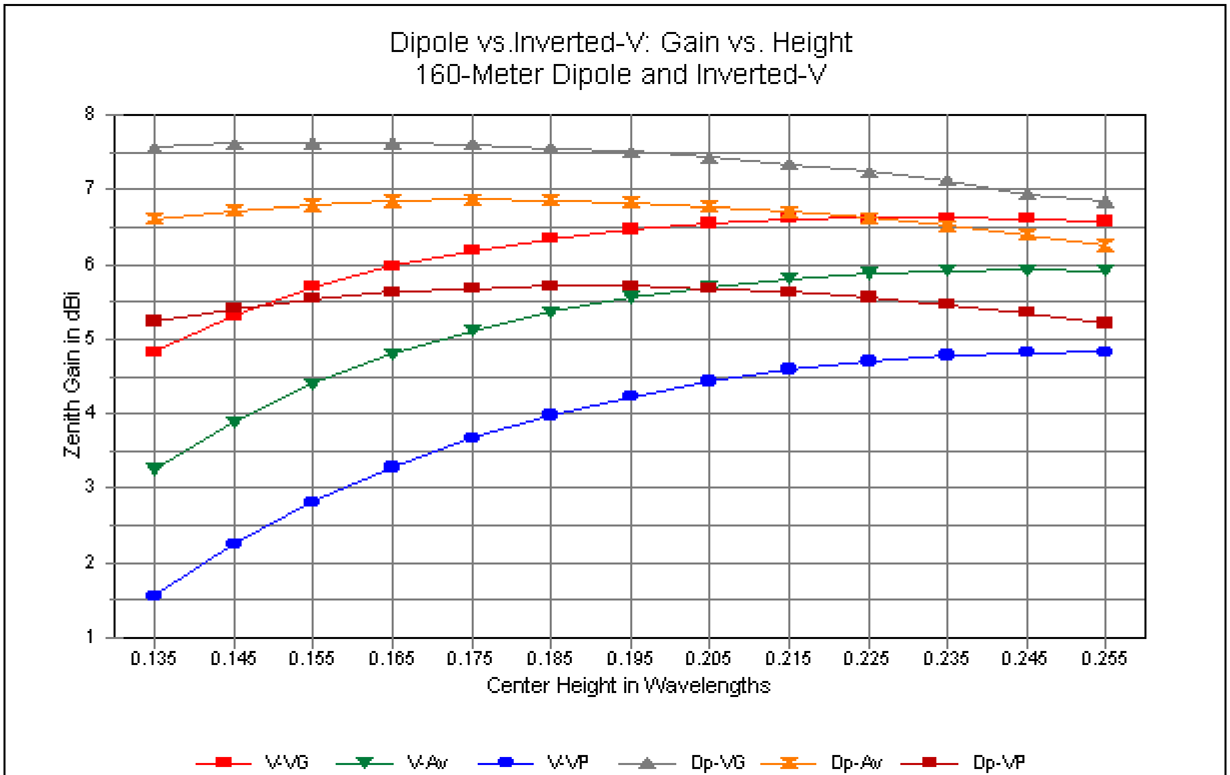


Fig. 24

Fig. 24 provides graphic evidence of how the zenith gain behavior of the inverted-V differs from corresponding behavior in a dipole (or by extension in a 1-λ loop). In the primary span of heights within which the dipole reaches its peak gain, the inverted-V shows considerably lesser gain, since this portion of the inverted-V height span is marked by a rising gain figure. Since amateur tend to build antennas within total height limitations dictated by available materials, skills, expense, and zoning restrictions, the comparison is fair. **Table 12** provides a summary view of the gain disparity between the V and the level antennas. The table uses height values for peak zenith gain, and we have already seen that the required heights for peak inverted-V gain are considerably higher than for the other antennas. If you change the table to record a constant height—perhaps 0.175-λ as an average of the heights of maximum gain of the level antennas over all soil types—the disparity is even greater. For example, a 75-meter dipole at 0.175-λ above average ground has a zenith gain of 6.4 dBi, while the 75-meter loop under the same conditions shows 7.0 dBi. However, a 75-meter inverted-V with a center height of 0.175-λ provides less than 4.5 dBi zenith gain.

Tri-Band Summary of Significant NVIS Inverted-V Values												Table 12
Ground	Very Good				Average				Very Poor			
	Max Gain	Height	Gain vs.	Gain vs.	Max Gain	Height	Gain vs.	Gain vs.	Max Gain	Height	Gain vs.	Gain vs.
Band	Zenith	WL	Dipole dB	Loop dB	Zenith	WL	Dipole dB	Loop dB	Zenith	WL	Dipole dB	Loop dB
160 m	6.63	0.230	-1	-1.55	5.93	0.245	-0.94	-1.51	4.83	0.255	-0.88	-1.52
75 m	6.42	0.235	-0.98	-1.54	5.52	0.250	-0.9	-1.52	4.33	0.255	-0.80	-1.52
40 m	6.19	0.240	-0.96	-1.55	5.24	0.255	-0.85	-1.52	4.11	0.255	-0.75	-1.53
Delta	0.44	0.010			0.69	0.010			0.72	0		
Notes:	Max Gain Zenith = maximum zenith gain in dBi											
	Height WL = maximum zenith gain height in wavelengths											
	(Where 2 heights have the same value, the average appears here.)											
	Gain vs. Dipole dB = maximum gain of inverted-V relative to a dipole maximum gain at same frequency											
	Gain vs. Loop dB: maximum gain of inverted-V relative to a 1-wl loop maximum gain at same frequency											
	(Heights of maximum gain are not the same for inverted-Vs and for dipoles and 1-wl loops.)											
	Delta = maximum inverted-V-only change between 160 and 40 meters											

The behavior of an inverted-V NVIS antenna differs in further ways from the behavior of the level antenna. For example, the beamwidth ratio (broadside to endwise) increases more rapidly with increases in center height than we find in the case of dipoles of 1-λ loops. **Fig. 25** shows the phenomenon in a 160-m V in contrast to the rates for the dipole on the same band. The faster rate of increase for the V coincides, at least in part, with the V's endwise elevation pattern, and both are results of the greater radiation off the ends of the element due to its slope. (Although 1-λ loop beamwidth ratios are smaller than those for a linear dipole, their curves are equally "flat.")

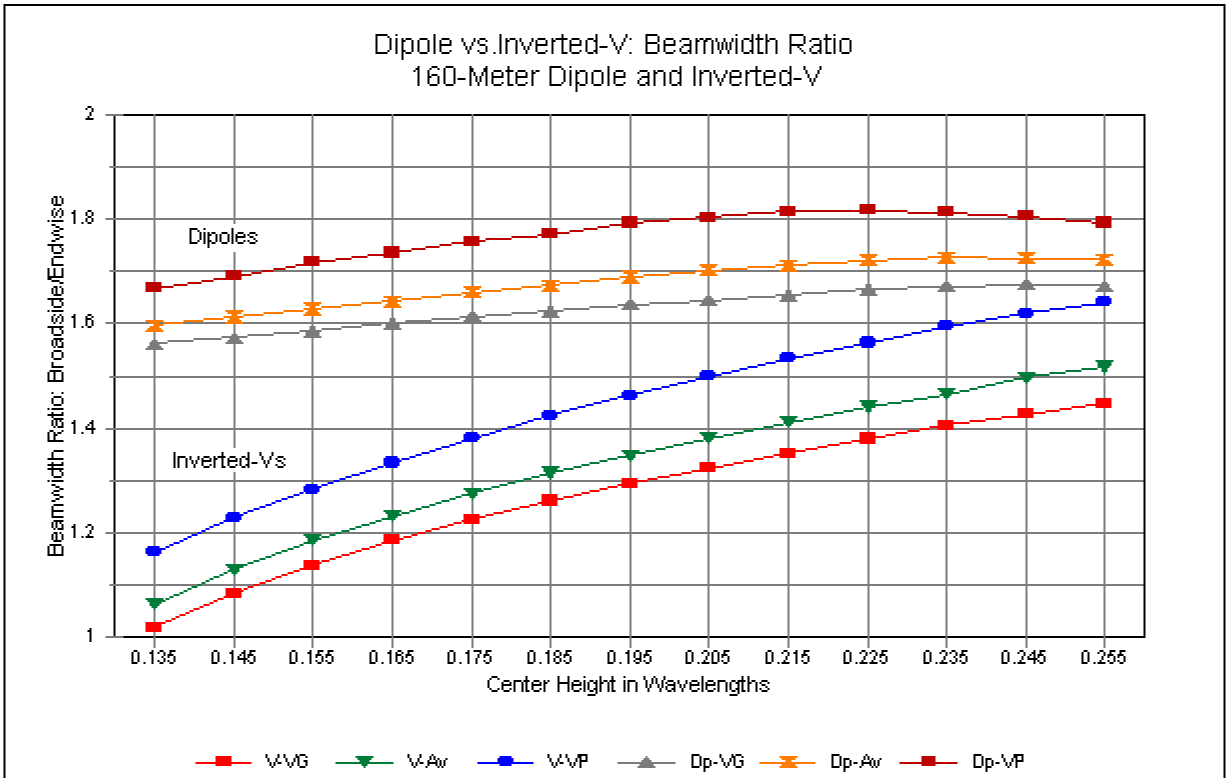


Fig. 25

As we increase the height of a dipole or a 1-λ loop, the feedpoint impedance components show particular patterns. Except for the lowest heights, the resistance tends to rise over all soil qualities, although the rate varies with the soil type. Hence, we saw the resistance values converge toward the top of the height range within the survey. In contrast, the reactance values tend to change fairly slowly. On 75 meters over average ground, the SWR curves in **Fig. 18** were equivalently wide for both level antennas, with a 2:1 SWR ratio relative to the resonant impedance (at 3.9 MHz) from 3.8 to 4.0 MHz.

If we track the feedpoint impedance in terms of the resistive and reactive components for an inverted-V, we find opposite trends. **Fig. 26** tracks the resistance and reactance of a 75-meter dipole and a 75-meter inverted-V over average ground—restricting the height coverage to the V's limited range. Although the patterns of lines may be difficult to follow, the two rising curves represent feedpoint resistance. The steeper curve belongs to the dipole, as the resistance of the V changes more slowly. Both descending curves belong to the feedpoint reactance values. The V's reactance changes more rapidly and radically than the dipole values. At the left in the graph, the V's reactance changes most rapidly when the wire ends are closest to the ground. Although the rate of change remains relatively high, it slows as the wire ends increase their height. In contrast, the dipole curve in the left part of the graph coincides with the region of highest gain, and the rate of change is very slow. The rate increases as we raise the antenna well past the region of maximum zenith gain.

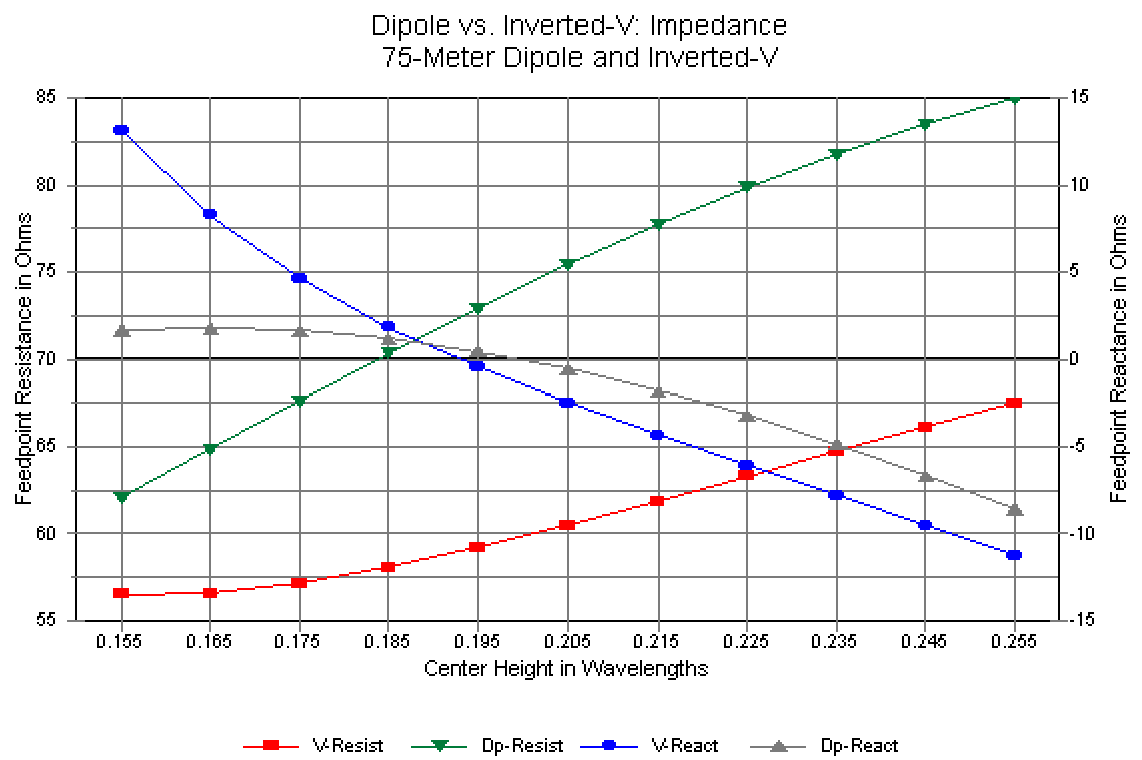
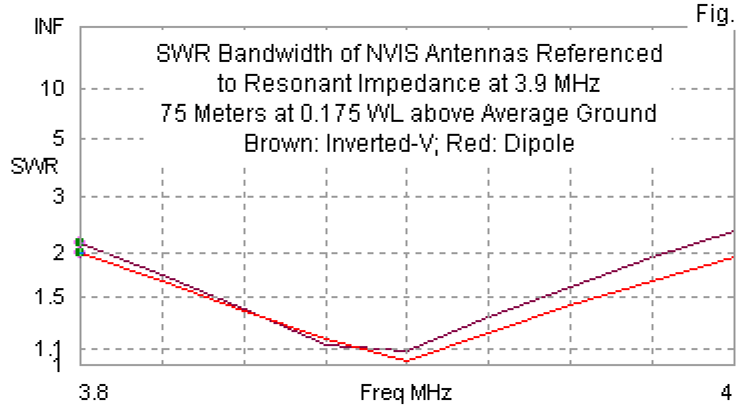


Fig. 26

The differences in the patterns of resistance and reactance change have very little effect upon the available SWR bandwidth. **Fig. 27** overlays SWR curves for a 75-meter dipole and V, both with center heights of 0.175-λ above average ground. If we judge by the endpoints of the sweeps, the V curve is not quite as broad as the dipole curve. Nevertheless, the SWR bandwidth is fully adequate to NVIS operations on the specified band. Allowing for the changes in frequency, similar curves would apply to NVIS antennas for the 40-meter and 160-meter bands.

Fig. 27



Conclusion

The three most basic NVIS antennas—the dipole, the 1-λ loop, and the inverted-V configuration of the dipole—share many properties, most often as a result of the close proximity of the antenna to ground. Hence, we discovered that ground quality plays an important role in determining the maximum possible zenith gain on each of the bands surveyed. As well, it plays a role in setting the optimal height for maximum zenith gain, although for all types of antennas, precision is not necessary in order to achieve excellent results. However, we did discover that an old idea that gives very low heights a presumed gain advantage is simply false. Averaging both level antennas over all soil types, a height of approximately 0.175-λ above ground places the antenna within the expanded range of best zenith gain performance.

The inverted-V, with its wire ends close to ground and a 30° slope angle, presents a conundrum for the NVIS antenna builder. Although easier to construct than either a linear dipole or a 1-λ loop, the inverted-V antenna shows a considerable gain deficit relative to level antennas with the same center height. The deficit may reach up to about 2.5 dB or close the half an S-unit. Although the inverted-V may be necessary for field antennas, a fixed station antenna might well enjoy the advantages of one of the level antennas.

The data compendium provided by these notes likely has surplus information. However, the extra data serves the twin goals of these notes. Not only is the information useful in making decisions about what type of antenna to create, it also aids in a better understanding of the behaviors of each antenna type. Despite the wealth of numbers and facts, these notes have only scratched the surface of even basic NVIS antennas.