Basic NVIS Antennas with Reflectors: Dipoles, Loops, and Vs

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An interesting facet of basic NVIS antennas—the dipole, the 1-λ loop, and the inverted-V—is the suggestion that we can improve antenna gain by placing some form of wire structure below it. The possibilities are numerous, but the most common suggestion is the addition of a single-wire element. In fact, with proper consideration, the suggestion will work, but with limitations. As well, there may be better, although more complex, solutions to obtain better zenith gain from the basic NVIS antenna.

The structure that we place below the driven wire has acquired two names, one correct, the other misplaced and misleading. The correct name for the element is a reflector. If the reflector is a single-wire element optimized in size for best performance, then it is a parasitic reflector. Still, the circumstances of its use will force us to modify the expectations that we have of such elements when used with highly elevated beam antennas. If the structure below the driven element consists of a screen or a series of wires parallel to the endwise orientation of the driven element, then we have a planar reflector (sometimes called a sheet, curtain, or screen reflector). We shall eventually examine both types of reflectors for NVIS applications.

The incorrect name for the element—usually applied to the single-wire reflector—is “counterpoise.” Although widely bandied about, the term “counterpoise” actually applies only to a certain form of monopole completion structure that substitutes for buried radials. Very slightly elevated from the ground and not connected to ground by any direct means, the counterpoise serves the monopole by capacitive coupling to the ground. Although quite effective for its function, the counterpoise has disappeared from active use, seemingly freeing the terms for other uses. Unfortunately, the terms has greatest use in lazy applications, where an investigator or writer does not take the trouble to analyze the structure’s role in an application and further does not go on to optimize its physical parameters relative to the application. This situation too often applies to NVIS applications with careless element sizing and placement. Perhaps it is time to drop both the term and the associated carelessness from not only NVIS concerns, but from any antenna considerations whatsoever—except, of course, when working with the original engineering designs for monopole-counterpoise antenna systems.

In these notes, we shall treat NVIS antenna reflectors, whether parasitic or planar, as parts of an antenna system consisting of a driven element and the element or structure below it. For parasitic reflectors, we shall size them for nearly optimal performance and carefully consider their placement. We may measure placement in two ways: as their height above ground or as their separation from the driven element. For both perspectives, we shall discover that the height of the driver above ground plays a significant role in reflector placement. In addition, the ground quality also dictates the placement of a carefully designed reflector element.

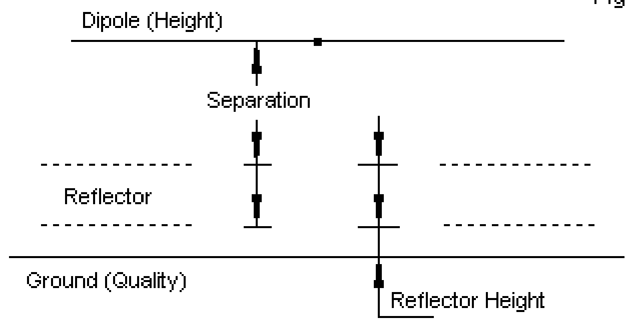
We shall also discover that dipoles and 1-λ loops, despite the similarities of their optimal heights over various ground qualities when used alone, do not respond identically to reflector elements. Eventually, we shall look at the inverted-V to let it reveal further oddities. Although planar reflectors improve gain most when placed close to their driven elements, practicalities dictate that we place them on or very near to the ground. Nevertheless, they will prove their merits, especially when we give proper attention to their size.

We have much to explore, even if the concept of a NVIS reflector seems simple. Let’s begin with the dipole.

The NVIS Dipole and a Parasitic Reflector

At its optimal height, the common linear or level dipole provides quite good NVIS performance with a range of about 5 to 7.4 dBi zenith gain, depending upon the operating frequency and the quality of the soil beneath it. Under certain conditions, we can increase the gain by adding a parasitic reflector somewhere between the dipole and the ground. Unfortunately, we cannot specify a specific place for the reflector, since numerous variables enter into the optimal placement. **Fig. 1** provides indicators of the most relevant variables.

Fig. 1



NVIS Dipole + Reflector Variables

Like almost all parasitic reflectors, the element length must exceed the length of the resonant dipole. As well, the proper placement will vary with the dipole's height above the ground and with the quality of the ground. As shown in the sketch, we may specify the placement by two measures: the height of the dipole above ground or the separation of the dipole from the driver. Unfortunately for ease of analysis, both parameters tend to vary with the height of the dipole itself and the quality of the ground beneath.

In these notes, we shall confine ourselves to 75-meter and 40-meter dipole arrays. Rarely are 160-m dipoles high enough to sustain a reflector element. On 60 meters, one may interpolate between the 75- and 40-meter data to arrive at a reliable value, since the gain curves are not sharp enough to modify performance drastically with small variations.

Beginning with the 75-meter dipole, we shall again use AWG #14 copper wire for all elements. The main unit of measure will be the wavelength, and the dipole will be 0.4803-λ long. The reflector element will be 0.5-λ long. The reflector length theoretically will change as we move the reflector around, but not enough to disturb the trends that we find with a constant length. We shall catalog the results of modeling the dipole at three heights (to reduce the number of continuously changing variables). Heights of 0.15-λ, 0.175-λ, and 0.2-λ will surround the optimum heights over all three of our standard ground types: very good, average, and very poor.

Tabulated results (**Table 1**) will include, for each dipole, reflector heights from 0.005-λ to 0.06-λ in 0.005-λ increments. In addition, we shall include two special heights: -0.001-λ to cover the potential for a buried reflector element and 0.001-λ to cover the case of a reflector so low that someone might trip over it. The table shows the height in feet for every increment of reflector height. It also indicates in boldface the reflector height of maximum zenith gain and shows on the right side the indicated separation from the dipole. For each height, the tables show the zenith gain and the broadside beamwidth.

NVIS 3.9-MHz Dipole with a Single-Wire Reflector Element								Table 1
Dipole: 0.4806-wl AWG #14 Copper Wire				Reflector: 0.5-wl AWG #14 Copper Wire				
Dipole Height		0.15	wl	37.83	feet			
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl
No Reflector		7.37	103.2	6.23	108.4	4.79	117.8	
-0.001	-0.25	7.40	103.2	6.33	108.4	5.04	117.4	
0.001	0.25	7.46	103.2	6.50	108.2	5.39	116.8	
0.005	1.26	7.53	103.2	6.67	108.4	5.68	116.4	
0.01	2.52	7.57	103.4	6.78	108.4	5.86	116.4	Vry Gd
0.015	3.78	**7.59**	103.5	6.85	108.6	5.98	116.4	0.135
0.02	5.04	7.58	103.8	6.90	108.8	6.05	116.4	
0.025	6.30	7.55	104.2	6.91	109.2	6.11	116.6	Ave
0.03	7.57	7.51	104.6	**6.92**	109.2	6.15	116.6	0.120
0.035	8.83	7.47	105.0	6.90	109.8	6.17	116.8	Vry Pr
0.04	10.09	7.42	105.4	6.88	110.2	**6.18**	117.0	0.110
0.045	11.35	7.37	105.8	6.84	110.4	6.17	117.2	
0.05	12.61	7.31	106.4	6.80	110.8	6.16	117.4	
0.055	13.87	7.25	106.8	6.75	111.2	6.13	117.8	
0.06	15.13	7.19	107.2	6.69	111.6	6.09	118.0	
Max. Delta Gain		*0.22*		*0.69*		*1.39*		
Dipole Height		0.175	wl	44.13	feet			
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl
No Reflector		*7.39*	107.4	*6.40*	113.0	5.06	122.4	
-0.001	-0.25	7.40	107.5	6.47	113.0	5.25	122.0	
0.001	0.25	7.44	107.5	6.59	112.8	5.52	121.4	
0.005	1.26	7.49	107.5	6.71	112.8	5.75	121.0	Vry Gd
0.01	2.52	**7.52**	107.6	6.80	112.8	5.90	120.8	0.165
0.015	3.78	**7.52**	107.8	6.85	113.0	6.00	120.8	0.160
0.02	5.04	7.51	108.2	6.88	113.2	6.07	120.8	Ave
0.025	6.30	7.49	108.4	**6.89**	113.6	6.12	120.8	0.150
0.03	7.57	7.45	109.0	**6.89**	113.8	6.15	121.0	0.145
0.035	8.83	7.42	109.2	6.88	114.2	6.18	121.0	Vry Pr
0.04	10.09	7.38	109.8	6.86	114.4	**6.19**	121.2	0.135
0.045	11.35	7.34	110.2	6.83	114.8	**6.19**	121.4	0.130
0.05	12.61	7.30	110.8	6.80	115.4	**6.19**	121.6	0.125
0.055	13.87	7.26	111.2	6.77	115.6	6.18	121.8	
0.06	15.13	7.21	111.6	6.73	116.2	6.17	122.0	
Max. Delta Gain		*0.13*		*0.49*		*1.13*		
Dipole Height		0.20	wl	50.44	feet			
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl
No Reflector		7.28	112.4	6.39	118.4	5.14	127.4	
-0.001	-0.25	7.29	112.4	6.45	118.2	5.29	127.0	
0.001	0.25	7.32	112.4	6.53	118.1	5.51	126.4	
0.005	1.26	7.35	112.6	6.62	118.1	5.69	126.0	Vry Gd
0.01	2.52	**7.37**	112.6	6.69	118.1	5.82	125.8	0.190
0.015	3.78	**7.37**	112.8	6.73	118.2	5.91	125.7	0.185
0.02	5.04	7.35	113.2	6.75	118.4	5.97	125.6	Ave
0.025	6.30	7.33	113.6	**6.76**	118.6	6.02	125.6	0.175
0.03	7.57	7.30	114.0	6.75	119.0	6.05	125.7	
0.035	8.83	7.26	114.6	6.74	119.2	6.08	125.8	
0.04	10.09	7.23	114.8	6.73	119.5	6.09	125.9	
0.045	11.35	7.19	115.4	6.71	119.8	6.10	126.0	Vry Pr
0.05	12.61	7.16	115.8	6.68	120.3	**6.11**	126.0	0.150
0.055	13.87	7.13	116.2	6.66	120.6	**6.11**	126.2	0.145
0.06	15.13	7.09	116.8	6.63	121.0	6.10	126.4	
Max. Delta Gain		*0.09*		*0.37*		*0.96*		

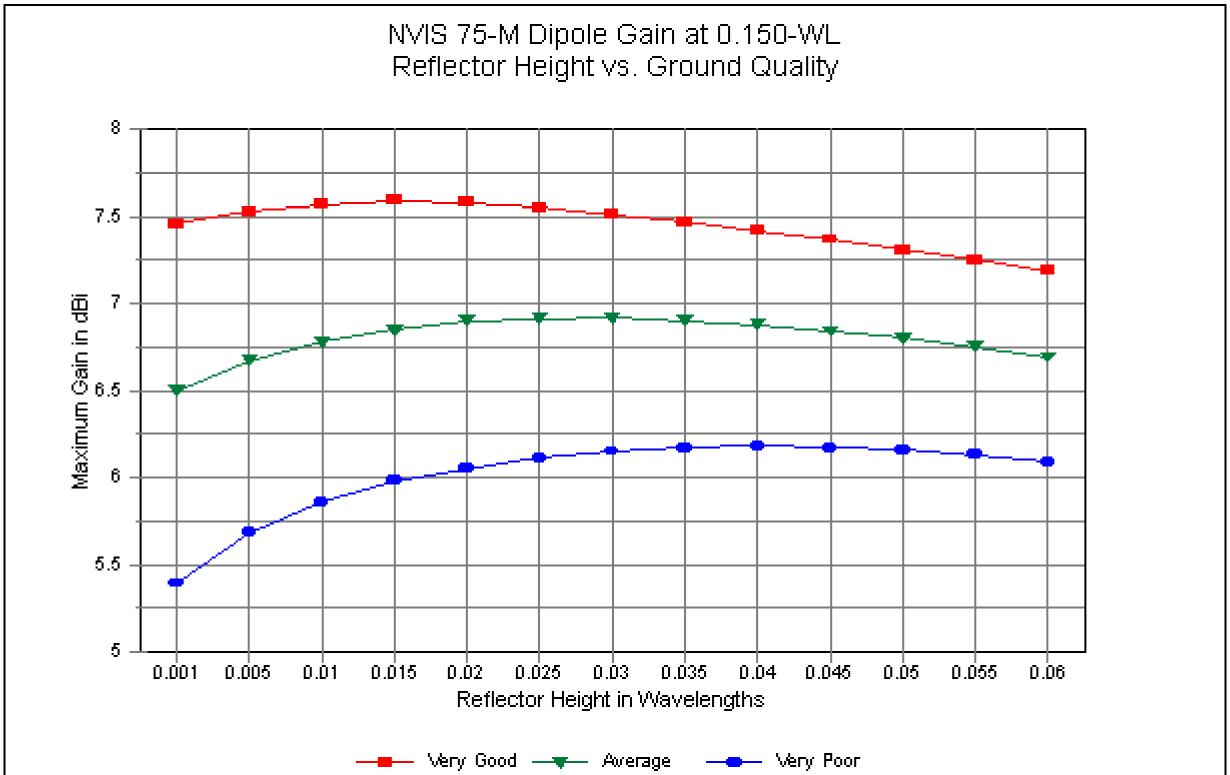

NVIS 75-M Dipole Gain at 0.150-WL
Reflector Height vs. Ground Quality
Maximum Gain in dBi
8
7.5
7
6.5
6
5.5
5
0.001
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
Very Good
Average
Very Poor

Fig. 2

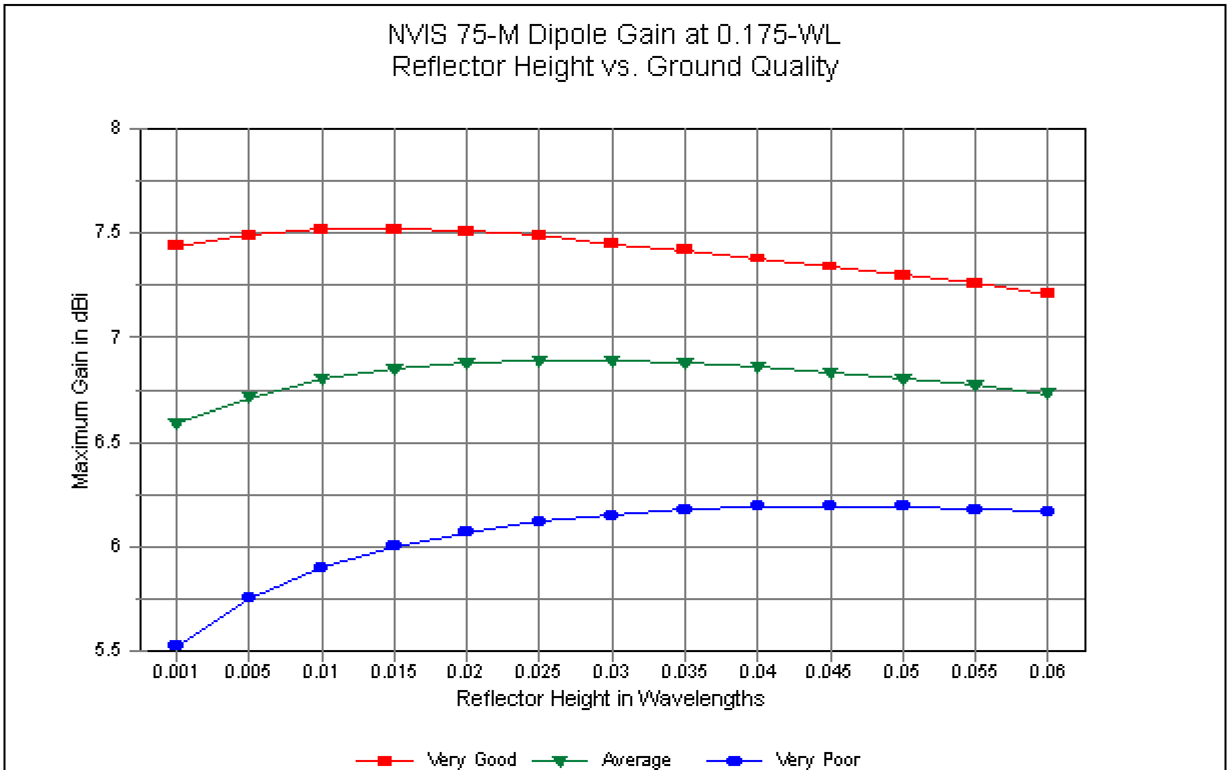

NVIS 75-M Dipole Gain at 0.175-WL
Reflector Height vs. Ground Quality
Maximum Gain in dBi
8
7.5
7
6.5
6
5.5
0.001
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
Very Good
Average
Very Poor

Fig. 3

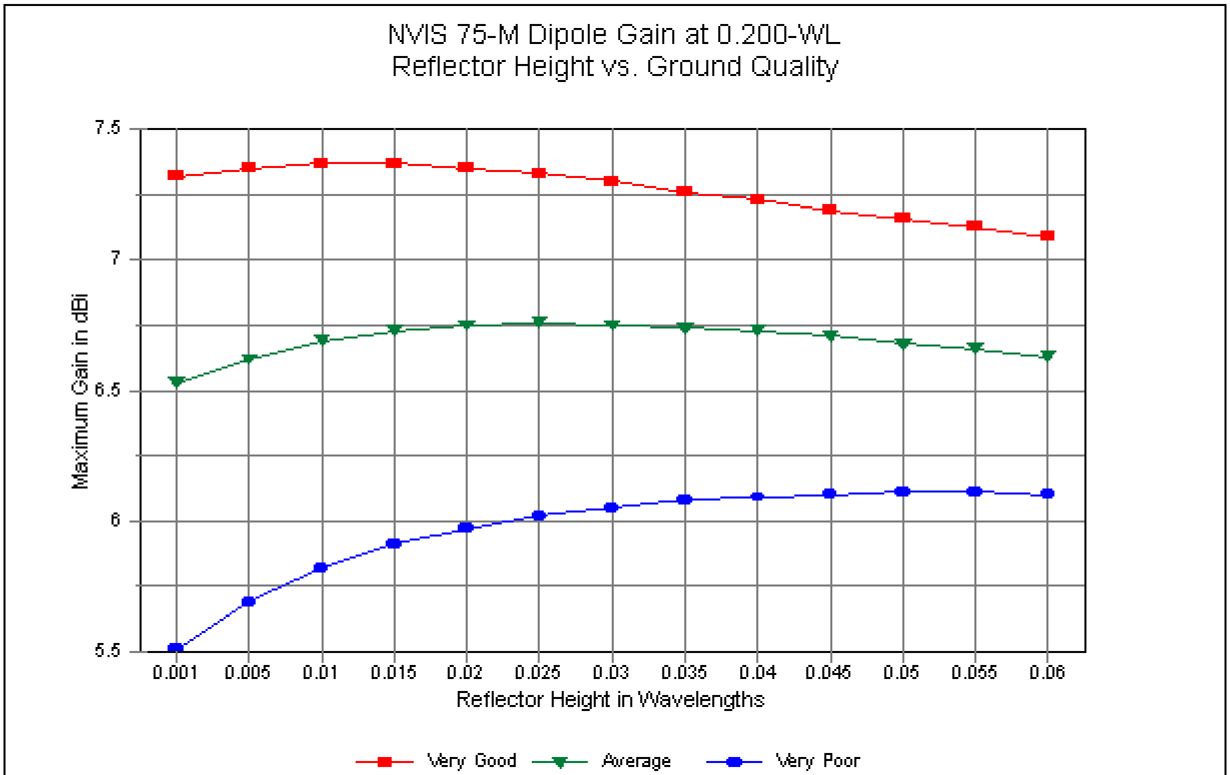

NVIS 75-M Dipole Gain at 0.200-WL
Reflector Height vs. Ground Quality
Maximum Gain in dBi
7.5
7
6.5
6
5.5
0.001
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
Very Good
Average
Very Poor

Fig. 4

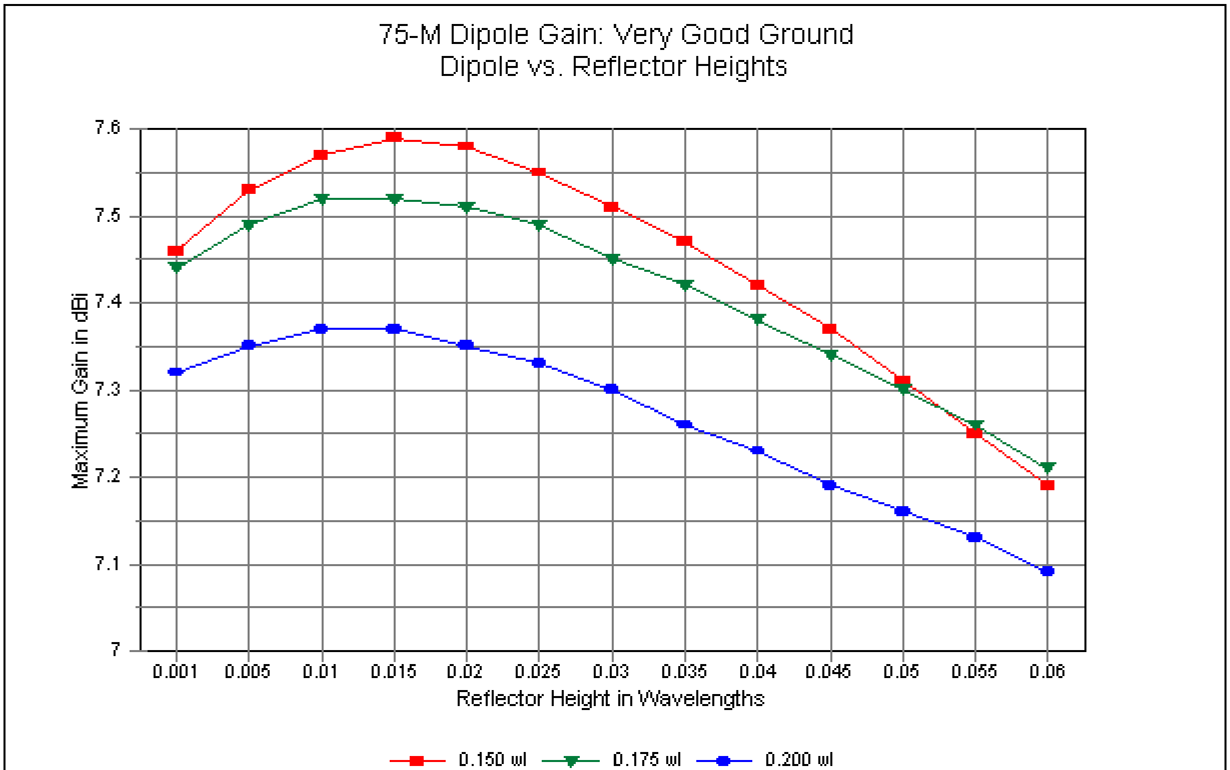

75-M Dipole Gain: Very Good Ground
Dipole vs. Reflector Heights
Maximum Gain in dBi
7.6
7.5
7.4
7.3
7.2
7.1
7
0.001
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 5

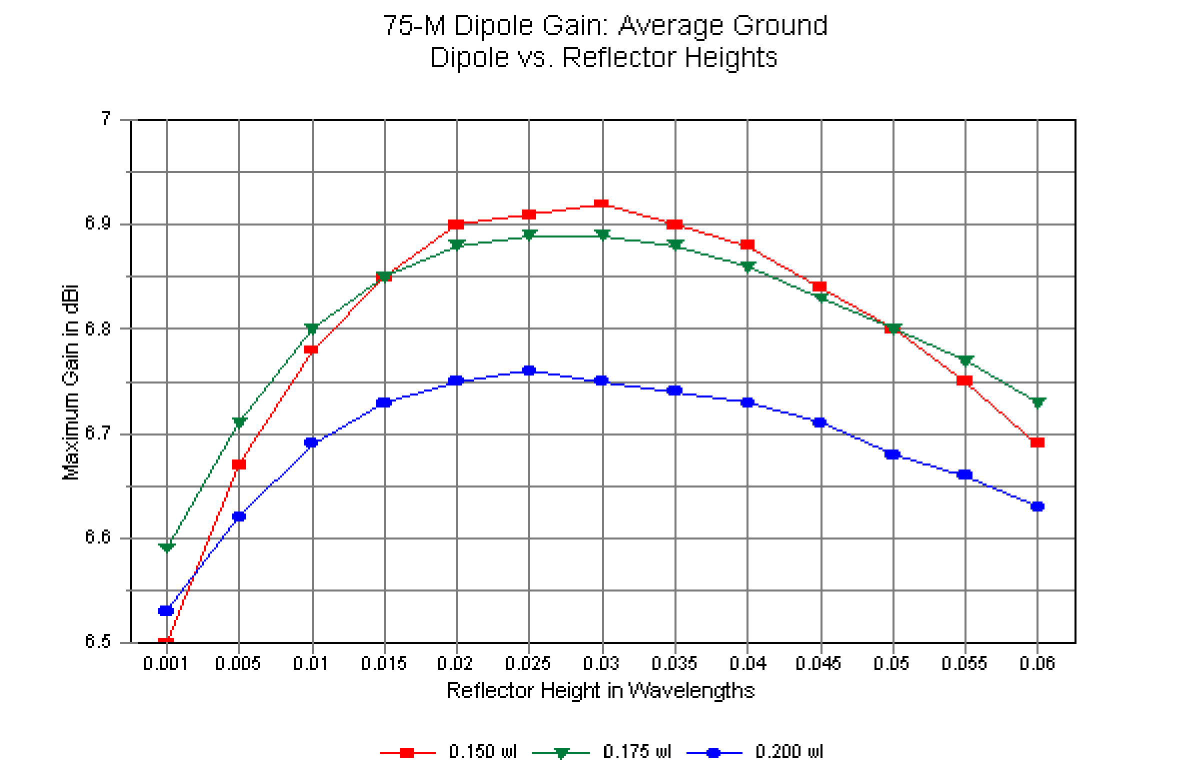

75-M Dipole Gain: Average Ground
Dipole vs. Reflector Heights
Maximum Gain in dBi
7
6.9
6.8
6.7
6.6
6.5
0.001
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 6

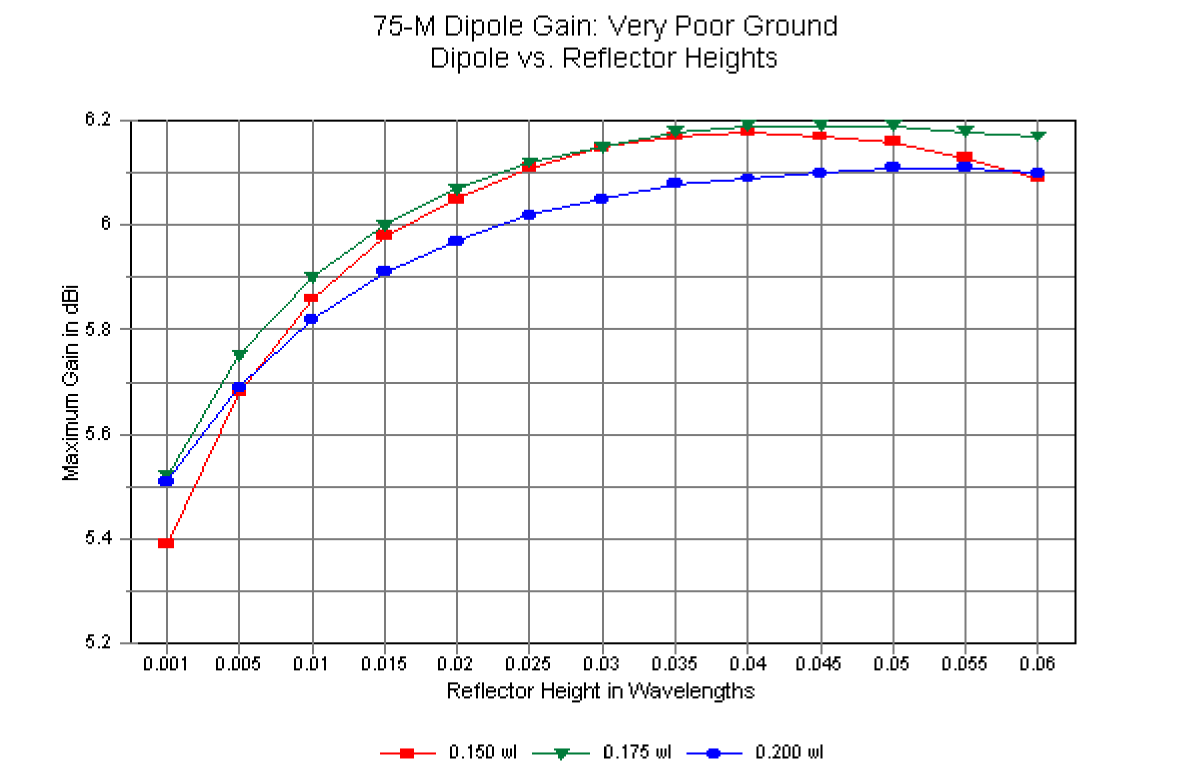

75-M Dipole Gain: Very Poor Ground
Dipole vs. Reflector Heights
Maximum Gain in dBi
6.2
6
5.8
5.6
5.4
5.2
0.001
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 7

As the pages following the table show (in **Fig. 2** through **Fig. 7**) we may graphically examine the data in two different ways. The easy way is to graph the gain curves for each dipole height using separate lines for each quality of soil. The first three graphs follow this plan and resemble the curves in the last set of notes for dipoles alone. They establish that the dipole-reflector over very good soil has more gain at any height than equivalent systems over lesser soil types. The three graphs vary by virtue of the dipole height since a dipole and a dipole-reflector array both reach maximum gain at lower dipole heights with very good ground than over lesser ground qualities. In contrast, the lines close up somewhat as we raise the dipole height, since the version over very good ground has passed its optimal height, while the versions over average and very poor soil reach their peak values at higher dipole altitudes.

Although the initial three graphs relate easily to past performance graphs, **Fig. 5** through **Fig. 7** may prove more revealing. In this set, each graph uses a single soil quality, with individual lines in each graph for the three selected dipole heights. With very good soil, the 0.15-λ-dipole height is clearly most nearly optimal. Over average soil, the peak values for dipole heights of 0.15-λ and 0.175-λ approach each other as most nearly optimal. Over very poor soil, the values for the two lower heights are nearly the same, while the values for a dipole at 0.2-λ above ground have nearly caught up to the other lines. These graphs are more than merely interesting; they indicate a fundamental property of all enhancements that we may bring to basic NVIS antennas. The enhancement—in this case a parasitic reflector—becomes more effective in raising zenith gain as the soil decreases in quality. In **Table 1**, compare for each major subdivision the delta values for the three soil types. The maximum improvement for an optimized reflector over very good soil is only about 0.2 dB over very good soul. The overall performance improvement is between 0.4 and 0.7 dB over average soil, but it grows to a full dB or more over very poor soil.

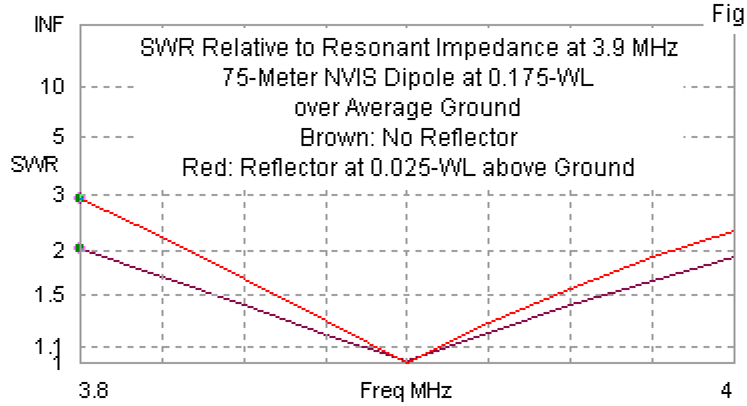
Soil quality determines in part whether adding a parasitic reflector to a given dipole is worth the effort involved for both installation and maintenance. It also tells us something very significant about parasitic reflectors in NVIS service. The added element may supplement ground reflection as the source of zenith gain, but it does not replace the ground. Note also that even though we find the greatest gain improvement over very poor ground, the total space of gain value ranges in each graph do not overlap those in another graph. Ground quality tends to dominate zenith gain, even with a parasitic reflector added to the NVIS dipole.

The table shows the antenna gain of the dipole at each height over each ground quality with no reflector. Compare the gain values to the next two entries, which show a slightly buried reflector and one just above ground. In both cases, the gain improvement is minimal to marginal, at best. The reflector does not significantly improve performance until it is well above ground. For very good soil, the reflector height is between 0.01-λ and 0.015-λ, regardless of the height of the dipole (within the surveyed range). Over average soil, the best reflector heights have an equally narrow range, but a different one: 0.025-λ to 0.03-λ. Over very poor soil, where the reflector has maximum effect in improving the dipole's zenith gain, the ranges are split, running in the region of 0.04-λ for the lowest dipole up to about 0.055-λ for the highest.

Over very good and average soil, the reflector height remains constant, but the separation between the dipole and the reflector changes with a change in the dipole's height. The separation between the dipole and the reflector also changes for each dipole height over very poor soil, but that change combines with a change in the best height above ground to produce a more complex picture. In just the region of soil quality for which a parasitic reflector effects a worthy improvement, uniformity disappears. In fact, over poorer soils, one cannot recommend either a single height above ground or a single spacing between elements that will cover the remaining variables, such as dipole height. As soils improve, we can recommend some reasonably good reflector heights above ground, but not without also considering whether the potential improvement justifies the installation and maintenance efforts.

Because the reflectors are parasitic, the overall array is a tuned system with operating bandwidth limits. Like all parasitic systems, the SWR bandwidth (referred to the resonant impedance) is narrower than the bandwidth of the dipole alone. **Fig. 8** provides a sample comparison of dipoles at a 0.175-λ height, one with no reflector and the other with a reflector at 0.025-λ above ground. The dipole covers the 3.8-4.0-MHz spread of 75 meters completely, but the dipole-reflector array manages to cover only about ¾ of the range.

Fig. 8



One purpose in adding 40-meter arrays to this initial examination is to determine if the trends that we saw on 75 meters are general or idiosyncratic to the lower of the two bands. From our study of dipoles alone, we know to expect slightly lower gain values for each dipole height when measured as a fraction of a wavelength and from each soil quality. Looking at 40-meter dipole-reflector arrays can tell us if there are other variations in the trends that are frequency sensitive.

Table 2 provides the data for 40-meter dipoles at the same three heights (measured in wavelengths. Of course, the physical heights, as shown in the table, will be only about half the 75-meter values. Otherwise, the data takes the same steps as for the longer antenna. The reflector height increments are 0.005-λ between 0.005-λ and 0.06-λ, with the addition of –0.001-λ to simulate a buried reflector and 0.001-λ to simulate one very close to ground level. The table also includes reference data for independent dipoles so that we can see the level of improvement created by the addition of a parasitic reflector.

The data for each entry includes the zenith gain and the broadside bandwidth. The beamwidth data has an obvious story to tell, namely, that for practical operating purposes, the beamwidth does not vary enough to be a concern over any soil quality with any dipole height. However, for both 75 and 40 meters, the beamwidth information conveys some subtle pattern changes. Over very good soil, the beamwidth continuously rises. Over average soil, the general trend is a rise in beamwidth value as we raise the reflector height, but we find in some cases an initial drop in value for the lowest reflector height. Over very poor soil, the beamwidth decreases from the initial value until we approach or reach the reflector height for maximum zenith gain, after which point, the value rises. We might also note that the rate of beamwidth value change slows or stops just before we arrive at maximum zenith gain for each soil and dipole height combination.

NVIS 7.2-MHz Dipole with a Single-Wire Reflector Element								Table 2
Dipole: 0.4786-wl AWG #14 Copper Wire				Reflector: 0.5-wl AWG #14 Copper Wire				
Dipole Height		0.15	wl	21.48	feet			
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl
No Reflector		7.08	104.6	5.79	110.4	4.38	119.0	
-0.001	-0.14	7.13	104.6	5.94	110.2	4.71	118.4	
0.001	0.14	7.22	104.5	6.15	109.8	5.13	117.6	
0.005	0.72	7.32	104.6	6.37	109.8	5.49	117.0	
0.01	1.43	7.39	104.8	6.52	110.0	5.71	116.8	
0.015	2.15	7.43	104.8	6.62	110.0	5.86	116.8	Vry Gd
0.02	2.86	**7.44**	105.2	6.68	110.2	5.97	116.6	0.130
0.025	3.58	7.43	105.5	6.73	110.4	6.05	116.6	
0.03	4.30	7.41	105.8	6.75	110.6	6.11	116.6	Ave
0.035	5.01	7.38	106.2	**6.76**	110.8	6.15	116.8	0.115
0.04	5.73	7.34	106.8	6.75	111.2	6.18	116.8	Vry Pr
0.045	6.44	7.30	107.2	6.73	111.6	**6.19**	117.0	0.105
0.05	7.16	7.26	107.6	6.71	111.8	**6.19**	117.2	0.100
0.055	7.87	7.21	108.2	6.68	112.2	6.18	117.4	
0.06	8.59	7.16	108.4	6.64	112.6	6.17	117.6	
Max. Delta Gain		*0.36*		*0.97*		*1.81*		
Dipole Height		0.18	wl	25.05	feet			
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl
No Reflector		7.15	108.8	6.03	114.8	4.71	123.3	
-0.001	-0.14	7.18	108.8	6.14	114.6	4.97	122.6	
0.001	0.14	7.23	109.0	6.28	114.4	5.30	121.8	
0.005	0.72	7.30	109.0	6.45	114.2	5.59	121.4	
0.01	1.43	7.35	109.0	6.56	114.4	5.77	121.0	Vry Gd
0.015	2.15	**7.37**	109.2	6.63	114.4	5.90	120.8	0.160
0.02	2.86	**7.37**	109.6	6.68	114.6	5.99	120.8	0.155
0.025	3.58	7.36	110.0	6.72	114.6	6.06	120.8	
0.03	4.30	7.34	110.4	6.73	115.0	6.12	120.8	Ave
0.035	5.01	7.31	110.8	**6.74**	115.2	6.16	120.8	0.140
0.04	5.73	7.29	111.0	6.73	115.6	6.19	120.8	
0.045	6.44	7.25	111.6	6.72	115.8	6.21	121.0	
0.05	7.16	7.22	112.0	6.71	116.2	6.22	121.2	Vry Pr
0.055	7.87	7.19	112.4	6.69	116.6	**6.23**	121.2	0.120
0.06	8.59	7.15	113.0	6.66	117.0	**6.23**	121.4	0.115
Max. Delta Gain		*0.22*		*0.71*		*1.52*		
Dipole Height		0.20	wl	28.63	feet			
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl
No Reflector		7.06	114.2	6.08	120.0	4.85	128.0	
-0.001	-0.14	7.08	114.2	6.15	119.8	5.05	127.4	
0.001	0.14	7.12	114.2	6.26	119.6	5.31	126.8	
0.005	0.72	7.17	114.2	6.39	119.4	5.56	126.0	
0.01	1.43	7.21	114.2	6.48	119.4	5.72	125.7	Vry Gd
0.015	2.15	**7.22**	114.4	6.53	119.4	5.83	125.5	0.185
0.02	2.86	**7.22**	114.6	6.57	119.6	5.91	125.4	0.180
0.025	3.58	7.20	115.0	6.60	119.6	5.98	125.3	
0.03	4.30	7.18	115.4	6.61	120.0	6.03	125.2	Ave
0.035	5.01	7.16	115.8	**6.62**	120.2	6.07	125.2	0.165
0.04	5.73	7.13	116.2	6.61	120.5	6.10	125.3	
0.045	6.44	7.10	116.6	6.60	120.8	6.13	125.3	
0.05	7.16	7.07	117.2	6.59	121.0	6.14	125.4	Vry Pr
0.055	7.87	7.04	117.6	6.58	121.3	**6.16**	125.4	0.145
0.06	8.59	7.01	118.0	6.56	121.6	**6.16**	125.6	0.140
Max. Delta Gain		*0.16*		*0.54*		*1.31*		

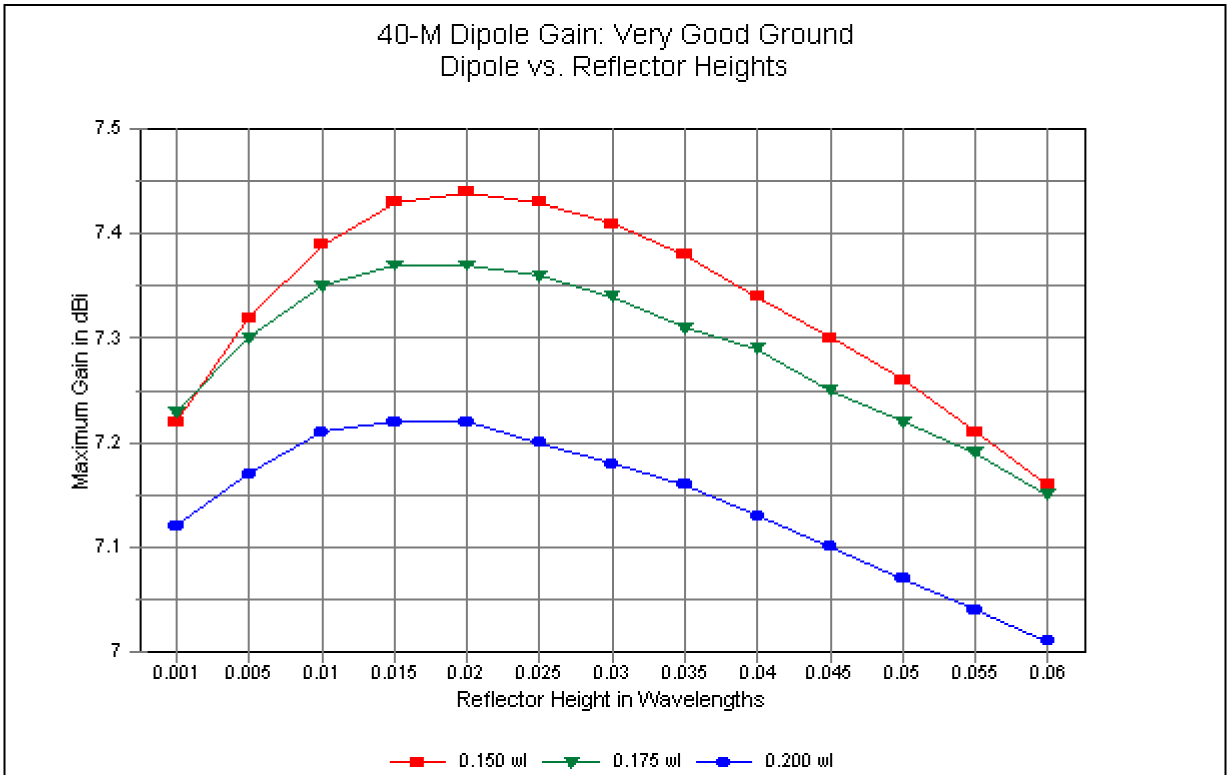

40-M Dipole Gain: Very Good Ground
Dipole vs. Reflector Heights
7.5
7.4
7.3
7.2
7.1
7
Maximum Gain in dBi
0.001 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04 0.045 0.05 0.055 0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 9

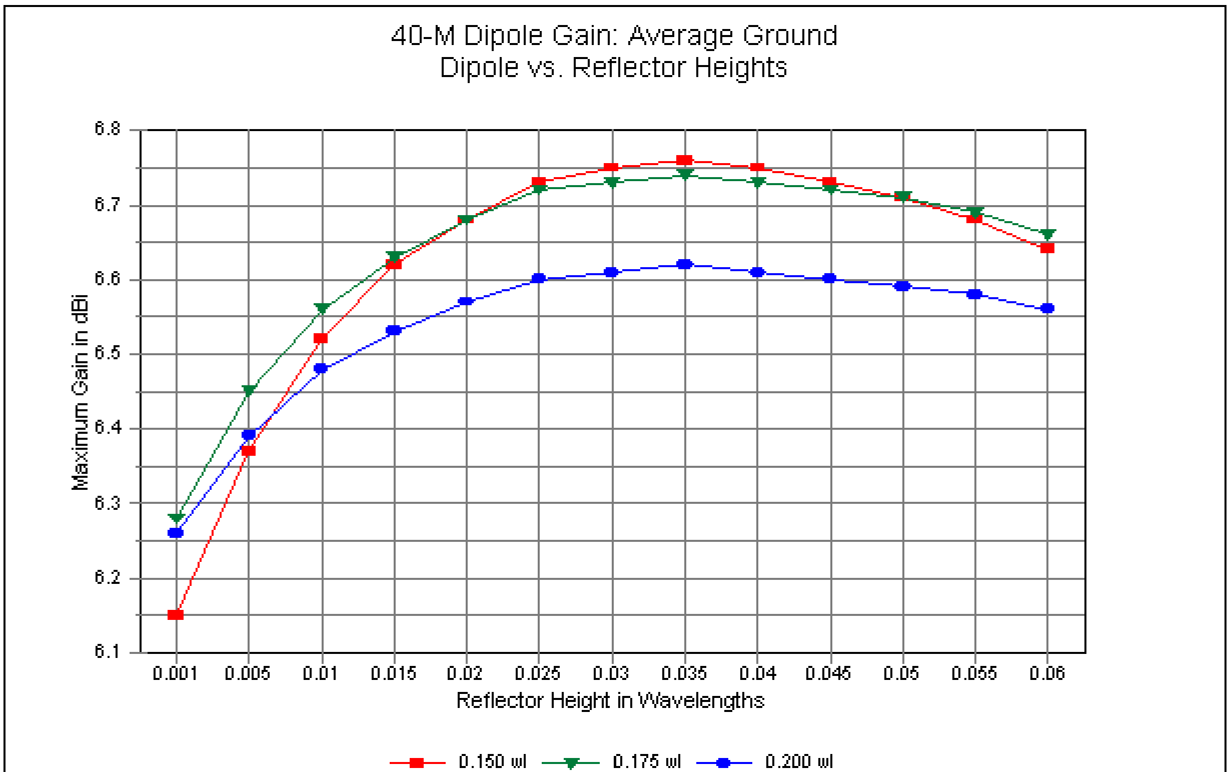

40-M Dipole Gain: Average Ground
Dipole vs. Reflector Heights
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
Maximum Gain in dBi
0.001 0.005 0.01 0.015 0.02 0.025 0.03 0.035 0.04 0.045 0.05 0.055 0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 10

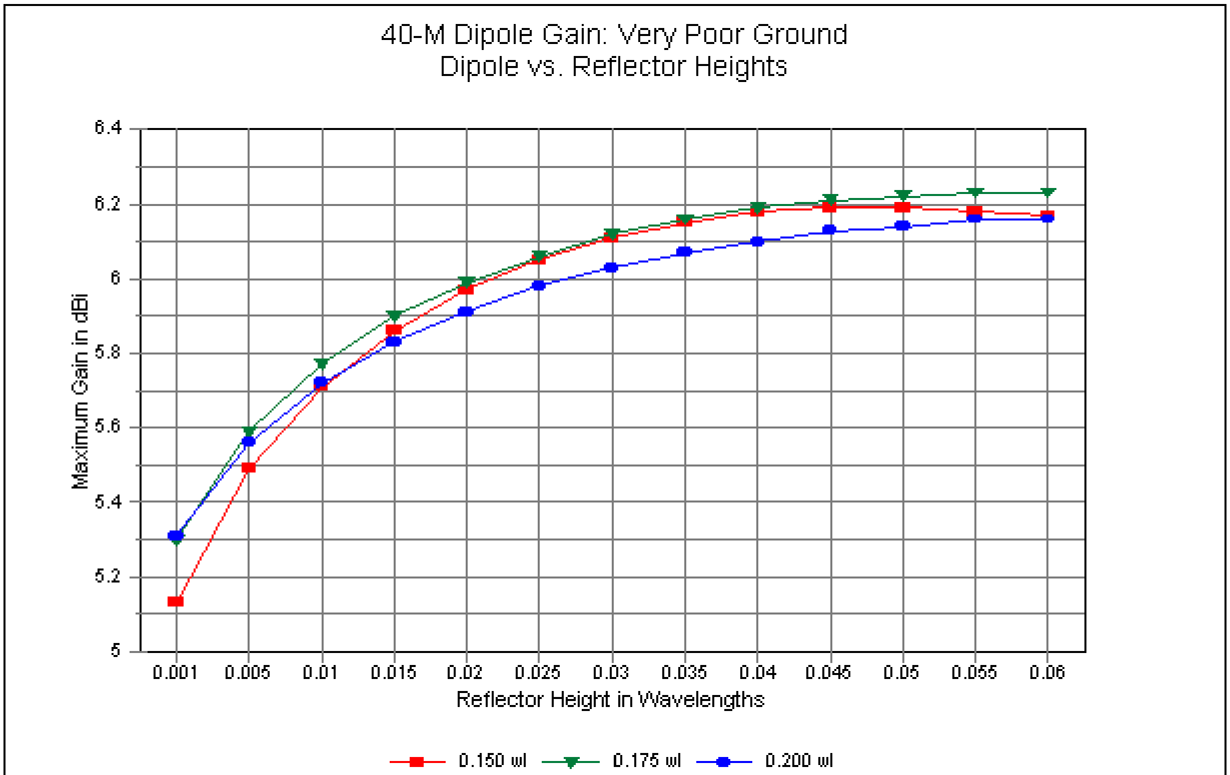


Fig. 11

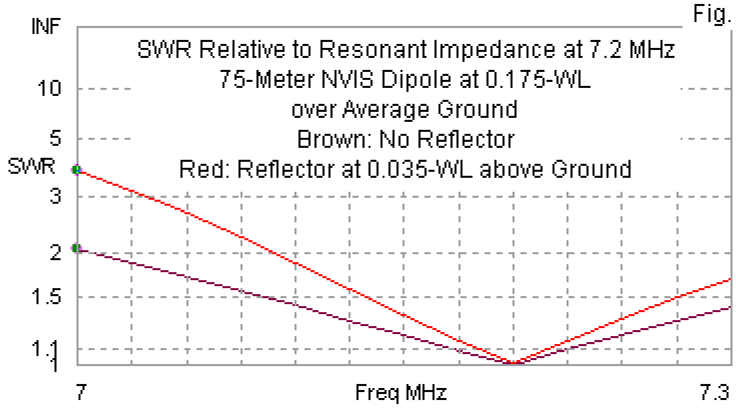
The graphs in **Fig. 9** through **Fig. 11** catalog the tabular differences by separating soil types. In each graph, we have individual lines for each dipole height. Hence, we can directly compare these 40-meter graphs to those in **Fig. 5** through **Fig. 7** for 75 meters. In the main, we find the same data trends at work for each soil type, but with variations. For example, over very poor soil, the lines for each dipole height are closer together than in the corresponding 75-meter graph. Nevertheless, the overall gain ranges for each chart show no overlap from one soil quality to the next.

Like the 75-meter reflector heights that yield maximum zenith gain, the 40-meter reflector heights over very good and average soil show only a small range, regardless of the dipole height. However, on 40 meters, the ranges are slightly higher: 0.015-λ to 0.02-λ over very good soil and 0.03-λ to 0.035-λ over average soil. Over very poor soil, the ranges are also higher on 40 meters than on 75 meters, reaching 0.06-λ for dipole heights from 0.175-λ to 0.2-λ. In all cases, we find a change in the spacing from the dipole to the reflector as we change the soil quality.

One interesting, although perhaps small difference between the 75-meter and the 40-meter systems is the net improvement created by adding a reflector to the dipole over all soil qualities. The improvement is a bit better on 40 meters. This fact is consistent with the increased ground losses that we find on 40 meters relative to 75 meters. As a result, the reflector helps a bit more on the upper band. Whether the slightly higher improvement offered, for example, over average soil warrants a reflector on the upper band is a user judgment.

The 40-meter dipole-reflector arrays are just as tuned a set of systems as they are on 75 meters. Therefore, we also find a narrower operating bandwidth (measured here in terms of SWR relative to the resonant impedance of the individual antennas). **Fig. 12** provides a comparison of a solitary dipole and a dipole-reflector array. Both dipoles are at 0.175-λ, while the reflector is at 0.03-λ above ground. By a simple adjustment of the element lengths, one can better center the SWR curves within the band. However, for our purposes, the comparison of the two curves is sufficient.

Fig. 12



At this point, we can see the relatively close parallel behavior between the two dipole-reflector arrays despite their frequency differences. In both cases, adding a reflector to a dipole over very good soil makes little sense, while adding one over very poor soil may be justified if an additional dB or more of zenith gain will enhance operations. Average soil on both bands presents a case in the margins.

We have two directions in which we might now go. One involves the question of whether there are any reflector systems that might bring about better results than a parasitic array, considering both gain and operating bandwidth. A subsidiary question will focus on whether such systems can materially improve antenna performance over very good and average soil as well as over very poor soil.

The second direction involves our alternative level antenna, the 1-λ loop. To what degree loops follow or depart from the trends established by the dipole arrays is a significant inquiry, since we found a close correlation between the heights of maximum zenith gain for both dipoles and loops. Because any differences might impact the investigation of alternative reflector systems, we likely should turn down the loop road first.

The 1-λ Loop and a Parasitic Reflector

The 1-λ loop inherently has more gain than a ½-λ dipole. Its advantages for NVIS operation lie both in the gain and the greater circularity of its upward radiation patterns. As we saw in the study of the loop alone, the gain advantage of the loop tends to be about 0.6 dB (on average) over the dipole. Adding a reflector to the NVIS loop is simply a matter of creating a second loop below the first. Like the 2-element dipole parasitic array, the loop array requires a larger reflector loop circumference relative to the driven loop circumference.

The loop presents essentially the same open question as the dipole. To what degree does soil quality play a role in the final array zenith gain and in the placement and size of the reflector loop? **Fig. 13** outlines the loop situation. As with the dipole, we shall sort possible loop reflector heights from the ground upward and add special notes the show the optimal separation of the loop at its best height for each ground quality.

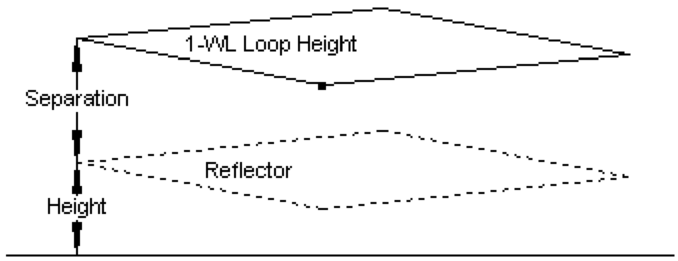


Fig. 13

NVIS 1-WL Loop + Reflector Variables

We may shorten the data gathering by omitting some of the improbable lower reflector heights from the survey, although we shall retain an entry for 0.001-λ above ground to reinforce the relative futility of trying to improve NVIS performance with essentially a trip wire. As well, we may reduce the number of graphs to one per band per ground quality to capture of trends in performance. As with the dipoles, we shall track data with driven loop heights of 0.15-λ, 0.175-λ, and 0.2-λ to surround in finite steps the region of highest gain of the loop over all soil types.

Table 3 provides the data applicable to loops with reflectors for 75 meters, again using 3.9 MHz as the test frequency. **Fig. 14** through **Fig. 16** graph the performance over very good, average, and very poor soil. Perhaps the most notable feature of adding parasitic reflectors to NVIS loops is the fact that the optimal reflector heights employ only a very small range for all ground qualities: from 0.02-λ (for very good soil) up to 0.04-λ (for very poor soil). Since the reflector heights change very little with driven loop height, the separation values vary a lot.

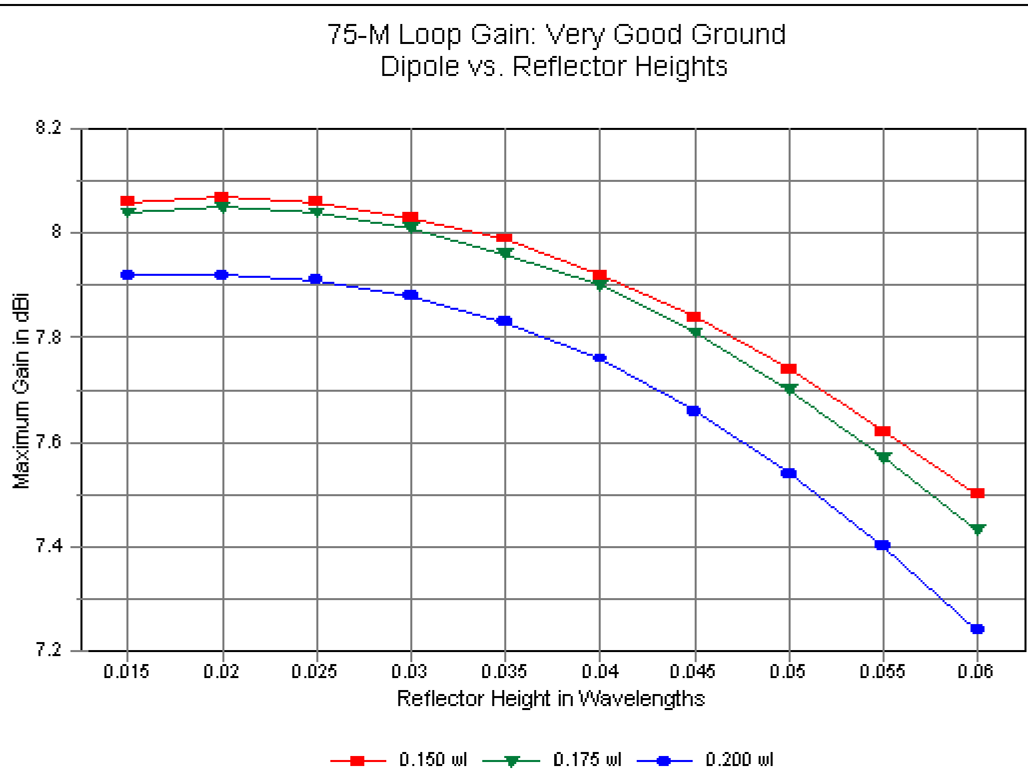


Fig. 14

NVIS 3.9-MHz 1-WL Loop with a Single-Wire Loop Reflector Element									Table 3
Driver: 1.0176-wl AWG #14 Copper Wire				Reflector: 1.0248-wl AWG #14 Copper Wire					
Loop Height		0.15	wl	37.83	feet				
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.	
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl	
No Reflector		7.92	82.9	6.85	86.5	5.51	93.4		
0.001	0.25	7.97	83.2	7.01	86.8	5.90	92.8		
0.015	3.78	8.06	83.3	7.26	86.6	6.42	91.8		
0.02	5.04	**8.07**	83.2	7.30	86.7	6.50	91.6	0.130	Vry Gd
0.025	6.30	8.06	83.4	**7.33**	86.6	6.55	91.5	0.125	Ave
0.03	7.57	8.03	83.5	**7.33**	86.9	6.59	91.4	0.120	Ave
0.035	8.83	7.99	83.6	7.32	86.9	**6.60**	91.4	0.115	Vry Pr
0.04	10.09	7.92	83.8	7.28	87.1	6.58	91.4		
0.045	11.35	7.84	84.0	7.23	87.1	6.54	91.3		
0.05	12.61	7.74	84.0	7.15	87.2	6.49	91.2		
0.055	13.87	7.62	84.3	7.05	87.3	6.41	91.2		
0.06	15.13	7.50	84.4	6.93	87.6	6.32	91.1		
Max. Delta Gain		*0.15*		*0.48*		*1.09*			
Loop Height		0.175	wl	44.13	feet				
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.	
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl	
No Reflector		7.95	86.1	7.02	90.3	5.78	97.6		
0.001	0.25	7.98	86.4	7.13	90.3	6.08	97.0		
0.015	3.78	8.04	86.5	7.33	90.2	6.53	95.7		
0.02	5.04	**8.05**	86.5	7.37	90.2	6.60	95.5	0.155	Vry Gd
0.025	6.30	8.04	86.6	**7.39**	90.2	6.66	95.3	0.150	Ave
0.03	7.57	8.01	86.9	**7.39**	90.4	6.70	95.2	0.145	Ave
0.035	8.83	7.96	87.1	7.38	90.5	**6.71**	95.2	0.140	Vry Pr
0.04	10.09	7.90	87.3	7.35	90.7	6.70	95.1		
0.045	11.35	7.81	87.6	7.29	90.9	6.67	95.1		
0.05	12.61	7.70	88.0	7.21	91.2	6.62	95.1		
0.055	13.87	7.57	88.4	7.12	91.4	6.56	95.1		
0.06	15.13	7.43	88.7	7.00	91.8	6.48	95.2		
Max. Delta Gain		*0.10*		*0.37*		*0.93*			
Loop Height		0.2	wl	50.44	feet				
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.	
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl	
No Reflector		7.86	90.2	7.02	95.0	5.85	102.9		
0.001	0.25	7.87	90.6	7.10	95.1	6.11	102.1		
0.015	3.78	**7.92**	90.6	7.27	94.7	6.50	100.6	0.185	Vry Gd
0.02	5.04	**7.92**	90.7	7.30	94.7	6.58	100.1	0.180	Vry Gd
0.025	6.30	7.91	90.9	**7.32**	94.8	6.63	99.9	0.175	Ave
0.03	7.57	7.88	91.1	**7.32**	94.9	6.67	99.8	0.170	Ave
0.035	8.83	7.83	91.3	7.30	95.1	**6.68**	99.8	0.165	Vry Pr
0.04	10.09	7.76	91.7	7.27	95.3	**6.68**	99.5	0.160	Vry Pr
0.045	11.35	7.66	92.3	7.21	95.7	6.65	99.6		
0.05	12.61	7.54	92.8	7.13	96.0	6.60	99.7		
0.055	13.87	7.40	93.5	7.03	96.4	6.54	99.8		
0.06	15.13	7.24	94.1	6.91	97.0	6.47	100.0		
Max. Delta Gain		*0.06*		*0.30*		*0.83*			

The gain benefits of a reflector follow the dipole pattern: over very good soil, added gain is minimal. Even over average soil, the maximum gain addition is under a half dB. Over very poor soil, the reflector may add up to 1 dB of gain, depending upon the driven loop height.

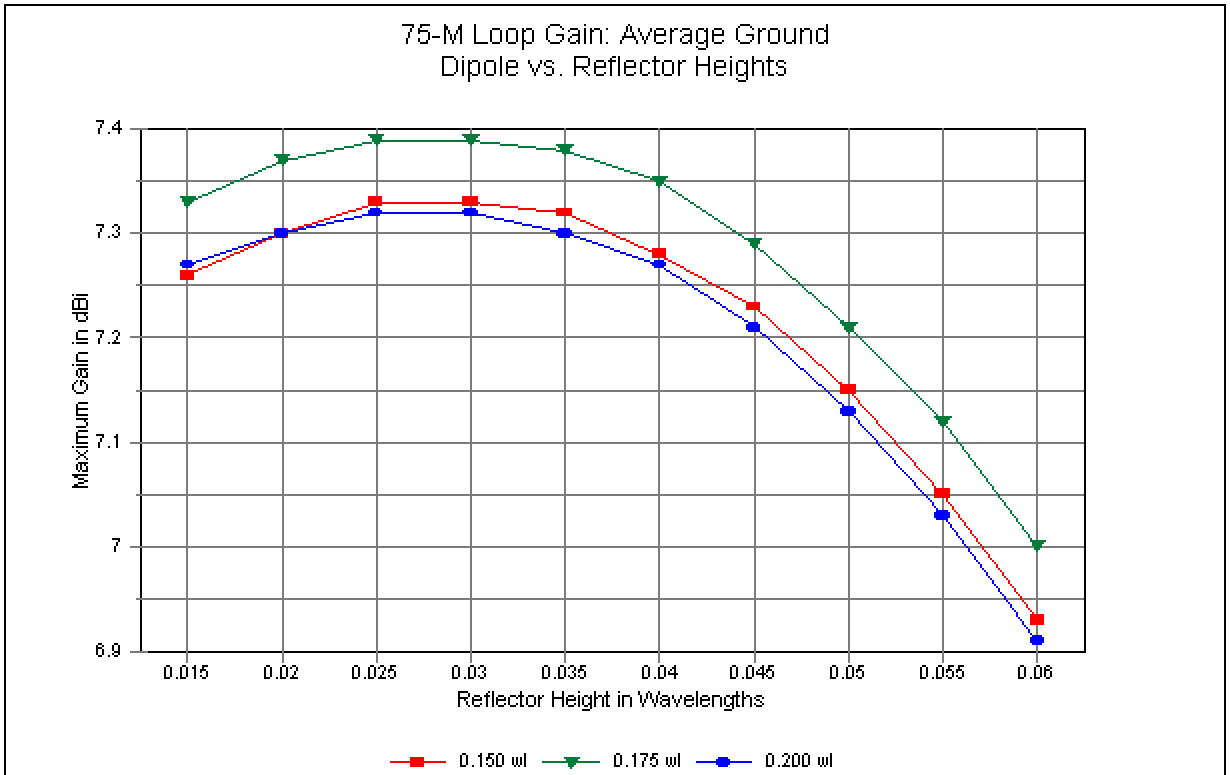

75-M Loop Gain: Average Ground
Dipole vs. Reflector Heights
Maximum Gain in dBi
7.4
7.3
7.2
7.1
7
6.9
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 15

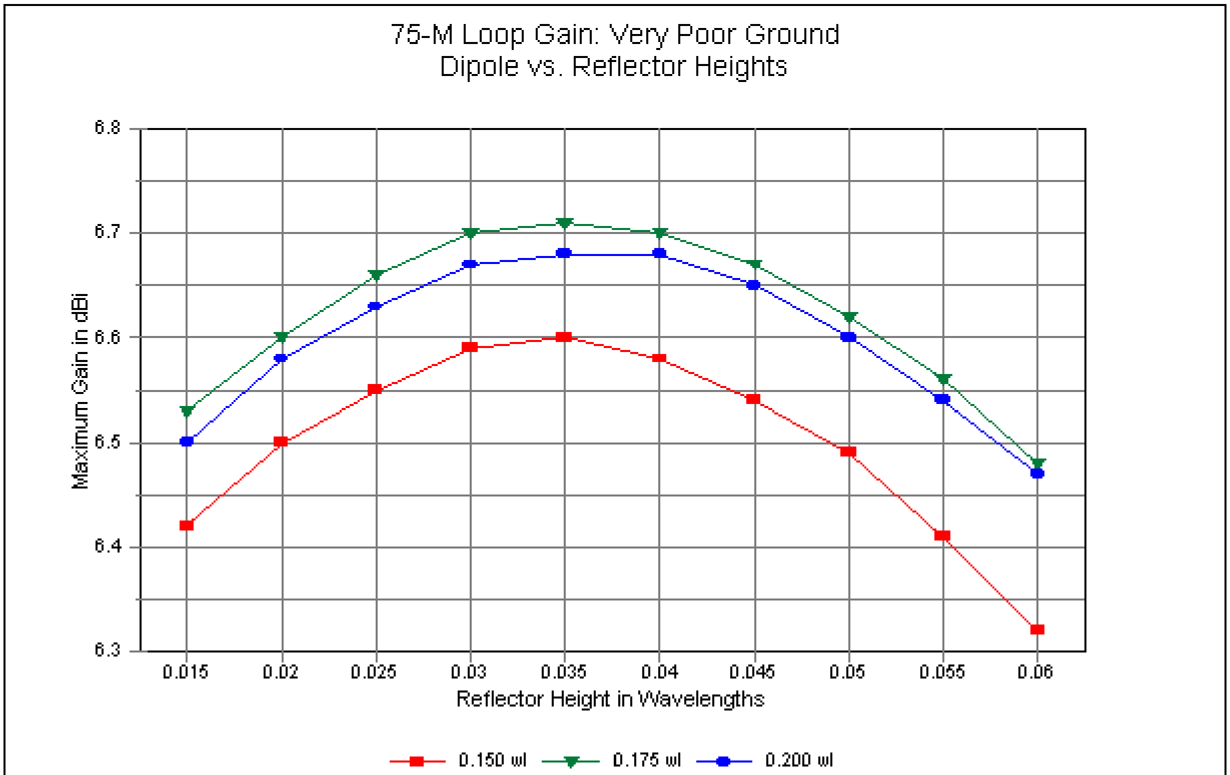

75-M Loop Gain: Very Poor Ground
Dipole vs. Reflector Heights
Maximum Gain in dBi
6.8
6.7
6.6
6.5
6.4
6.3
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 16

Similarly to the dipole-reflector combination, the loop-reflector combination results in a narrowing of the operating bandwidth compared to a loop without supplement. **Fig. 17** overlays SWR curves relative to the resonant impedance values for a loop by itself and for a loop with a reflector when both driver loops are at 0.175-λ above ground. The sample case uses a reflector that is 0.03-λ above ground, about optimal for the antenna height over average ground.

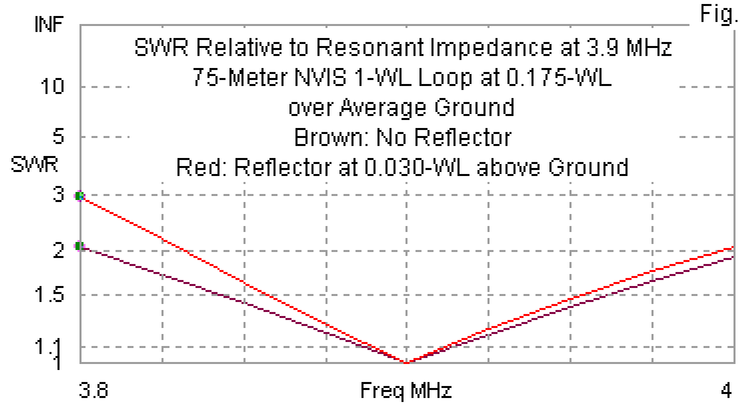


Fig. 17

On 40 meters, we find the same parallels with the dipole cases, as modified by the narrower range of optimal reflector heights that we found with the 75-meter loops. **Table 4** provides the numerical information. **Fig. 18** through **Fig. 20** graph the gain data for each antenna height over each of the soil qualities. The 40 meter gain values are universally slightly less than those for 75-meters. As well, we find some differences in other details of array behavior.

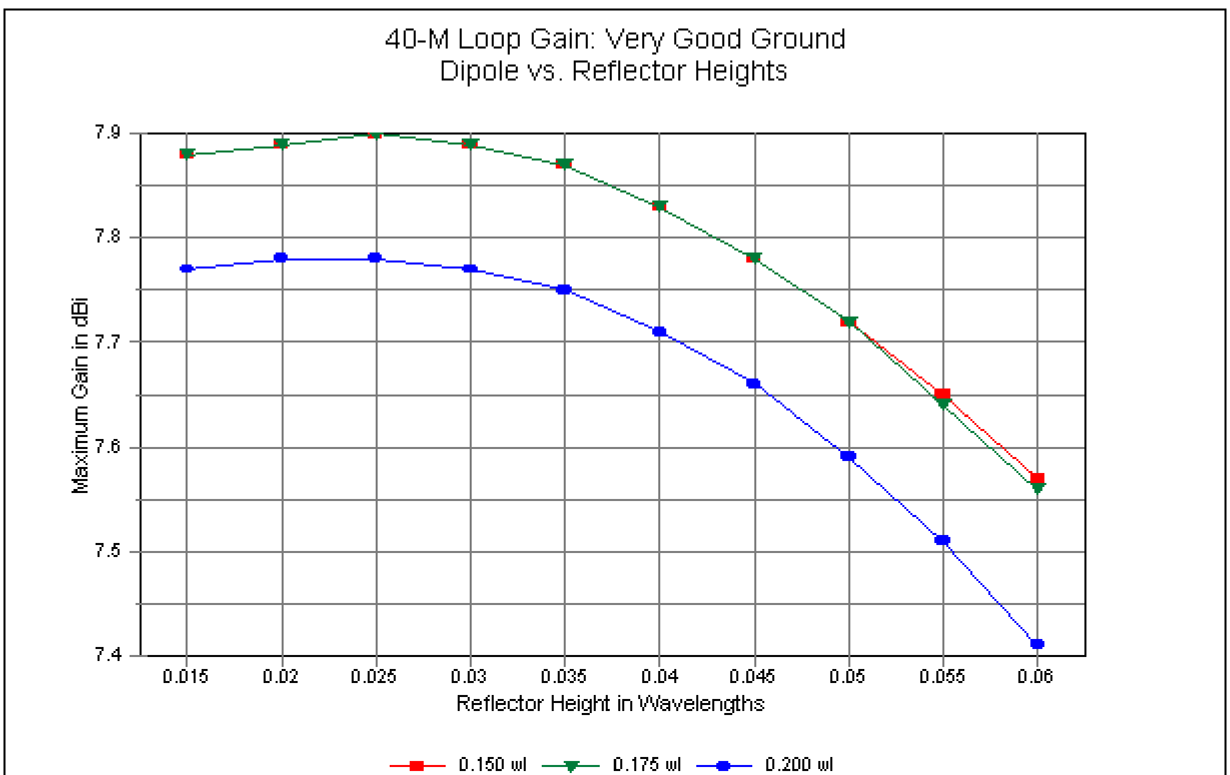


Fig. 18

NVIS 7.2-MHz 1-WL Loop with a Single-Wire Loop Reflector Element									Table 4
Driver: 1.0184-wl AWG #14 Copper Wire				Reflector: 1.0296-wl AWG #14 Copper Wire					
Loop Height		0.15	wl	21.48	feet				
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.	
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl	
No Reflector		7.68	83.7	6.48	87.6	5.21	93.7		
0.001	0.14	7.75	84.0	6.68	87.8	5.65	93.3		
0.015	2.15	7.88	84.1	7.00	87.5	6.29	91.7		
0.02	2.86	7.89	84.2	7.06	87.4	6.41	91.4		
0.025	3.58	**7.90**	84.2	7.10	87.4	6.49	91.2	0.125	Vry Gd
0.03	4.30	7.89	84.3	**7.13**	87.4	6.56	90.9	0.120	Ave
0.035	5.01	7.87	84.3	**7.13**	87.4	6.60	90.6	0.115	Ave
0.04	5.73	7.83	84.5	7.12	87.5	**6.61**	90.6	0.110	Vry Pr
0.045	6.44	7.78	84.5	7.09	87.5	6.60	90.4		
0.05	7.16	7.72	84.7	7.05	87.5	6.57	90.3		
0.055	7.87	7.65	84.7	6.98	87.6	6.53	90.1		
0.06	8.59	7.57	84.8	6.91	87.5	6.47	89.9		
Max. Delta Gain		*0.22*		*0.65*		*1.40*			
Loop Height		0.175	wl	25.05	feet				
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.	
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl	
No Reflector		7.74	87.0	6.71	91.4	5.51	97.9		
0.001	0.14	7.78	87.3	6.84	91.5	5.87	97.1		
0.015	2.15	7.88	87.4	7.10	91.1	6.44	95.3		
0.02	2.86	7.89	87.6	7.16	90.9	6.55	94.8		
0.025	3.58	**7.90**	87.6	7.20	90.9	6.64	94.5	0.150	Vry Gd
0.03	4.30	7.89	87.7	7.23	90.9	6.71	94.3		
0.035	5.01	7.87	87.9	**7.24**	91.0	6.75	94.0	0.140	Ave
0.04	5.73	7.83	88.1	7.23	91.1	**6.77**	93.8	0.135	Vry Pr
0.045	6.44	7.78	88.3	7.21	91.1	**6.77**	93.7	0.130	Vry Pr
0.05	7.16	7.72	88.5	7.17	91.3	6.76	93.5		
0.055	7.87	7.64	88.7	7.11	91.4	6.73	93.5		
0.06	8.59	7.56	89.0	7.05	91.4	6.69	93.4		
Max. Delta Gain		*0.16*		*0.53*		*1.26*			
Loop Height		0.2	wl	28.63	feet				
		Very Good Soil		Average Soil		Very Poor Soil		Refl. Sep.	
Ref Ht wl	Ref Ht ft	Gain dBi	BS BW	Gain dBi	BS BW	Gain dBi	BS BW	wl	
No Reflector		7.67	91.3	6.75	96.1	5.64	102.8		
0.001	0.14	7.69	91.7	6.85	96.1	5.93	101.9		
0.015	2.15	7.77	91.7	7.07	95.6	6.45	99.7		
0.02	2.86	**7.78**	91.8	7.12	95.5	6.56	99.2	0.180	Vry Gd
0.025	3.58	**7.78**	91.9	7.16	95.5	6.64	98.9	0.175	Vry Gd
0.03	4.30	7.77	92.2	7.19	95.3	6.71	98.5		
0.035	5.01	7.75	92.2	**7.20**	95.4	6.75	98.2	0.165	Ave
0.04	5.73	7.71	92.6	7.19	95.4	**6.78**	97.8	0.160	Vry Pr
0.045	6.44	7.66	92.7	7.17	95.6	**6.78**	97.8	0.155	Vry Pr
0.05	7.16	7.59	93.1	7.13	95.7	6.77	97.7		
0.055	7.87	7.51	93.5	7.07	96.0	6.75	97.5		
0.06	8.59	7.41	94.0	7.00	96.3	6.71	97.4		
Max. Delta Gain		*0.11*		*0.44*		*1.11*			

If you compare **Fig. 14** with **Fig. 18**, you can see that over very good soil, the gain level at the two lower heights on 40 meters result in overlapping lines, rather than separate lines. Similarly, over very poor soil, the 40-meter lines for the two higher levels overlap, whereas on 75 meters, they are separate. Compare **Fig. 16** with **Fig. 20**.

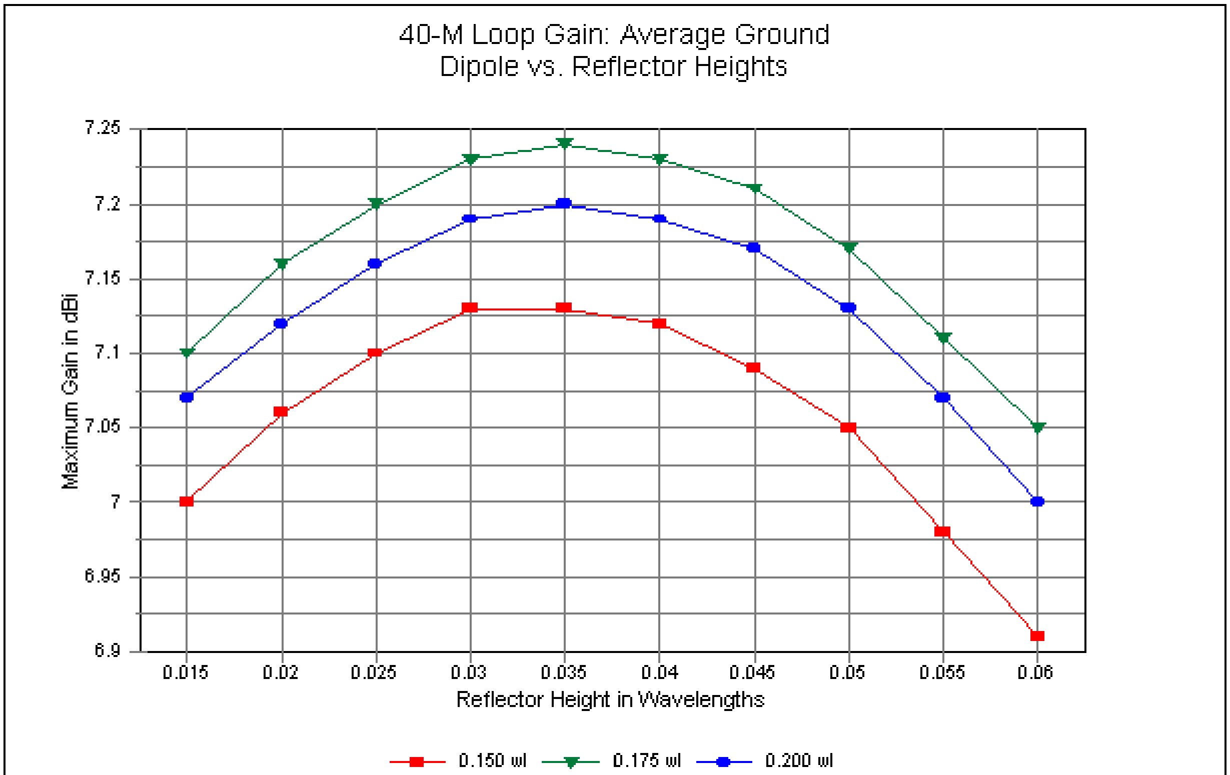

40-M Loop Gain: Average Ground
Dipole vs. Reflector Heights
Maximum Gain in dBi
7.25
7.2
7.15
7.1
7.05
7
6.95
6.9
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 19

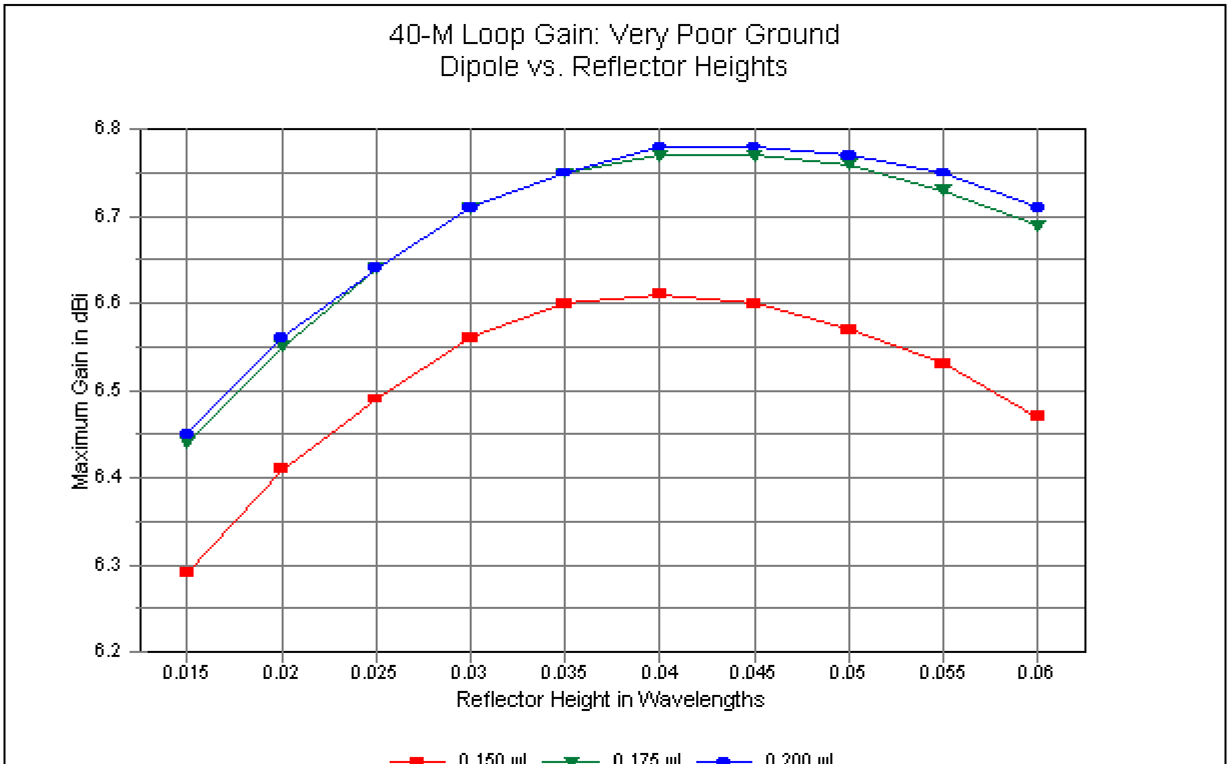
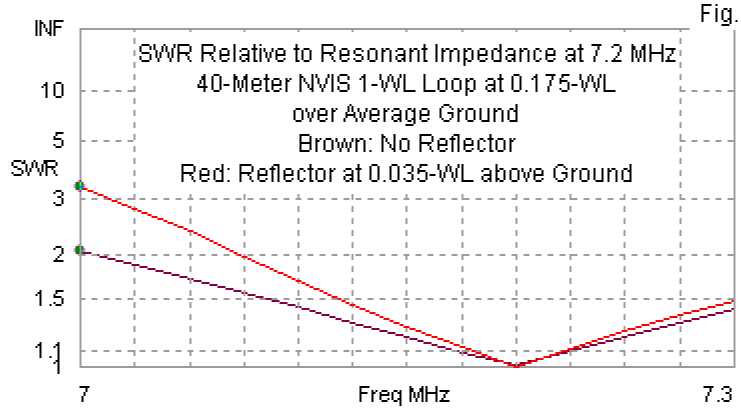

40-M Loop Gain: Very Poor Ground
Dipole vs. Reflector Heights
Maximum Gain in dBi
6.8
6.7
6.6
6.5
6.4
6.3
6.2
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Reflector Height in Wavelengths
0.150 wl
0.175 wl
0.200 wl

Fig. 20

Nevertheless, the loop-reflector combinations for both bands are consistent with each other and in the main are consistent with results for the dipole-reflector combinations. The consistency extends to the reduction in operating bandwidth on 40 meters, as shown in the SWR curves in **Fig. 21**. The addition of the reflector at an optimal height (0.035-λ) for average soil and a loop at 0.175-λ results in a significant reduction in the bandwidth. With respect to gain increase, on 40 meters, the use of a reflector is questionable over very good soil, marginal over average soil, and possibly productive over very poor soil.

Fig. 21



As noted with respect to dipoles, the use of a parasitic reflector with a driven element creates a tuned system, although not fully isolated from ground effects. Besides limiting the operating bandwidth, the tuned system also tends to reduce the resonant impedance relative to a loop without a reflector. However, the parasitic reflector element is not the only method of improving NVIS performance.

Dipoles, Loops, and Planar Reflectors

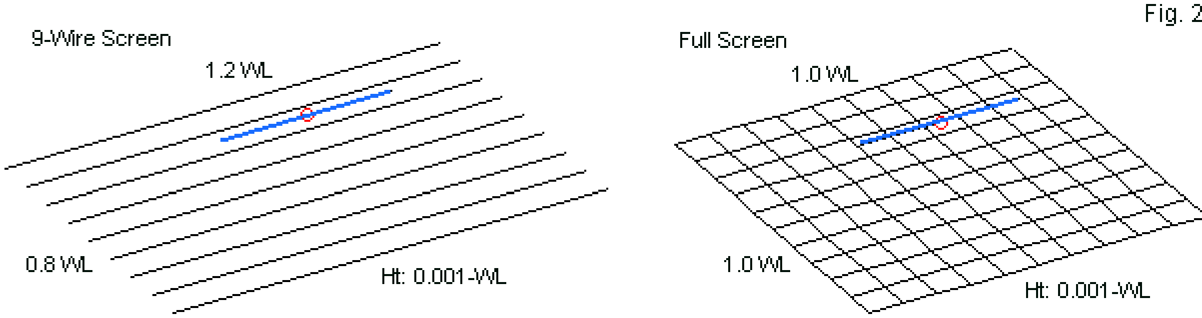
An alternative method of provide improved reflection of energy upward relative to reflections from the bare ground is the use of a planar reflector. In other applications, HF planar reflectors go under a variety of names, including screens, curtain, and billboards. A planar reflector operates according to principles largely derived from optics. In general, the reflections from an essentially flat conductive surface depend upon the size of the planar reflector and its distance from the driven element—in this case, either a dipole or a 1-λ loop. Although it is possible to elevate a planar reflector closer to the driven element to optimize performance, we cannot simply reduce the height of the driven element toward a ground-level reflector. The far-field gain is a function not only of the area covered by the reflector, but depends on the region several wavelengths away from the reflector. As a result, we shall only be able to obtain benefits that result from a practical ground-level reflector and an elevated driver.

As the best compromise among all possibilities, I have placed the driver at 0.175-λ above all ground qualities. Very good soil would prefer a slightly lower height, while very poor soil prefers a slightly greater height. However, to achieve some consistency within the results of systematic modeling, a common height is best.

The dimensions of an optimal planar reflector vary according to the method used to construct it. In these notes, we shall consider two forms of planar reflectors, as illustrated by **Fig. 22**. The simpler reflector consists of at least 9 wires (using the same diameter wire as the driven element) spread to cover an area at least 0.4-0.5-λ beyond each limit of the antenna.

The sample array, which yields the best performance at ground level, is 1.2-λ in the direction of the wires and 0.8-λ broadside to the antenna. One might add additional wires within the field.

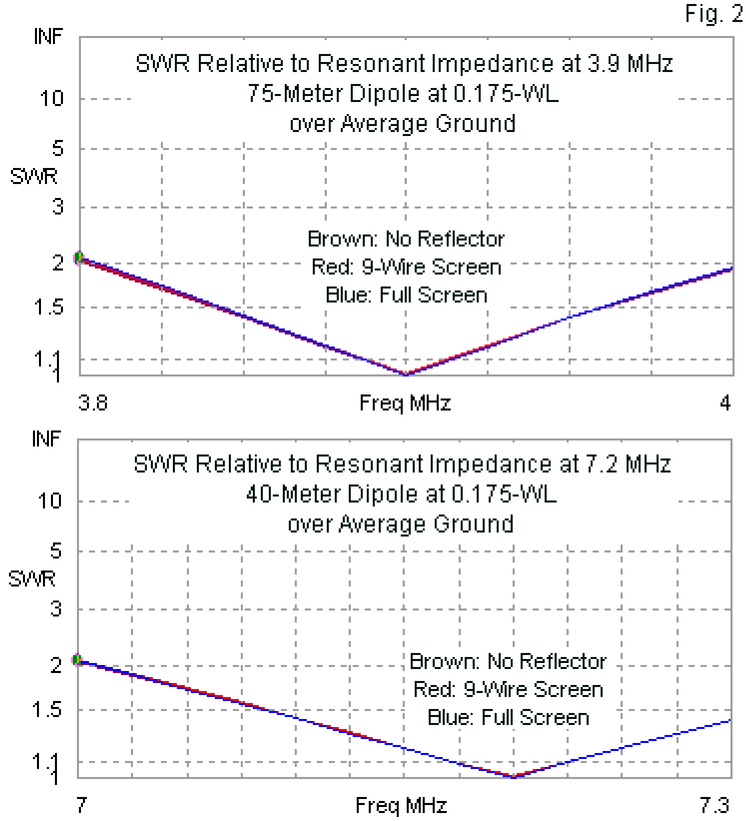
Fig. 22



NVIS Dipole and Planar Reflectors

As an alternative, one might cover the ground with conductive screening with holes smaller than 0.05-λ. In this case, a full screen that is 1.0-λ by 1.0-λ proved to be the most effective version. The modeled screen has twice as many wires as shown in the sketch, although to add them would have made it impossible to find the dipole above them.

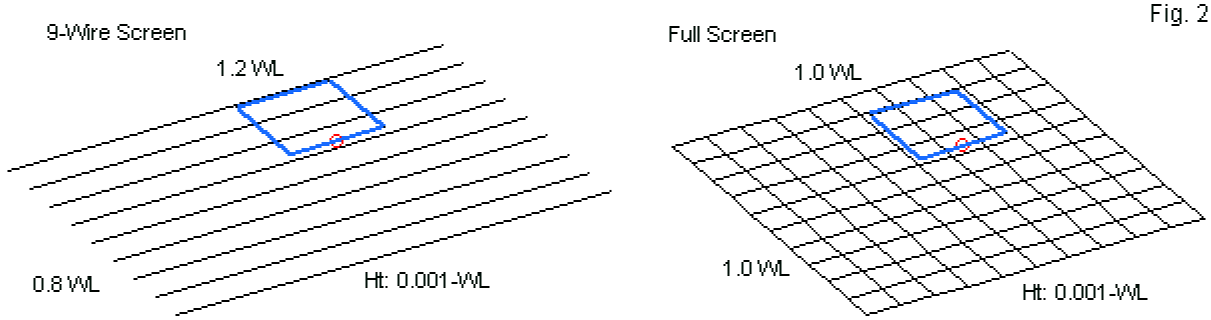
Fig. 23



One advantage of the planar reflector in either form is that it does not alter the impedance or the operating bandwidth of the driven element above it. **Fig. 23** provides the SWR curves for both types of reflector overlaid on the SWR curve for the dipole alone for both 75 and 40 meters. With or without the planar reflector, the curves are essentially identical.

We obtain similar properties is we place either type of planar reflector at ground level beneath a 1-λ loop, as suggested by the sketches in **Fig. 24**. The same 9-wire and full screen reflectors used with the dipole also serve the loop very well. Like the dipole, the loops are at 0.175-λ above all ground types to ease the problem of performance comparison.

Fig. 24



NVIS 1-Wavelength Loop and Planar Reflectors

Also like the dipole with a planar reflector, the loop-planar-reflector combination results in an operating bandwidth essentially identical to the bandwidth of a loop alone. **Fig. 25** provides SWR curves for loop-reflector combinations for 75- and 40 meters, with the loop-along curve superimposed. Separating the curves visually is virtually impossible.

Fig. 25

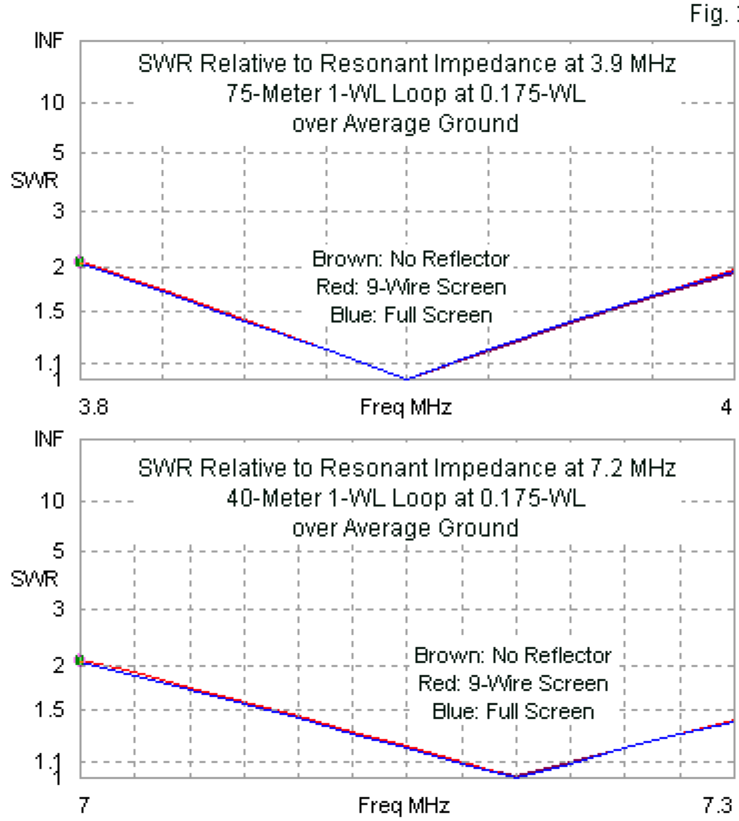


Table 5 provides data on the planar reflectors for both dipoles (on the left) and loops (on the right). However, it also includes data for isolated NVIS antennas and for antenna-reflector

combinations using the same set of limiting constraints. In all cases, the driven antenna is 0.175-λ above ground. The table indicates the antenna dimensions and, where relevant, the reflector dimensions. For dipoles, the element dimensions are linear lengths, while for loops, they are circumference values. The arrays are sized for resonance over average ground, and the changes of impedance for very good and very poor soil are indicators of stability. For example, the arrays with parasitic reflectors show the least change with changes in soil quality, which is consistent with one role of a parasitic reflector, namely, to control the driver feedpoint impedance.

Summary Comparisons of Basic NVIS Antennas										Table 5
75 Meters (3.9 MHz)										
	Dipole: 0.4804-wl					1-WL Loop: 1.0248-wl				
Ground	Max Gain	BS BW	EW BW	Feed R	Feed X	Max Gain	BS BW	EW BW	Feed R	Feed X
Vy Good	7.38	107.5	66.2	62.48	7.82	7.95	86.1	69.8	120.00	15.05
Average	6.40	113.0	66.4	67.55	0.66	7.02	90.3	70.2	128.20	-0.64
Vy Poor	5.06	122.4	67.2	71.66	-9.55	5.78	97.6	71.2	132.80	-23.87
	Dipole + Reflector: 0.4794-wl + 0.5-wl @ 0.25-wl					Loop + Reflector: 1.0176-wl + 1.0248-wl @ 0.03-wl				
Vy Good	7.48	108.6	66.2	51.27	2.40	8.01	86.9	70.2	104.60	3.59
Average	6.88	113.6	66.4	52.79	0.21	7.39	90.4	70.8	108.10	-0.54
Vy Poor	6.11	120.8	66.8	52.62	-2.25	6.70	95.2	71.6	107.00	-0.39
	Dipole + 9-Wires: 0.4798-wl + 1.2-wl BS x 0.8-wl EW					Loop + 9-Wires: 1.024-wl + 1.2-wl BS x 0.8-wl EW				
Vy Good	7.58	106.2	64.3	62.15	5.55	8.16	85.3	67.2	119.60	11.82
Average	7.15	108.2	62.2	66.46	0.24	7.79	87.2	64.7	126.00	-0.38
Vy Poor	6.74	111.0	60.6	72.41	-4.91	7.40	89.1	62.6	135.60	-13.26
	Dipole + Screen: 0.4776 + 1.0-wl x 1.0-wl					Loop + Screen: 1.0192-wl + 1.0-wl x 1.0-wl				
Vy Good	7.79	104.8	65.8	59.78	-0.04	8.33	84.5	69.2	115.50	1.43
Average	7.74	103.0	65.0	63.06	-0.20	8.26	83.5	68.2	121.70	0.28
Vy Poor	7.88	98.8	63.4	65.51	0.42	8.38	80.7	65.9	126.60	0.60
40 Meters (7.2 MHz)										
	Dipole: 0.4800-wl					1-WL Loop: 1.0248-wl				
Ground	Max Gain	BS BW	EW BW	Feed R	Feed X	Max Gain	BS BW	EW BW	Feed R	Feed X
Vy Good	7.15	108.8	66.2	63.86	8.98	7.74	87.0	69.8	123.10	19.63
Average	6.03	114.8	66.0	67.28	0.26	6.71	91.4	69.6	127.30	0.84
Vy Poor	4.71	123.3	66.8	69.99	-9.21	5.51	97.9	70.6	128.50	-20.72
	Dipole + Reflector: 0.4786-wl + 0.5-wl @ 0.35-wl					Loop + Reflector: 1.0184-wl + 1.0296-wl @ 0.035-wl				
Vy Good	7.31	110.8	66.6	45.94	1.95	7.87	87.9	70.6	102.30	3.19
Average	6.74	115.2	66.2	46.62	0.26	7.24	91.0	70.8	104.60	0.36
Vy Poor	6.16	120.8	66.4	45.83	-1.38	6.75	94.0	71.4	101.80	-4.73
	Dipole + 9-Wires: 0.4790-wl + 1.2-wl BS x 0.8-wl EW					Loop + 9-Wires: 1.0272-wl + 1.2-wl BS x 0.8-wl EW				
Vy Good	7.53	106.8	63.5	62.62	5.84	8.15	85.6	66.2	120.40	12.23
Average	7.02	109.0	61.8	66.66	0.19	7.69	87.4	64.2	126.10	-0.47
Vy Poor	6.74	109.6	59.8	72.40	-4.47	7.41	88.2	61.7	135.30	-12.45
	Dipole + Screen: 0.4762 + 1.0-wl x 1.0-wl					Loop + Screen: 1.0212-wl + 1.0-wl x 1.0-wl				
Vy Good	7.78	104.6	65.6	60.21	-0.08	8.33	84.2	69.0	116.80	1.81
Average	7.79	101.8	64.4	63.31	-0.36	8.32	82.4	67.4	122.70	0.37
Vy Poor	7.98	96.6	62.7	65.34	0.34	8.48	79.6	65.0	126.90	0.90
Notes:	All dipoles and 1-wl loops at 0.175-wl above ground									
	Dipole dimensions are linear lengths; loop dimensions are circumferences									
	Max. Gain = maximum zenith gain in dBi									
	BS BW; EW BW = broadside and endwise beamwidths in degrees									
	Feed R; Feed X = feedpoint resistance and reactance in Ohms									

Reading from left to right provides a guide to the gain advantage in all cases of the 1-λ loop over the dipole, whether alone or in the surveyed arrays. Reading within an array type summarizes the gain change with soil quality. Reading from one group to the next provides a guide to the increasing gain advantage offered by successively more effective arrays. The table includes broadside and endwise beamwidth values to allow estimates of pattern circularity.

The entries for the full screen planar reflector may seem odd at first sight. For all preceding arrays, we find that very good soil yields the highest zenith gain. However, with a full screen, using either a dipole or a loop, the highest gain occurs over very poor soil. The difference is not operationally significant within each full screen group, but the phenomenon is interesting. Only the full screen provides sufficient coverage to isolate the antenna from the ground to the degree that very poor soil approaches the quality of free space. Even the 9-wire screen has ground losses between wires, losses that one can reduce by increasing the reflector wire diameter or by increasing the number of wires—or both.

Measured against the performance benefits of a 1-λ-by-1-λ full ground screen must be the site preparation difficulties, factors that lie beyond the scope of these notes. However, to focus more clearly on the potential gain benefits, **Table 6** provides a summary view. Even though the exercise does not place single-element reflectors at their optimum heights for very good and very poor soil, the maximum improvement in the gain values for those cases would be about 0.05 dB.

Gain Comparisons by Ground Quality and Supplements						Table 6
75-M	Very Good		Average		Very Poor	
Dipoles	Zen Gain	Change	Zen Gain	Change	Zen Gain	Change
Dp	7.38	-----	6.40	-----	5.06	-----
Dp+Ref	7.48	0.10	6.88	0.48	6.11	1.05
Dp+9W	7.58	0.20	7.15	0.75	6.74	1.68
Dp+Scr	7.79	*0.41*	7.74	*1.34*	7.88	*2.82*
Loops	Zen Gain	Change	Zen Gain	Change	Zen Gain	Change
Loop	7.95	-----	7.02	-----	5.78	-----
Lp+Ref	8.01	0.06	7.39	0.37	6.70	0.92
Lp+9W	8.16	0.21	7.79	0.77	7.40	1.62
Lp+Scr	8.33	*0.38*	8.26	*1.24*	8.38	*2.60*
40-M	Very Good		Average		Very Poor	
Dipoles	Zen Gain	Change	Zen Gain	Change	Zen Gain	Change
Dp	7.15	-----	6.03	-----	4.71	-----
Dp+Ref	7.31	0.16	6.74	0.71	6.16	1.45
Dp+9W	7.53	0.38	7.02	0.99	6.74	2.03
Dp+Scr	7.78	*0.63*	7.79	*1.76*	7.98	*3.27*
Loops	Zen Gain	Change	Zen Gain	Change	Zen Gain	Change
Loop	7.74	-----	6.71	-----	5.51	-----
Lp+Ref	7.87	0.13	7.24	0.53	6.77	1.26
Lp+9W	8.15	0.41	7.69	0.98	7.41	1.90
Lp+Scr	8.33	*0.59*	8.32	*1.61*	8.48	*2.97*
Notes:	See Table 5 for source of values. Dp = Dipole; Lp = 1-wl loop					
	+Ref = reflector element; +9W = 9-wire screen; +Scr = full screen					
	Zen Gain = zenith gain					
	Change = gain increase relative to dipole or loop					

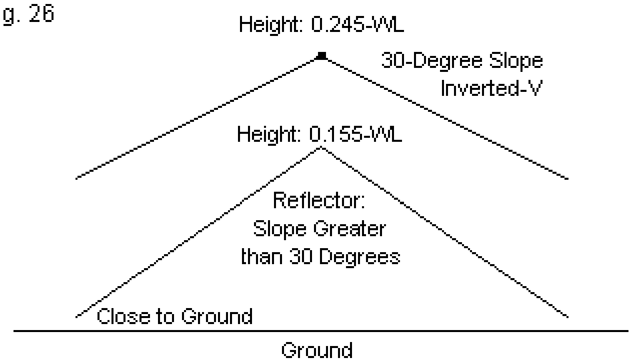
The gain-table is not only useful in estimating the benefits of supplementing a basic level NVIS antennas in various ways, but it also sets in bold relief the overall range of gain values that we may expect from these antennas as a group. That data is useful in comparing basic antenna performance with the performance of more complex antenna types, such as variations on the lazy-H. More relevant to our discussion of basic antennas is the one that is missing so far: the inverted-V.

The Inverted-V with Parasitic and Planar Reflectors

I have set aside the inverted-V from the discussion because it represents a special case when we consider adding a parasitic reflector to the antenna. Within the range of our survey, which has a maximum (center) height of 0.255-λ, an inverted-V obtains maximum gain over almost any ground quality only near the maximum height. In NVIS operation, the effective or virtual height of an inverted-V relative to its performance falls between half and 2/3 the physical center height. For most amateur installations, 0.255-λ is practical on 40 meters (about 35'), but less so on 75 meters (about 64'). However, we need to consider such heights if we wish relatively good performance from an inverted-V over the full range of soil qualities.

Inverted-V antennas with lower center heights will work, as shown in the preceding set of notes, but they do not permit the addition of a parasitic reflector. The reflector element must have at least some spacing from the driven element and still clear the ground at the reflector wire ends. In fact, ground effects upon a reflector for an inverted-V impose interesting geometry requirements that oppose our natural desire to flatten the slope angle of the element. **Fig. 26** shows the general requirements for an effective inverted-V with a parasitic reflector.

Fig. 26

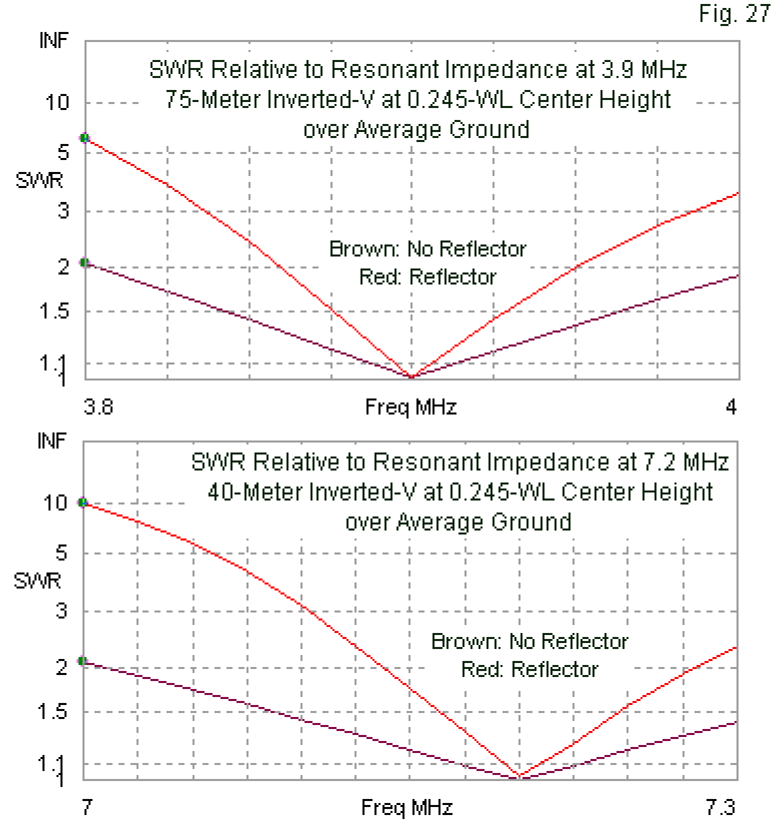


NVIS Inverted-V with Reflector Element

For all soil qualities, the sketch shows the average optimal height for an inverted-V with a 30° slope (or a 120° included angle). The reflector, by virtue of its need for greater length than the driven element requires a center height of about 0.155-λ, but the slope angle is greater than 30°. The precise angle is a function of the wire-end heights, which tend to be between 0.01-λ and 0.015-λ above ground. With respect to user safety, the reflector ends are too close to ground, but we shall bypass this legitimate concern in order to evaluate antenna performance.

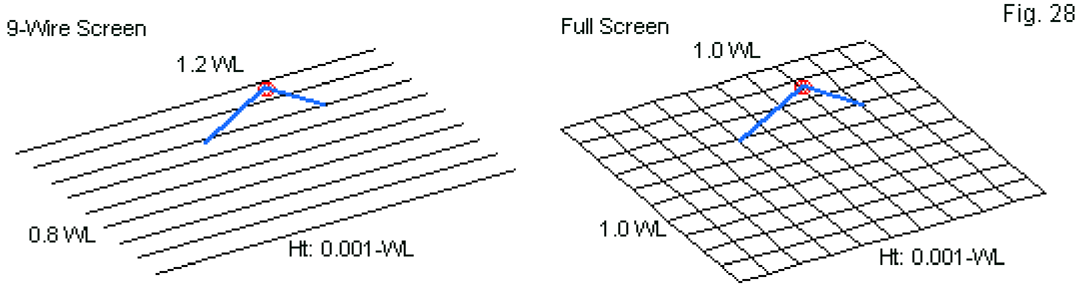
One facet of the inverted-V array's performance that we may readily compare to the performance of the level antennas is the operating bandwidth as measured by SWR curves referenced to the antenna resonant impedance. **Fig. 27** superimposes the curves for an inverted-V alone at the optimum height with the curve for the same antenna supplemented by a parasitic reflector. Both are over average ground, although the general shape of the curves would apply equally to all soil types. The figure records separate sweeps for 75 meters and for 40 meters. In the case of level antennas (dipoles and loops) using parasitic reflectors, we found moderate shrinkage of the 2:1 SWR bandwidth. See **Fig. 8**, **Fig. 12**, **Fig. 17**, and **Fig. 21** for samples. In contrast, the SWR bandwidth shrinkage for the inverted-V with a parasitic reflector is more radical, reducing the 2:1 SWR region by more than half relative to the inverted-V alone. One immediate consequence of this phenomenon for antenna builders is that field adjusting the antenna to a desired frequency will be a somewhat finicky task.

Fig. 27



There are means to obtain additional gain from the inverted-V while preserving the SWR bandwidth available with the V alone. We may place a ground-level planar reflector below the V using essentially the same techniques that we employed for the dipole and the loop antennas. Indeed, as shown in **Fig. 28**, the 9-wire and full-screen reflectors may use the same dimensions as used with the level antennas. The same application rules also apply. We may improve the 9-wire reflector performance by adding either thicker wires or more wires. The full screen may use materials with opening no larger than 0.05-λ, although common materials will normally have much smaller openings relative to NVIS operating frequencies.

Fig. 28



NVIS Inverted-V and Planar Reflectors

Table 7 summaries the performance values for all of the variations on supplementing an inverted-V, beginning with the V alone to form a reference data set for the three ground types. All driven inverted-V elements have a maximum center height of 0.245-λ and a 30° slope. Because the total element length varies from one design to the next, the end heights will vary slightly but fall within the range of 0.123-λ and 0.125-λ. The reflector ends are about 0.01-λ above ground.

Comparisons of NVIS Inverted-V Antennas					Table 7
75 Meters (3.9 MHz)					
	V: 0.4844-wl				
Ground	Max Gain	BS BW	EW BW	Feed R	Feed X
Vy Good	6.41	113.8	78.6	64.66	6.99
Average	5.52	119.4	77.4	67.15	-0.47
Vy Poor	4.30	128.6	76.2	67.32	-10.65
	V + Reflector: 0.4864-wl + 0.5114-wl @ 0.155-wl				
Vy Good	6.56	118.1	74.4	33.40	0.91
Average	5.98	123.0	73.6	33.51	-0.57
Vy Poor	5.19	129.6	72.4	32.80	-2.59
	V + 9-Wires: 0.4844-wl + 1.2-wl BS x 0.8-wl EW				
Vy Good	6.70	112.0	74.2	64.24	6.41
Average	6.42	114.8	69.6	65.32	0.75
Vy Poor	6.14	117.4	65.8	67.81	5.39
	V + Screen: 0.4822 + 1.0-wl x 1.0-wl				
Vy Good	6.84	110.6	77.6	62.95	1.30
Average	6.88	109.0	74.8	65.49	0.20
Vy Poor	7.14	104.4	71.0	67.55	-0.28
40 Meters (7.2 MHz)					
	V: 0.4844-wl				
Ground	Max Gain	BS BW	EW BW	Feed R	Feed X
Vy Good	6.19	115.4	78.4	65.57	8.56
Average	5.22	121.2	76.5	66.01	0.10
Vy Poor	4.06	129.2	75.4	64.95	-8.85
	V + Reflector: 0.4864-wl + 0.5062-wl @ 0.155-wl				
Vy Good	6.43	120.6	73.8	28.64	0.56
Average	5.87	124.8	72.4	28.23	-0.73
Vy Poor	5.28	129.6	71.2	26.95	-2.03
	V + 9-Wires: 0.4838-wl + 1.2-wl BS x 0.8-wl EW				
Vy Good	6.69	112.8	72.8	63.77	6.48
Average	6.31	115.4	69.6	64.69	0.85
Vy Poor	6.16	116.2	65.2	67.07	-4.88
	V + Screen: 0.4810 + 1.0-wl x 1.0-wl				
Vy Good	6.86	110.4	76.8	63.22	0.67
Average	6.96	107.6	73.8	65.48	-0.55
Vy Poor	7.24	103.0	70.3	67.21	-0.85
Notes:	All inverted-Vs have a 0.245-wl center height and a				
30 degree slope. Dimensions are total element lengths.					
Wire-end heights vary with element lengths.					
Max. Gain = maximum zenith gain in dBi					
BS BW; EW BW = broadside, endwise beamwidths in degrees					
Feed R; Feed X = feedpoint resistance and reactance in Ohms					

The impedance columns for both 75 and 40 meters are instructive in accounting for the relatively narrow SWR bandwidth of the inverted-V with a parasitic reflector. On both bands, the average feedpoint impedance for the V is about 65 Ω, a value preserved with either planar reflector. However, with a parasitic reflector, the resistive component of the impedance drops to about 30 Ω. At this impedance, small changes in the reactive component of the impedance have more notable effects upon the SWR.

For all of the entries, the inverted-V arrays have gain levels about a full dB below the levels achieved by the level dipole, despite the V's greater center height. (Loop arrays, of course, provide an additional gain increment.) Over very good ground, the gain benefits of any of the reflector systems are quite marginal, but over very poor soil, the gain increase can approach 3 dB. The gain of the full screen (using a model with twice the wire density shown in **Fig. 28**) over very poor ground parallels the value increases that we observed with the level antennas. To approach this level of performance with the 9-wire screen would require extensive revisions to cover the ground more thoroughly with conductive wires.

Conclusion

The idea of adding a reflector element to a basic NVIS antenna to improve performance has lived in sound bites and mythology since the initial uses of the propagation mode. Therefore I decided to perform a more thorough modeling analysis of the idea to see what order of improvement might be possible and the conditions under which we might optimize the improvement. This compendium of data is the result. For all three types of basic antennas—dipoles, 1-λ loops, and inverted-Vs—the addition is questionable or marginal until we reach very poor soil qualities. In addition, the use of a parasitic reflector (which is not under any circumstances a counterpoise) requires attention to its height above ground and its separation from the driven antenna, although the gain curves are broad enough to allow for variation from the ideal. Over any soil, a single wire reflector close to the ground proves to be an unproductive expenditure of materials and energy. Variations in reflector size will require element pruning to reach a resonant impedance value. In all cases, the use of a parasitic reflector will lower the feedpoint impedance relative to the impedance of the basic antenna alone. As well, the reflector will narrow the operating bandwidth. Both consequences are more extreme for the inverted-V than for the level antennas.

An alternative to the parasitic reflector is a planar reflector. In theory, we might elevate a planar reflector to a position below the main antenna at which we may obtain very significant gain improvements. The required size of a planar reflector militates against the elevated version, so we confined our examination to near-ground versions. In general, a planar reflector needs to have dimensions that exceed the driven antenna dimensions by about 0.4-λ to 0.5-λ on all sides. The 9-wire and full-screen reflectors that we sampled showed that these guidelines are not absolutes. In fact, smaller planar reflectors will work, but they will seriously reduce the gain benefits. Both the parallel-wire and the full-screen reflectors significantly improved the gain performance of the basic antennas, especially over lesser soil qualities. In addition, they preserved the impedance level and the SWR bandwidth of each individual basic NVIS antenna type.

The goal of these notes has been to provide as full and complete information as possible on reflectors for basic NVIS antennas. The notes make no recommendations about the selection of any reflector technique beyond the very general notes concerning the relative size of the gain benefits over the range of soil types in the survey. Such comments merely state the obvious. If blessed with very good soil, the antenna installation needs no supplementation, since reflectors in general only improve gain to the level of the antenna alone over very good soil. However, over lesser soils, including very poor soil, the use of a reflector can be beneficial, although one must measure the potential level of gain improvement against a host of other factors. Among these factors are the NVIS station mission, the difficulty of coverage, the available antenna site, and the investment of resources required for the improvements that might come from a reflector.

In general, parasitic reflectors require no additional supports or ground preparation. The investment comes in the field adjustments necessary to bring the antenna to best operation. In contrast, one may add a planar reflector to an existing antenna that is near an optimum height and incur very little need for subsequent adjustments. However, the work of installing either an extensive parallel-wire or full-screen reflector is very significant and requires access to a considerable area around the antenna. These factors are only some of the mechanical considerations that go into the decision to add a reflector to a basic NVIS antenna.