VHF Mobile Antenna Performance

The other half of the story

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Did you know that what size car you drive can and does have a profound effect upon how your antenna performs? You might be surprised at the variations in an antenna's pattern and gain depending if it is installed on a full-size or mid-sized passenger car. Let alone a pickup truck or SUV.

I had been trying to resolve for myself the many claims and counter-claims regarding the 3-dB gain attributed to the 5/8-wavelenght monopole when used in VHF mobile applications. In that pursuit, using computer modeling, I soon discovered that depending upon what vehicle was used made a noticeable difference in performance– sometimes profound.

Antenna Modeling

The availability of antenna modeling software has provided an excellent tool for predicting antenna performance, however, until recently modeling mobile antenna systems has been a major pain. Calculating and entering all the geometric data - without errors - for a wire-grid models of vehicles such as those shown in Figure 1 can take many hours of tedious work. Fortunately, the recent availability *NEC Win-Synth*[1], a software tool, that makes creating wire grid models of vehicles (and other structures) a snap that problem has been eliminated.

Using *NEC Win-Synth* generated vehicle models with *NEC2* I analyzed the three most widely used VHF mobile antennas (1/4, 1/2 and 5/8-wavelength monopoles) each installed on four different vehicles (a full and a mid-sized passenger car, a small pickup truck and an SUV).

The models themselves (Figure 1) are rather boxy reminiscent of the Volvos of years past and do not truly portray the droopy-snooted-high-back cars they are making now. They do, however, provide a reasonable approximation of the overall dimensions and, I felt, would be sufficient for making the antenna comparisons.

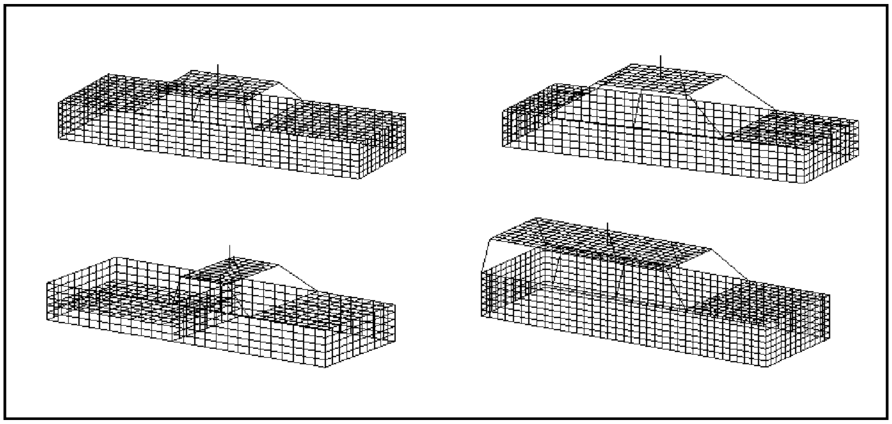


Figure 1 – Wire-grid vehicle structures used in the NEC analysis described in the text.

The dimensions for models were obtained by measuring four vehicles as follows; Dodge Intrepid (full-size car), Ford Tarsus (mid-size car), short bed Toyota pickup (pickup truck) and a Dodge Durango (SUV).

All modeling was done at a frequency of 146 MHz utilizing average ground parameters (conductivity 0.005 s/m – relative permitivity 13). The antennas were located a top dead center of the vehicle's roof in each model.

Divergence

I had anticipated that there would be some irregularities in radiation patterns between dissimilar vehicles but I truly didn't expect them to be so great among similar vehicles such as a full-sized and a mid-sized passenger car! The full-size and mid-size car models are fairly comparable in shape. The dimensions of roof sections are within a couple of inches of one another, the main difference being the overall length where there is a 12-13% variance.

NEC generated comparison plots for the cars with the three antennas are illustrated in Figure 2. The front of the vehicles is oriented at 0º azimuth for all plots. To better illustrate differences, each plot has been normalized consequently the dB reference value for outer ring (0 dB) varies from plot to plot and is not given. We'll discuss gain a little later.

Examining these patterns (Figure 2) we can find only few consistent traits between the cars. One is the greatest variations occur using the 1/4-wave whip and least with the 5/8-wave. Another apparent characteristic is that the maximum variances exist in a plane that follows the vehicle's length. From this we can see that the car's body is playing a significant influence in the antenna's performance. Why so much for similar vehicles?

Monopoles/Ground-Planes

To work an end fed monopole must

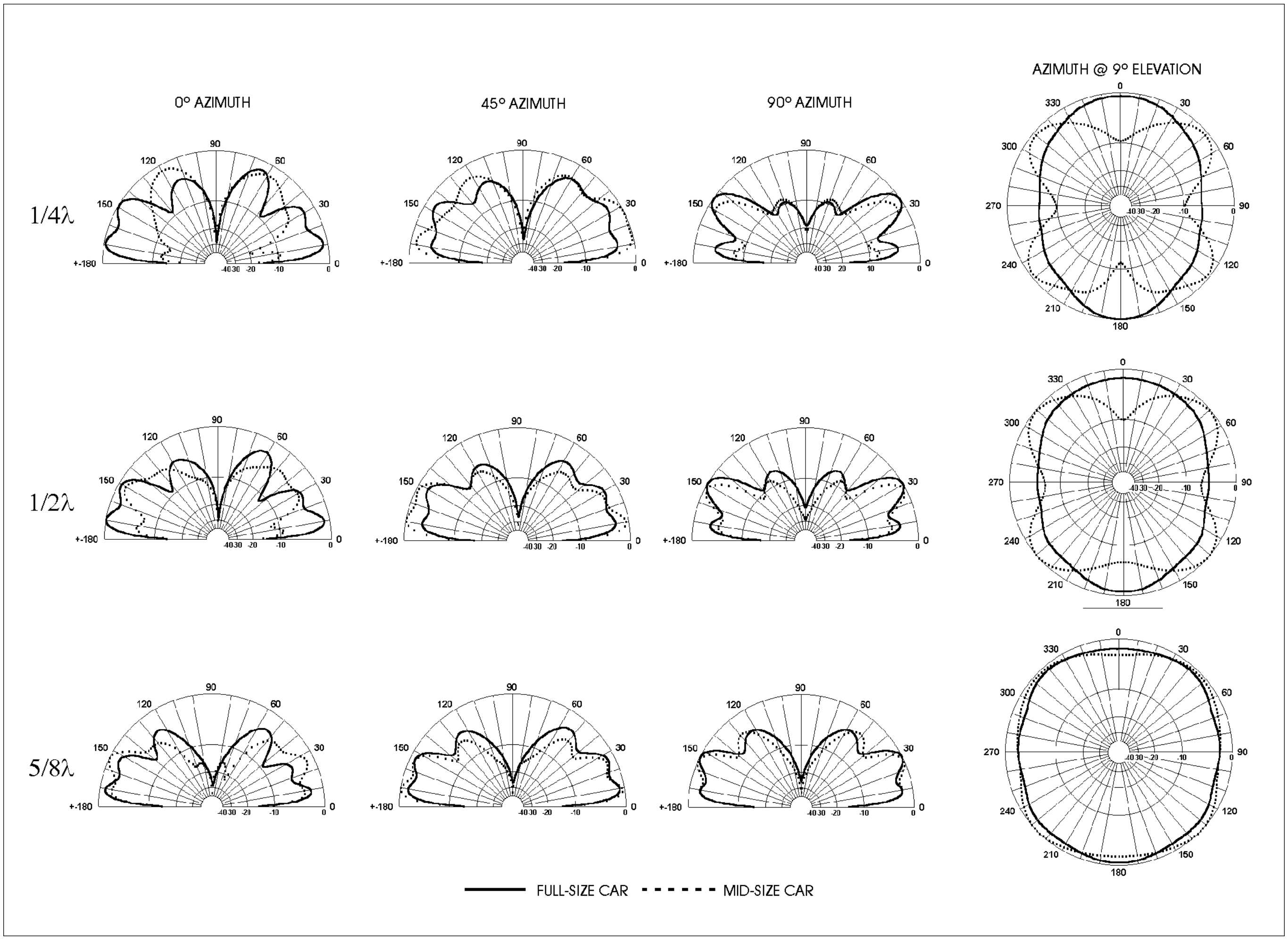


Figure 2 – Elevation and azimuth patterns showing the comparison between the full and mid-sized cars for the three most popular VHF mobile antennas

have something to work against. In ground-mounted HF systems this is the ground they are mounted upon. If they are elevated as are most VHF installations some form of counterpoise (usually a ground plane consisting of several ¼ or ½-wavelength radials) is used. A properly built groundplane does not radiate only the monopole portion of the antenna system does which produces an even omnidirectional azimuth pattern. For VHF mobile installations there is a misperception that a vehicle's roof serves as the ground-plane and doesn't radiate therefore the antenna radiates in the same fashion as conventional ground-plane. This is not true which I will now explain.

It's Not A Monopole

Although the car's roof section does provide an area for a monopole to work against there are some important details we need to look at. First, the roof is rectangular in shape and does not have the even disk-like form of a radial system used on a conventional ground-plane. This in itself will cause some skewing of the azimuth pattern. However, a more significant point is that the RF energy is not confined to just the roof area. There is nothing preventing it from flowing down the supporting columns to the doors, finders, hood and trunk lid. (This can be easily confirmed by examining the segment currents within the models reported by *NEC*.) The result being that the whole vehicle is radiating and is actually one half of a dipole antenna system - the other half being the roof-mounted vertical element. Granted, this is geometrically and electrically a very lop-sided dipole but, a dipole nonetheless. We know that changing the size and/or shape of one arm (half) of a dipole will certainly affect its pattern and gain. This is why we have the substantial differences between the antenna patterns for two cars although their roof dimensions are nearly identical.

Okay, now that we have a better picture of what's happening let's move on and take a look at the rest of our vehicle-dipole combinations.

The Results

To save you the drudgery of examining a multitude of antenna plots requiring many pages of magazine space let me give you a summary of a couple items that were similar in a majority of all the models.

Generally (about 80% or more of the time – there were exceptions) the 1/4-wave whip had the highest high angle radiation component. Elevation plots for the 1/4-wave revealed that the most of the energy being launched between 7º and 80º. The 1/2-wave antenna's was slightly lower (7º - 70º) with the 5/8-wave the lowest (7º - 60º).

In all the elevation plots the lowest significant lobe was about 9º. In most cases it was not the most significant lobe in amplitude, however, it is the most significant for long-range towards the horizon communications hence I used a 9º elevation angle for creating a series of azimuth antenna pattern comparisons.

I made two groups of azimuth plots. The first (Figure 3) displays the variations resulting when the different length antenna elements are placed on the same vehicle. The second (Figure 4) displays how the vehicles compare with one another using the same length antenna element. For best display all plots are normalized however, the outer ring's dBi value is shown for each plot.

I found it a real eye opener to see the amount of variations between the models. A noteworthy exception was the 5/8-wavelength element that consistency produced the best omni-direction pattern. An additional expanded linear plot for the 5/8-wave vehicle combinations in Figure 5 and provides a bit better view.

Gain

To the extent that the 5/8-wave produces more gain, well, that's another matter. Note that in Figure 5 the pattern for the 5/8-wave/SUV combination has an azimuth pattern that varies as much as 1½ dB. Adding to that you can also note that depending

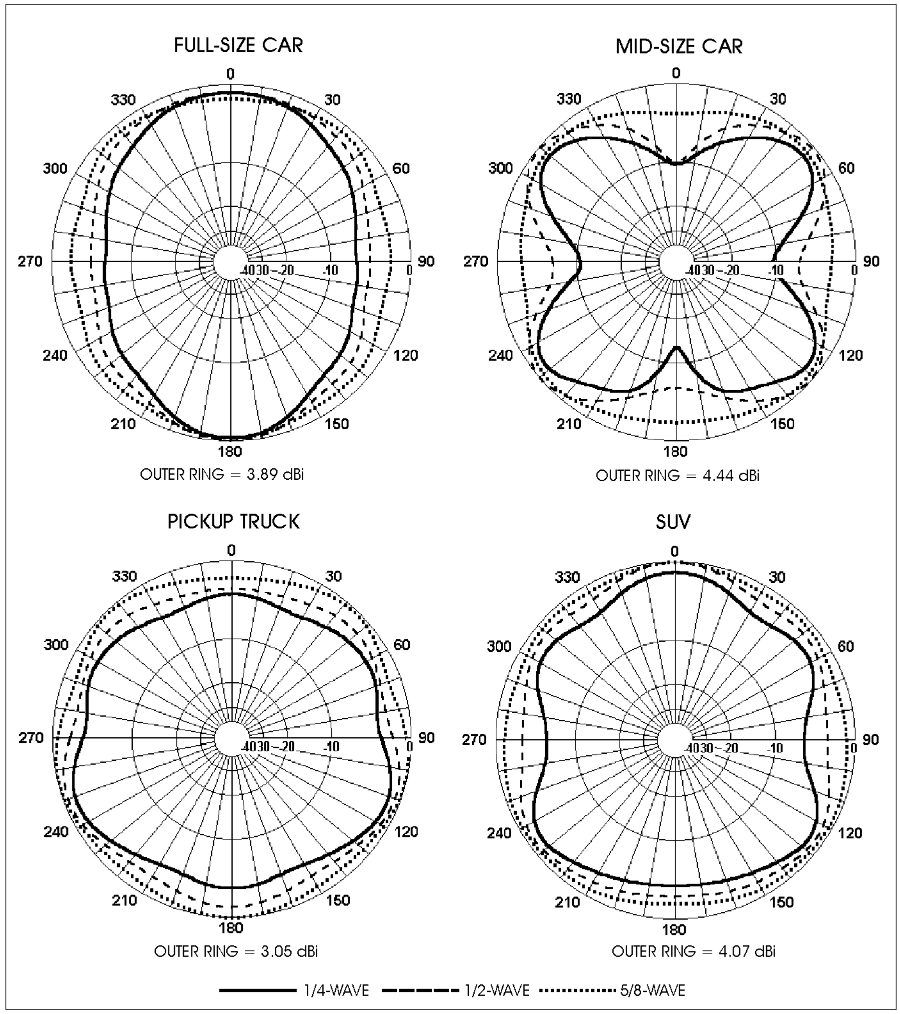
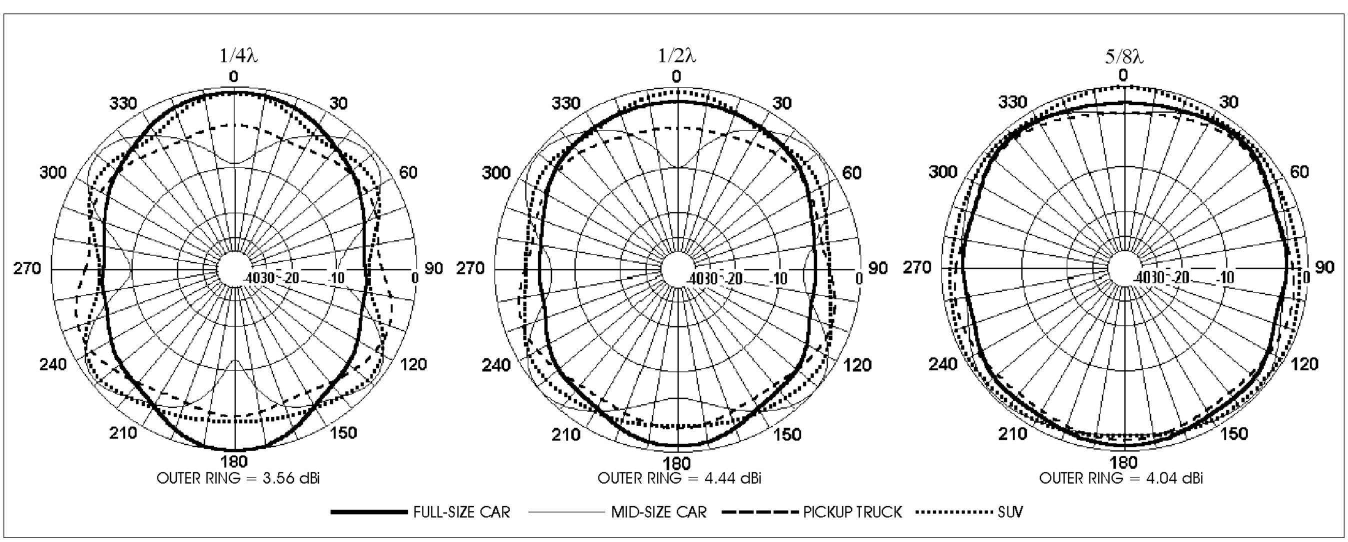


Figure 3 – Azimuth pattern variations (9º elevation) resulting with the different length antenna elements.

Figure 4 – Azimuth patterns (9º elevation) displaying how the vehicles compare using the same length antenna element.



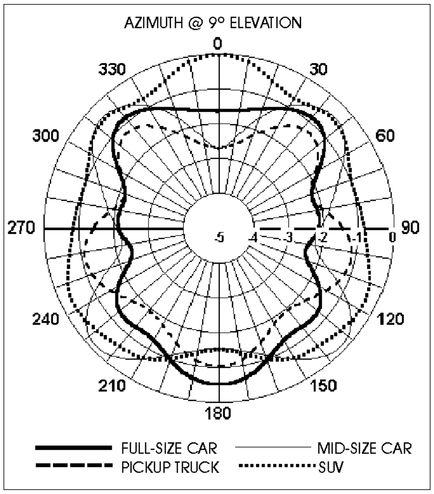


Figure 5 – Expanded linear azimuth pattern (9º elevation) for the 5/8-wave antenna mounted on the four vehicles.

upon the vehicle selected and what azimuth bearing is compared it is possible for a 5/8-wave to have 2½ dB gain over itself. You might also consider that the maximum gain figures shown for *all* the antenna and vehicle combinations in Figures 3 & 4 varied less than 1½ dB. So in the gain game it's your call.

Let's be realistic about gain. If you have ever operated mobile you know it is not at all unusual to observe a signal rapidly fluctuating 20 dB or more while driving. Under those conditions you aren't really going to distinguish any gains under 3 dB one way or the other. Possibly under marginal conditions with the vehicle at rest a 1 or 2 dB improvement may make a difference but it is highly doubtful, in normal mobile operation, such a small gain increase will be discernible.

Conclusion

As I stated at the onset I had originally plan to investigate the gain of a 5/8-wave monopole as used in UHF mobile operation. What I gleaned was that the 5/8-wave element was, in fact, operating as one arm of a dipole antenna system with the vehicle providing the other half. Subsequently the size and shape of a vehicle has a strong influence, sometimes very pronounced, on the radiation pattern regardless what length antenna element is used. Additionally, I found that it is not possible to accurately predict how a mobile antenna system will perform based upon some other mobile system – unless the vehicles and antenna installations are the same. To get any kind of meaningful estimation would require modeling each situation on a case by case bases.

Keep in mind that the models I have used are *approximate* and so are the findings. To have better accuracy requires more exacting models. Using CAD software to create wire-grid models that more closely conform to the vehicles actual form and size would generate more valuable results. *NEC Win-Synth* will import *AutoCad*® (*.dxf files).

Another item I did not considered here is the fact that some portions of vehicles today are constructed using composite materials thus the surfaces maybe more reflective than conductive. Which makes it highly problematic that accurate results could be obtained with *NEC* as one of the big cautions in *NEC* literature is not to try to model diffraction edges.

At this point, about the only thing I feel I can say with any certainty is that using a 5/8-wave *should* produce a better omni-directional pattern. Other than that all bets are off!

Footnote

1-NEC Win-Synth, Nittany Scientific, Inc., 1733 W 12600 S, Suite 420, Riverton, UT 84065 www.nittany-scientific.com