U.S. Department of Justice
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National Institute of Justice / *Technology Assessment Program*

Measured Vehicular Antenna Performance

NIJ Report-201-85

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101789

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James K. Stewart, Director
National Institute of Justice

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May 1986

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ACKNOWLEDGMENTS

This report was prepared by the Law Enforcement Standards Laboratory (LESL) of the National Bureau of Standards (NBS) under the direction of Marshall J. Treado, Communications Systems Program Manager, and Lawrence K. Eliason, Chief of LESL. NBS Electromagnetic Fields Division staff members who participated in the preparation of this report of this report were Robert McLaughlin, who developed the computer software and measurement system; Richard FitzGerrel, who refined the technique used to measure the absolute gain of vertically-polarized attennas; and Arthur Wainright, who performed the measurements. This work was sponsored by the National Institute of Justice, Lester D. Shubin, Standards Program Manager.

FOREWORD

The Law Enforcement Standards Laboratory (LESL) of the National Bureau of Standards (NBS) furnishes technical support to the National Institute of Justice (NIJ) program to strengthen law enforcement and criminal justice in the United States. LESL's function is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

LESL is: (1) Subjecting existing equipment to laboratory testing and evaluation and (2) conducting research leading to the development of several series of documents, including national voluntary equipment standards, user guides, and technical reports.

This document covers research on law enforcement equipment conducted by LESL under the sponsorship of NIJ. Additional reports as well as other documents are being issued under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equipment, investigative aids, vehicles, and clothing.

Technical comments and suggestions concerning this report are invited from all interested parties. They may be addressed to the Law Enforcement Standards Laboratory, National Bureau of Standards, Gaithersburg, MD 20899.

Lester D. Shubin
Program Manager for Standards
National Institute of Justice

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COMMONLY USED SYMBOLS AND ABBREVIATIONS

A	ampere	H	henry	nm	nanometer
ac	alternating current	h	hour	No.	number
AM	amplitude modulation	hf	high frequency	o.d.	outside diameter
cd	candela	Hz	hertz (c/s)	Ω	ohm
cm	centimeter	i.d.	inside diameter	p.	page
CP	chemically pure	in	inch	Pa	pascal
c/s	cycle per second	ir	infrared	pe	probable error
d	day	J	joule	pp.	pages
dB	decibel	L	lambert	ppm	part per million
dc	direct current	L	liter	qt	quart
°C	degree Celsius	lb	pound	rad	radian
°F	degree Fahrenheit	lbf	pound-force	rf	radio frequency
diam	diameter	lbf·in	pound-force inch	rh	relative humidity
emf	electromotive force	lm	lumen	s	second
eq	equation	ln	logarithm (natural)	SD	standard deviation
F	farad	log	logarithm (common)	sec.	section
fc	footcandle	*M*	molar	SWR	standing wave ratio
fig.	figure	m	meter	uhf	ultrahigh frequency
FM	frequency modulation	min	minute	uv	ultraviolet
ft	foot	mm	millimeter	V	volt
ft/s	foot per second	mph	mile per hour	vhf	very high frequency
g	acceleration	m/s	meter per second	W	watt
g	gram	N	newton	λ	wavelength
gr	grain	N·m	newton meter	wt	weight

area=unit^2 (e.g., ft^2, in^2, etc.); volume=unit^3 (e.g., ft^3, m^3, etc.)

PREFIXES

d	deci (10^{-1})	da	deka (10)
c	centi (10^{-2})	h	hecto (10^2)
m	milli (10^{-3})	k	kilo (10^3)
μ	micro (10^{-6})	M	mega (10^6)
n	nano (10^{-9})	G	giga (10^9)
p	pico (10^{-12})	T	tera (10^{12})

COMMON CONVERSIONS
(See ASTM E380)

ft/s×0.3048000=m/s
ft×0.3048=m
ft·lbf×1.355818=J
gr×0.06479891=g
in×2.54=cm
kWh×3 600 000=J

lb×0.4535924=kg
lbf×4.448222=N
lbf/ft×14.59390=N/m
lbf·in×0.1129848=N·m
lbf/in^2×6894.757=Pa
mph×1.609344=km/h
qt×0.9463529=L

Temperature: $(T_F-32)\times5/9=T_C$

Temperature: $(T_C\times9/5)+32=T_F$

MEASURED VEHICULAR ANTENNA PERFORMANCE

Ramon L. Jesch*

National Bureau of Standards, Boulder, CO 80303

Power gain radiation patterns of mobile antennas mounted in six different locations on a test vehicle were measured with and without typical lights and sirens mounted on the roof. The measurements were performed at frequencies representing the frequency bands of 25 to 50, 150 to 174, 400 to 512, and 806 to 866 MHz. In addition, the radiation patterns of three disguised antennas operating at discrete frequencies of 40.27, 162.475, and 416.975 MHz and one slot antenna operating at 413 MHz were also measured. Plots of power gain radiation patterns are given for the mobile antennas mounted in six different locations on the test vehicle, for the other four antennas, and to show the effects of improper grounding of the trunk lid and of the lights and siren. Recommended antenna mounting locations are given for specific frequency bands and an appendix of power gain measurement data is included.

Key words: antenna measurements; disguise antenna; gain; mobile antenna; mounting location; power gain; radiation pattern.

1. INTRODUCTION

Law enforcement and other public-safety personnel utilize various types of communications and electronic equipment in the performance of their normal day-to-day activities. Every patrol car has a minimum of one mobile transceiver installed; often there is more than one unit in the vehicle. Moreover, law enforcement officials are concerned about effective and reliable communications and maximum radio coverage to facilitate daily operations. Attainment of these goals results in more efficient use of manpower and equipment and promotes officer safety. One facet of effective and reliable communications is the correct positioning of the patrol car transceiver antenna. Positioning the antenna on the center of the car roof [1,2][1] ensures good radio transmission and reception in all directions and provides some protection against vandalism for unattended cars. Unfortunately, this location is also desirable for the patrol car lights and siren. Placing the lights and siren near the antenna should degrade radio transmission and reception; so should positioning the antenna on the car trunk or fender.

To determine the extent of this degradation, a program was undertaken by the National Bureau of Standards (NBS) Law Enforcement Standards Laboratory (LESL) to conduct tests with the antenna mounted in various locations on a vehicle, with and without typical lights and sirens mounted on the roof. Power gain radiation patterns [3,4] of the antenna were measured at frequencies representing the frequency bands of 25 to 50, 150 to 174, 400 to 512, and 806 to 866 MHz.

2. ANTENNAS AND MOUNTING LOCATIONS

Base-loaded mobile antennas that operate in the frequency ranges of 36 to 42, 132 to 174, and 450 to 470 MHz, plus a mobile gain antenna that operates in the 806 to 866 MHz range, all of which are typical of those used by law enforcement agencies, were obtained for the power gain radiation pattern measurements. The antenna whips were cut to operate at

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[1] Numbers in brackets refer to references in section 6.

discrete frequencies of 40, 150, 460, and 840 MHz, respectively. In addition, three disguised antennas operating at discrete frequencies of 40.27, 162.475, and 416.975 MHz plus one slot antenna operating at 413 MHz were also obtained.

Six mounting locations were chosen to mount the mobile antennas on the test vehicle as shown in figure 1; three locations on the roof, two locations on the trunk and one location on the right-front fender. The test vehicle was a 1976 four-door sedan whose silhouette plus the roof and trunk area compare quite favorably with the late model vehicles used by law enforcement agencies. The vehicle dimensions and mounting locations are shown in figure 2.

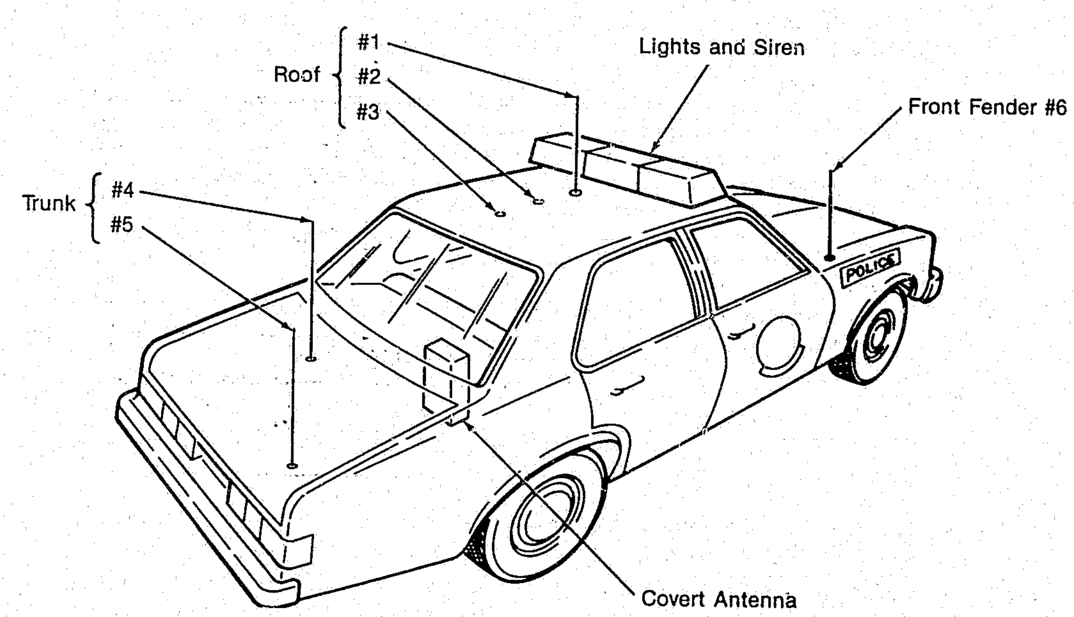

FIGURE 1. *Vehicle antenna locations.*

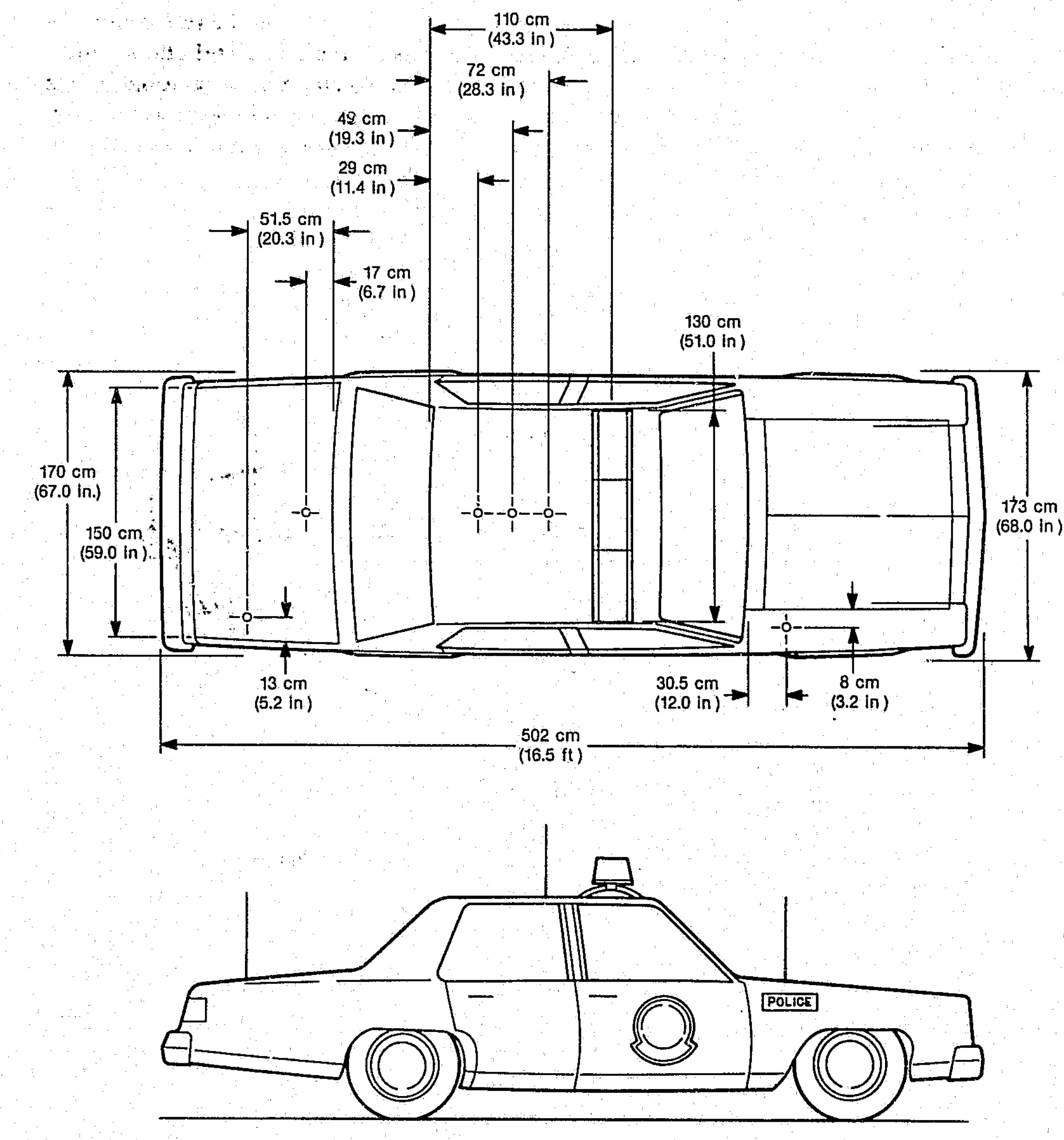

FIGURE 2. *Vehicle dimensions and mounting locations.*

3. MEASUREMENT APPROACH

3.1 Measurement System

Figure 3 shows a block diagram of the test configuration with the test vehicle located on a turntable at the test range where the power gain radiation patterns were measured. A halfwave dipole, vertically-polarized antenna was substituted for the log periodic antenna for measurements in the 25–50 MHz frequency band. The test equipment, some located under the turntable and some above ground, is also shown. Computer software was developed to perform various calculations and manipulations of measurement data from the shaft encoder and spectrum analyzer and to plot polar displays of the antenna radiation patterns.

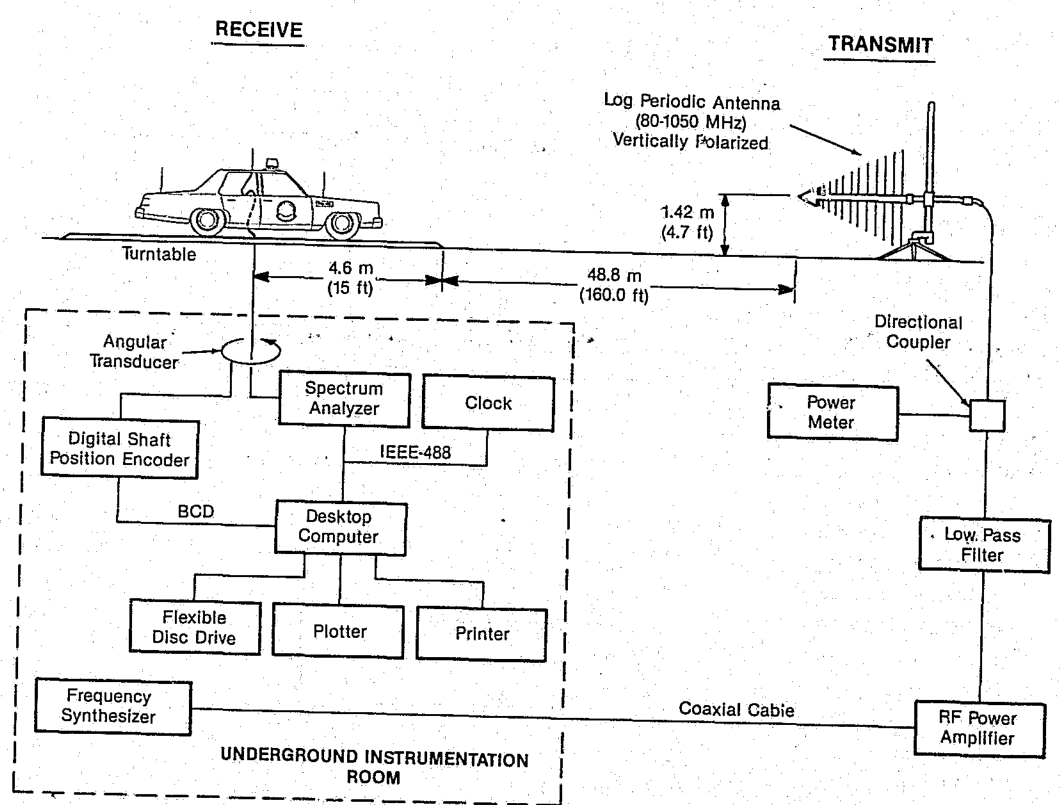

FIGURE 3. *Block diagram of measurement system.*

3.2 Power Gain of the Mobile Antenna

In preparation for the measurement of the power gain radiation patterns, standard reference level E-field conditions were established on the turntable at discrete frequencies of 40, 40.27, 150, 162.475, 413, 416.975, 460 and 840 MHz. Vertically-polarized calibrated dipoles with the feedpoint at the same height as the test vehicle roof-top were placed, in turn, on the turntable to cover the above frequencies. A vertically-polarized transmitting antenna at the same height was located approximately 53.4 m (175 ft) away from the center-point of the turntable (fig. 3). At each of the above frequencies, the power level at the transmitting antenna (approx 3 W) was recorded along with the spectral amplitude of the rf signal level received by the spectrum analyzer from the calibrated dipoles. Using the calibration curves for the dipoles, the electric field present at the test antenna location on the turntable at each of the discrete frequencies was calculated from this information. By substituting the test vehicle with the mobile antenna in place of the calibrated dipole on the turntable and duplicating the power levels at the transmitting antenna, the power gain of the mobile

antenna was obtained from the known electric field together with the rf power level received at the mobile antenna. The gain is given by the following equation [5]:

$$G=10\log_{10}\left[W_r\frac{\eta_v}{E^2}\left(\frac{4\pi}{\lambda^2}\right)\right] \quad (1)$$

where

G = gain in decibels,

W_r = power in watts received at the input to the test antenna as measured by the spectrum analyzer,

$\eta_v = \sqrt{\frac{\mu_o}{\epsilon_o}}$ (characteristic impedance of free space) $\simeq 120\pi$ ohms,

E = electric field in volts per meter at the test antenna, and

λ = the test frequency wavelength in meters.

This procedure enables absolute power gain measurements to be obtained for each of the mobile antennas at each of the frequencies of interest and thereby allows antenna performance to be accurately compared from one antenna and location to another.

3.3 Power Gain Radiation Patterns

Power gain radiation patterns were plotted for the mobile antennas operating at discrete frequencies of 40, 150, 460 and 840 MHz and in all six positions (fig. 1) following the same test procedure described in section 3.2, with and without lights and siren mounted on the test vehicle. The antenna being used was positioned directly over the center-point of the turntable for each antenna location measured. By rotating the turntable, the radiation pattern representing the power gain at each rotation point in the azimuth plane was plotted on a polar display as a function of angular rotation and gain for each test configuration. For each measurement run, approximately 300 to 400 data points were recorded for one complete revolution. These points were used to plot the radiation pattern, and the maximum and minimum power gain for each antenna in 15° intervals is tabulated in appendix A. In addition, three disguised antennas operating at discrete frequencies of 40.27, 162.475, and 416.975 MHz were measured in one location on the right-front fender, i.e., the location where a regular AM radio antenna is normally mounted. Again, the power gain was measured and the radiation pattern was plotted with and without the lights and siren. Finally, one other antenna, a disguised 413 MHz slot antenna used in covert operations, was mounted in the trunk (fig. 1) using the oval aperture normally used for a broadcast radio rear speaker. Once more, the power gain was measured and the radiation pattern was plotted with and without the lights and siren.

4. MEASUREMENT RESULTS

Figures 4–31 show plots of power gain radiation patterns as a function of the azimuth angle for each antenna measured at a designated frequency and mounting location; 0° is the front of the vehicle, 90° the right side, and 180° the rear. All radiation patterns are scaled to indicate gain and all measurements were taken with and without the lights and siren mounted. Except as noted, all power gain radiation patterns are plotted from data obtained when the lights and siren were mounted on the test vehicle.

The measurement uncertainty for the power gain measurements on the antennas was estimated to be ±1 dB. All measurement data were corrected for cable and coupler losses plus the calibration factors for the spectrum analyzer and the power meter. The measurement data presented in this report will be useful, for example, to the communications system design engineer. In cases where such technical advice is not available, the reader is advised that small variations of approximately ±1 dB may not have an adverse effect on the transmission and reception of signals from a vehicle operating in a good reception area.

4.1 840 MHz Mobile Antenna

Figures 4, 5, and 6 show plots of power gain radiation patterns of the 840 MHz mobile gain antenna measured at roof locations 1, 2, and 3, respectively, with and without the lights and siren mounted. Figure 4 shows very clearly that placing the antenna near the lights and siren at location 1 distorts the radiation pattern. The gain of the antenna at this location, with the lights and siren mounted, varied from 7.1 to −4.4 dB while the gain of the antenna without the lights and siren mounted offered a more omnidirectional radiation pattern that varied from 4.8 to 2.7 dB. The radiation patterns measured in locations 2 and 3 are less affected by the lights and siren as shown in figures 5 and 6, respectively. Figure 7 compares plots of the radiation patterns that were measured at locations 1, 2, and 3, respectively, with the lights and siren mounted. It is apparent that location 2 offers the best choice for this antenna on the roof at 840 MHz with lights and siren mounted. Even in this location, there still appears to be about a 2.5 dB transmission loss directly behind the lights and siren when compared with the measurements made without the lights and siren mounted.

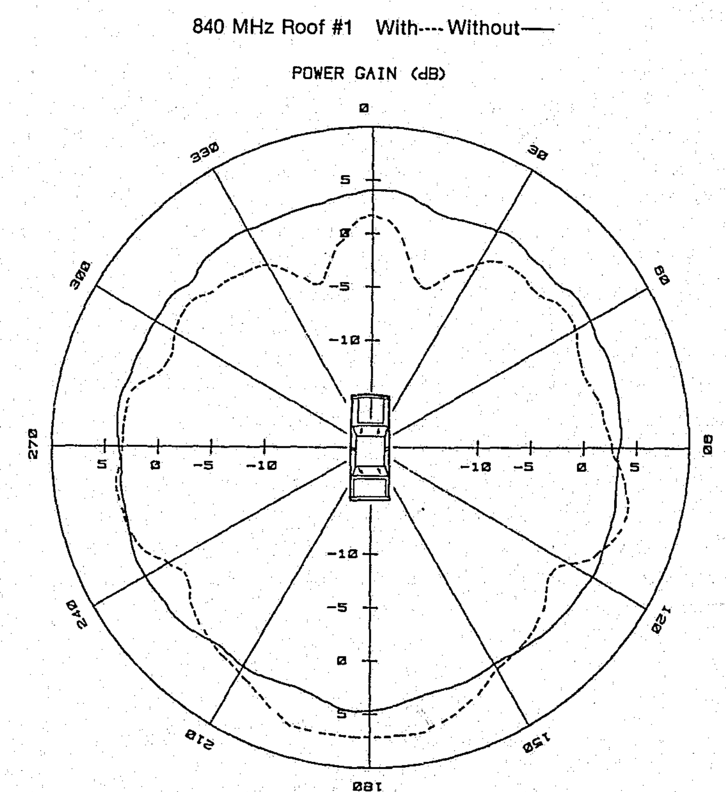

FIGURE 4. *Power gain radiation patterns of the 840 MHz mobile antenna measured at roof location 1 with and without lights and siren mounted.*

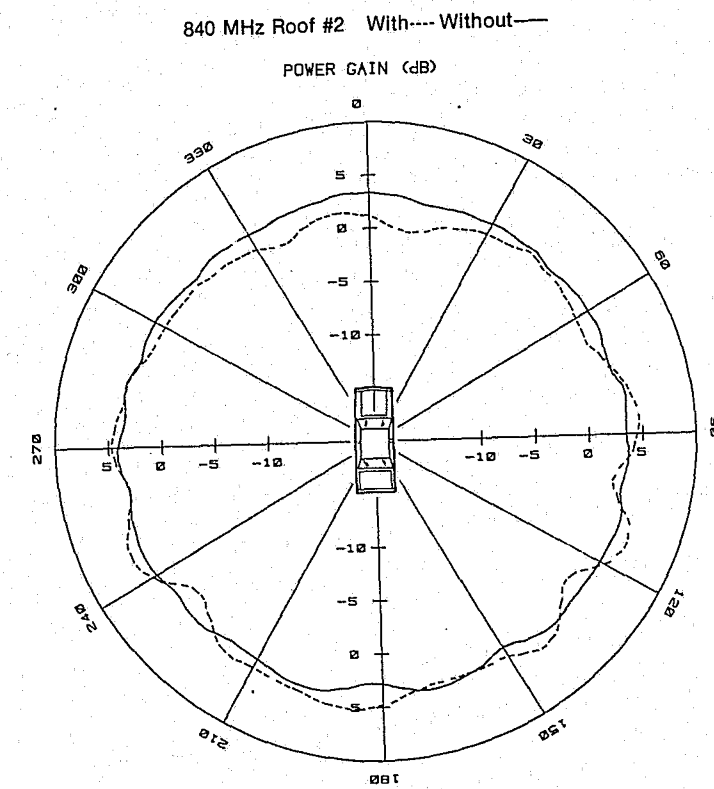

FIGURE 5. *Power gain radiation patterns of the 840 MHz mobile antenna measured at roof location 2 with and without lights and siren mounted.*

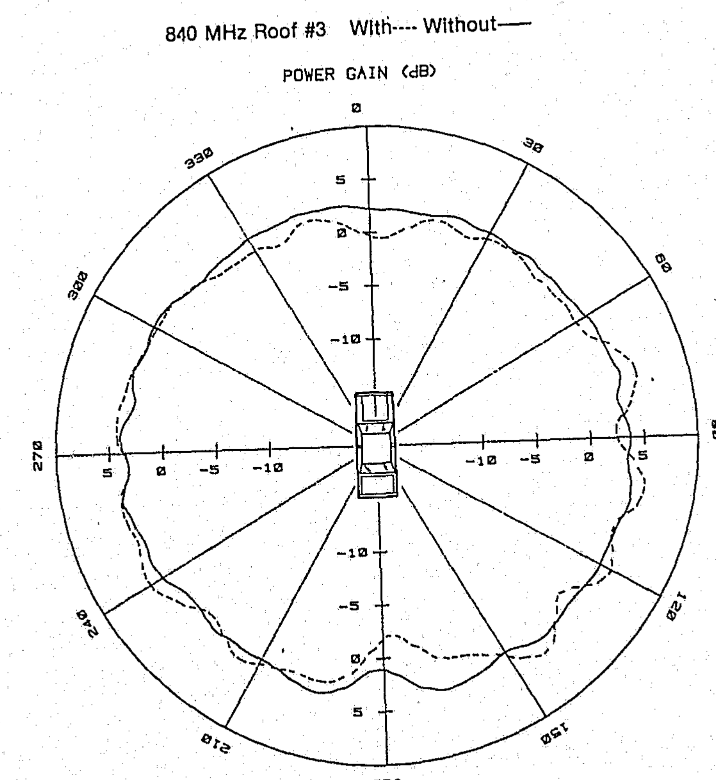

FIGURE 6. *Power gain radiation patterns of the 840 MHz mobile antenna measured at roof location 3 with and without lights and siren mounted.*

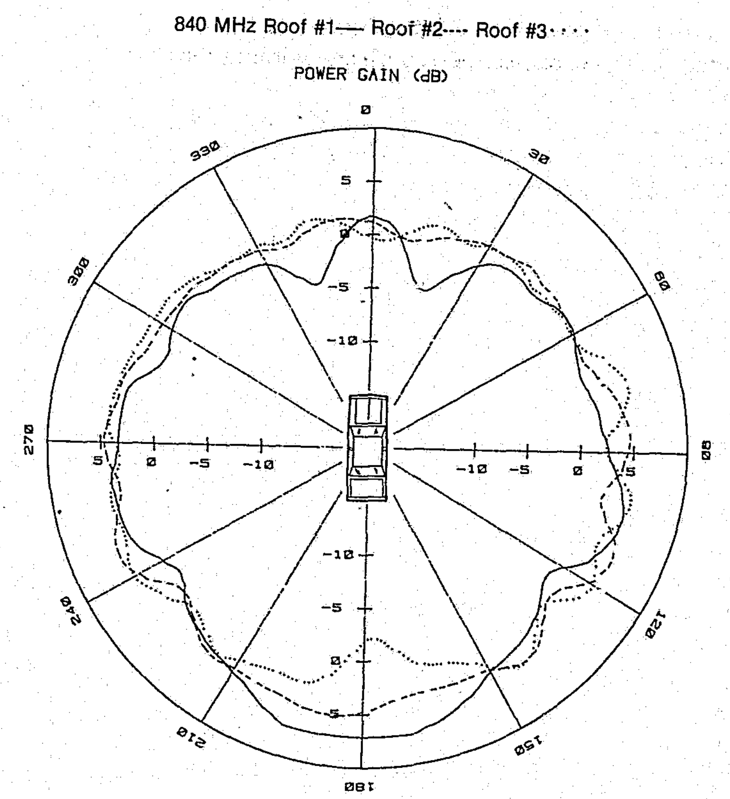

FIGURE 7. *Comparison of the power gain radiation patterns of the 840 MHz mobile antenna measured at roof locations 1, 2, and 3 with lights and siren mounted.*

Figures 8, 9, and 10 show plots of the radiation patterns of the 840 MHz antenna measured at locations 4, 5, and 6, respectively, with and without the lights and siren mounted. At these locations, the plots clearly show pattern distortion and several deep nulls. At location 4, the gain varied from 3.0 to −11.4 dB, while at location 5 the gain varied from 2.0 dB to a particularly deep null of −49.0 dB and, at location 6, the gain varied from 3.7 to −10.4 dB, all with the lights and siren mounted.

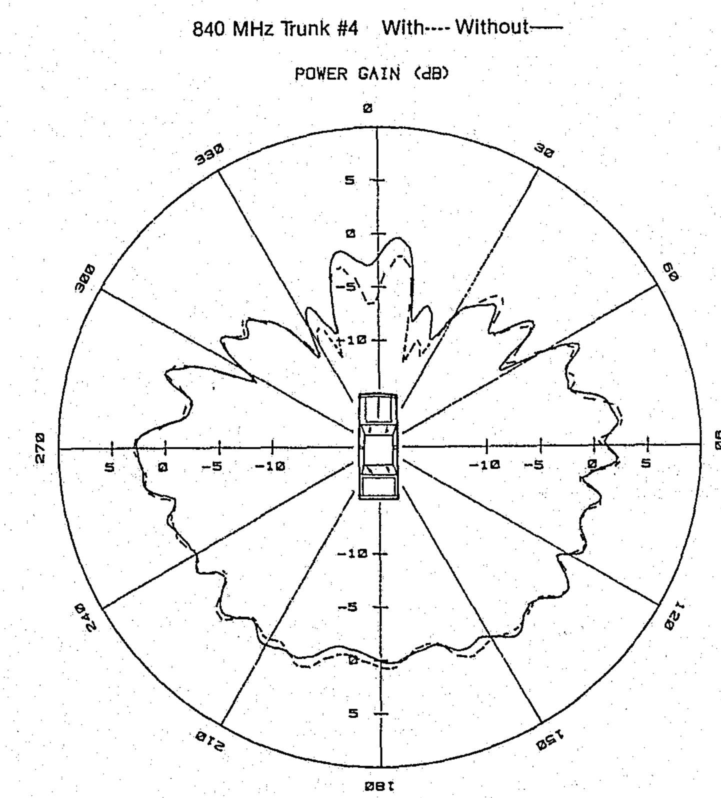

FIGURE 8. *Power gain radiation patterns of the 840 MHz mobile antenna measured at trunk location 4 with and without lights and siren mounted.*

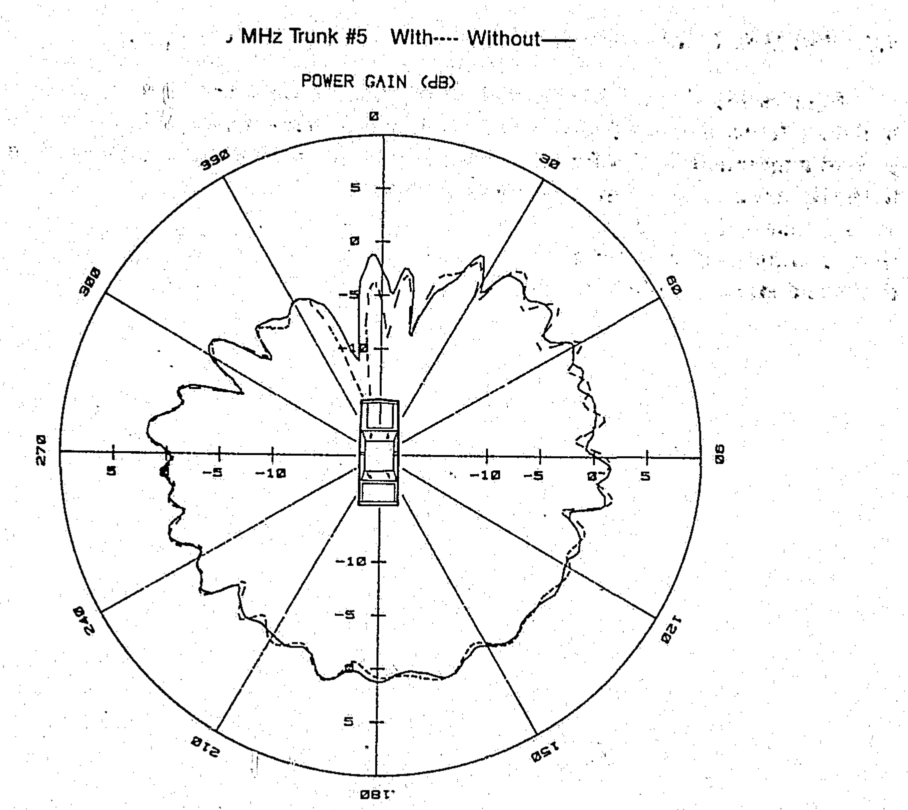

FIGURE 9. *Power gain radiation patterns of the 840 MHz mobile antenna measured at trunk location 5 with and without lights and siren mounted.*

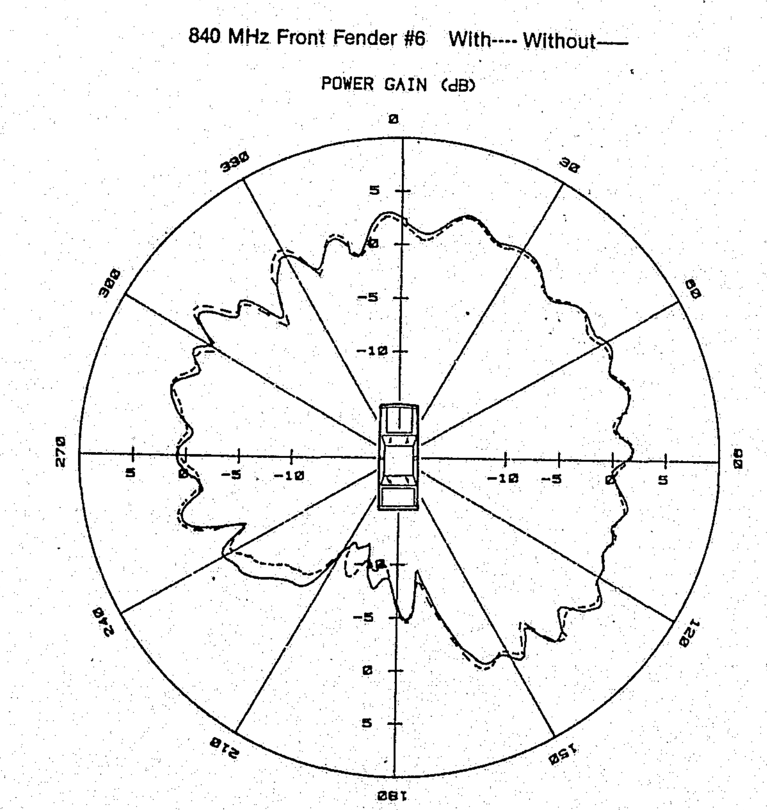

FIGURE 10. *Power gain radiation patterns of the 840 MHz mobile antenna measured at right-front fender location 6 with and without lights and siren mounted.*

4.2 460 MHz Mobile Antenna

Figures 11, 12, and 13 show plots of radiation patterns of the 460 MHz base-loaded mobile antenna measured at locations 1, 2, and 3, respectively, with and without the lights and siren mounted. In this frequency band, there is less distortion of the radiation pattern due to the lights and siren. Figure 14 compares plots of the radiation patterns that were measured at locations 1, 2, and 3, respectively, with the lights and siren mounted. Again, it appears that location 2 offers the best choice for locating this antenna on the roof at 460 MHz with lights and siren mounted. The gain at this location varied between 6.8 and 3.9 dB.

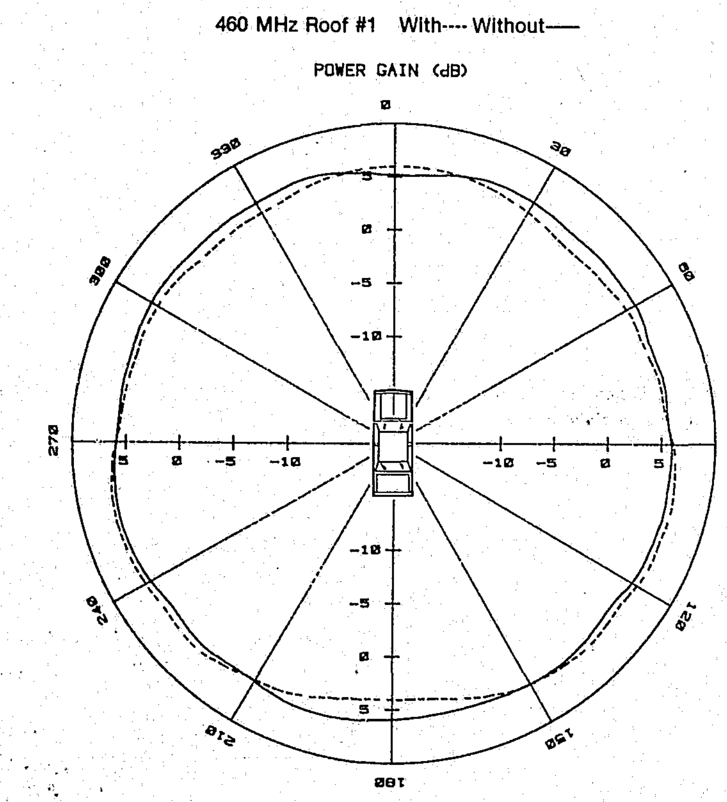

FIGURE 11. *Power gain radiation patterns of the 460 MHz mobile antenna measured at roof location 1 with and without lights and siren mounted.*

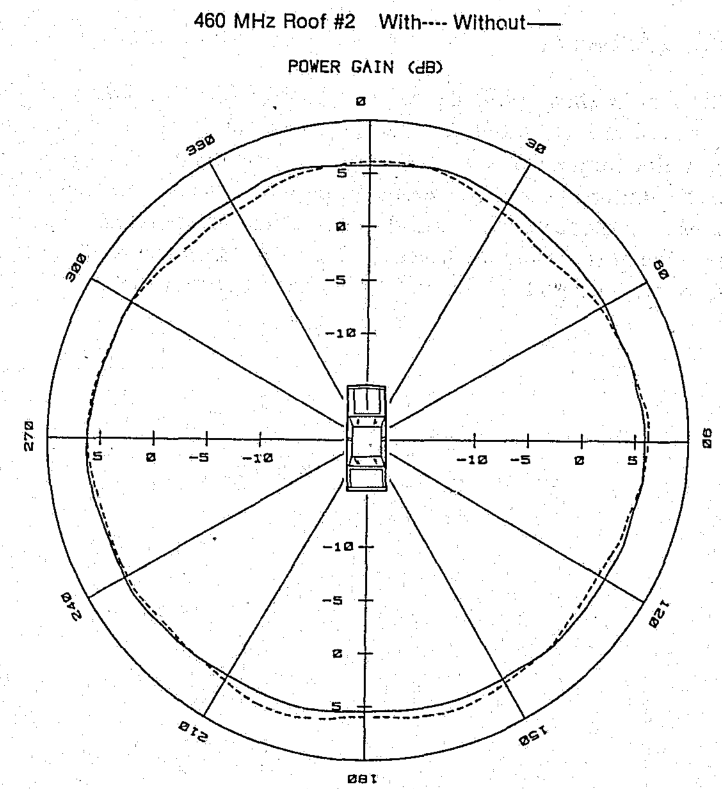

FIGURE 12. *Power gain radiation patterns of the 460 MHz mobile antenna measured at roof location 2 with and without lights and siren mounted.*

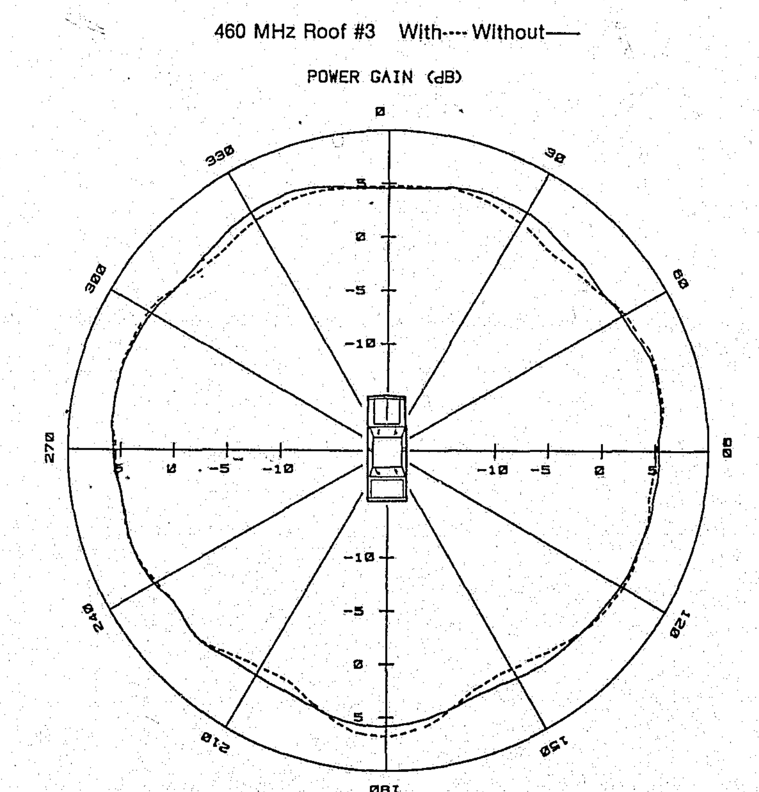

FIGURE 13. *Power gain radiation patterns of the 460 MHz mobile antenna measured at roof location 3 with and without lights and siren mounted.*

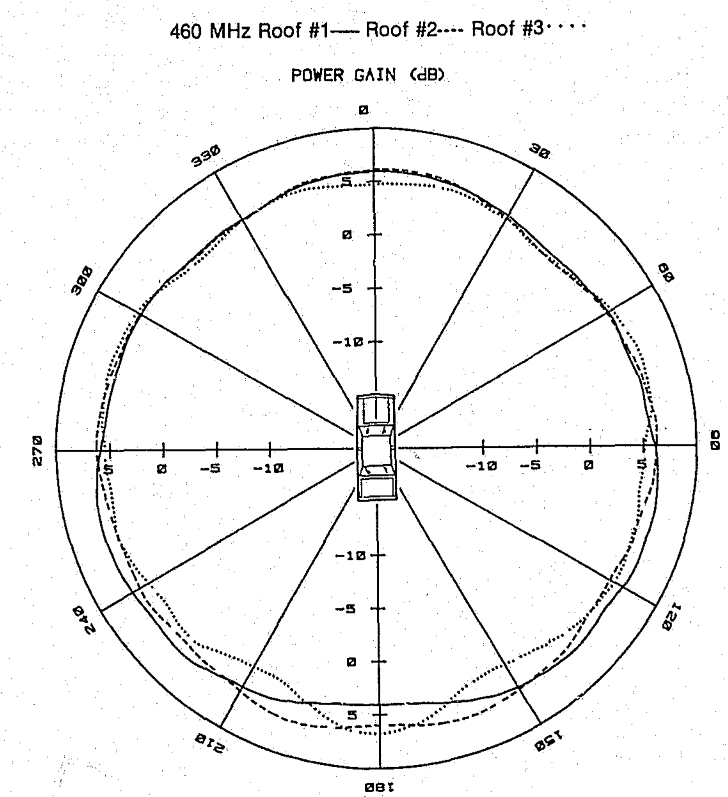

FIGURE 14. *Comparison of the power gain radiation patterns of the 460 MHz mobile antenna measured at roof locations 1, 2, and 3 with lights and siren mounted.*

Figures 15, 16, and 17 show plots of the radiation patterns of the 460 MHz antenna measured at locations 4, 5, and 6, respectively, with and without the lights and siren mounted. The pattern distortion is less at these locations than for the same locations at 840 MHz. At location 4, the gain varied from 5.2 to −2.7 dB, while at location 5 the gain varied from 4.7 to −2.0 dB, and at location 6 the gain varied from 5.7 to −3.0 dB, all with the lights and siren mounted.

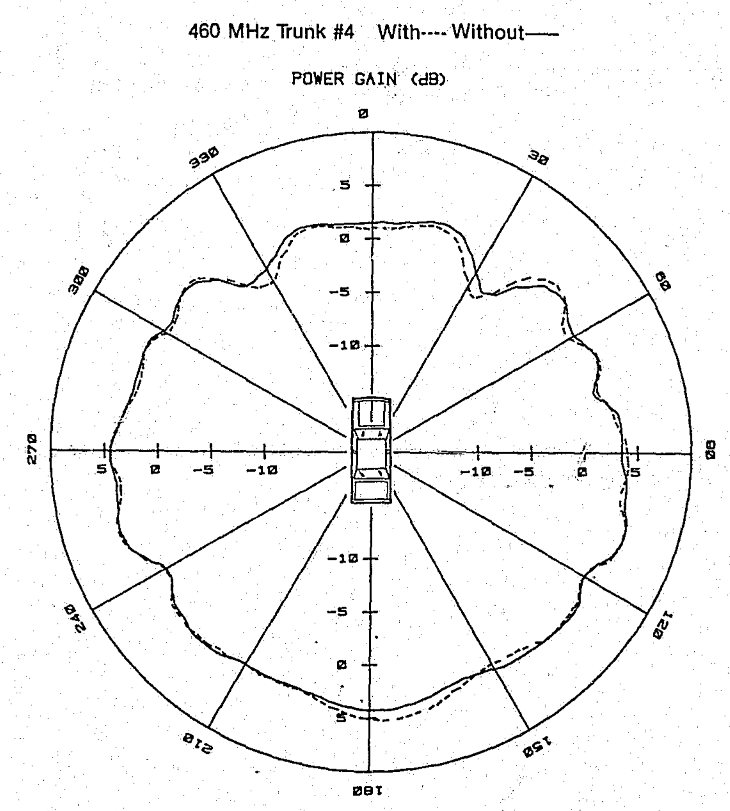

FIGURE 15. *Power gain radiation patterns of the 460 MHz mobile antenna measured at trunk location 4 with and without lights and siren mounted.*

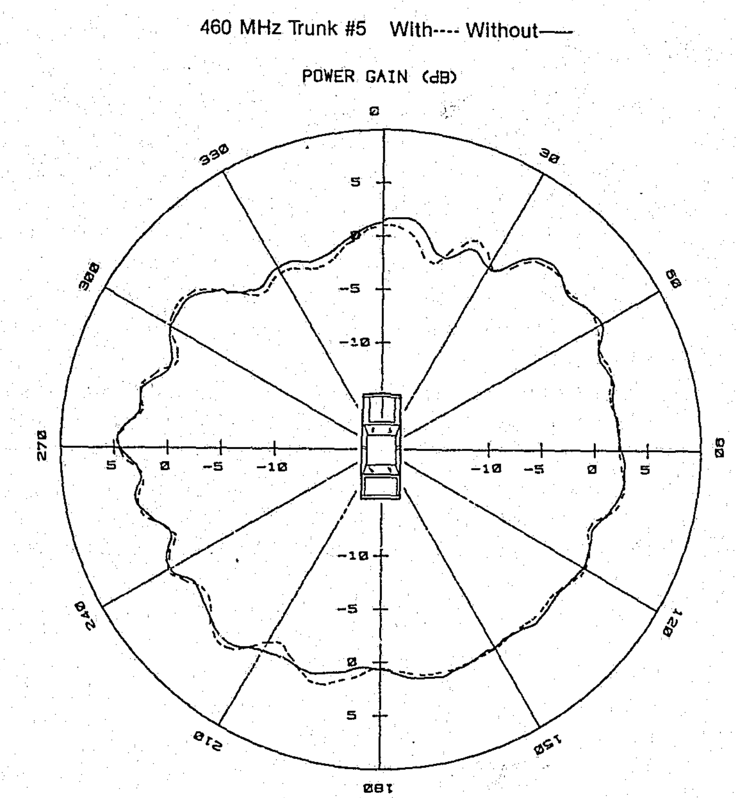

FIGURE 16. *Power gain radiation patterns of the 460 MHz mobile antenna measured at trunk location 5 with and without lights and siren mounted.*

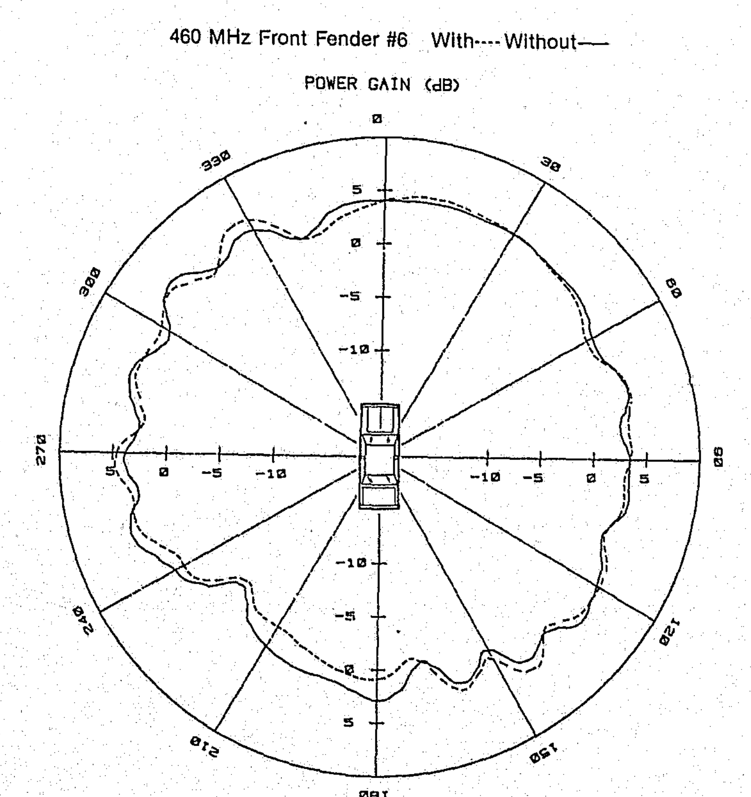

FIGURE 17. *Power gain radiation patterns of the 460 MHz mobile antenna measured at right-front fender location 6 with and without lights and siren mounted.*

4.3 150 MHz Mobile Antenna

Figure 18 shows plots of radiation patterns of the 150 MHz base-loaded mobile antenna measured at location 1 with and without the lights and siren mounted. At this location, there is very little distortion of the radiation pattern due to the lights and siren. This implies that similar patterns for locations 2 and 3 need not be measured. Figure 19 contains the same information which compares plots of the radiation patterns that were measured at locations 1, 2, and 3 with lights and siren mounted. Since there is little distortion of the radiation pattern due to the lights and siren, location 1 appears to offer a slightly better choice than location 2 for this antenna at 150 MHz with lights and siren mounted. The gain at location 1 varied between 0.5 and −1.6 dB.

Figure 20 compares the plots of the radiation patterns of the 150 MHz antenna that were measured at locations 4 and 5 with the lights and siren mounted. For location 4, the gain varied between 0.1 and −2.2 dB, thereby offering a good alternate location for mounting an antenna. Figure 21 shows plots of the power gain radiation patterns of the 150 MHz antenna that were measured at location 6 with and without the lights and siren mounted. Both plots are given since, at this location, the radiation pattern was more distorted due to the effect of the lights and siren.

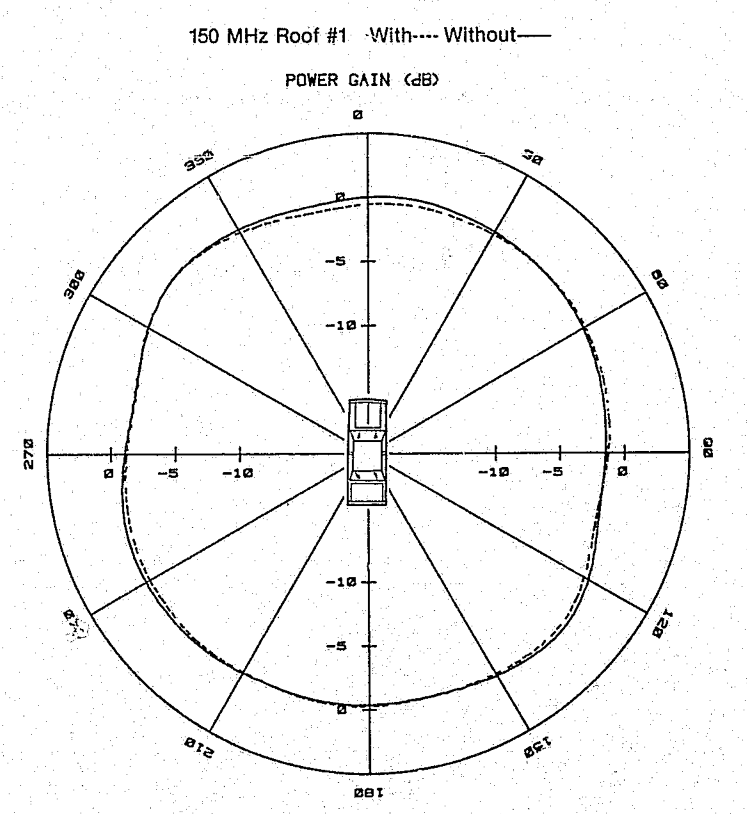

FIGURE 18. *Power gain radiation patterns of the 150 MHz mobile antenna measured at roof location 1 with and without lights and siren mounted.*

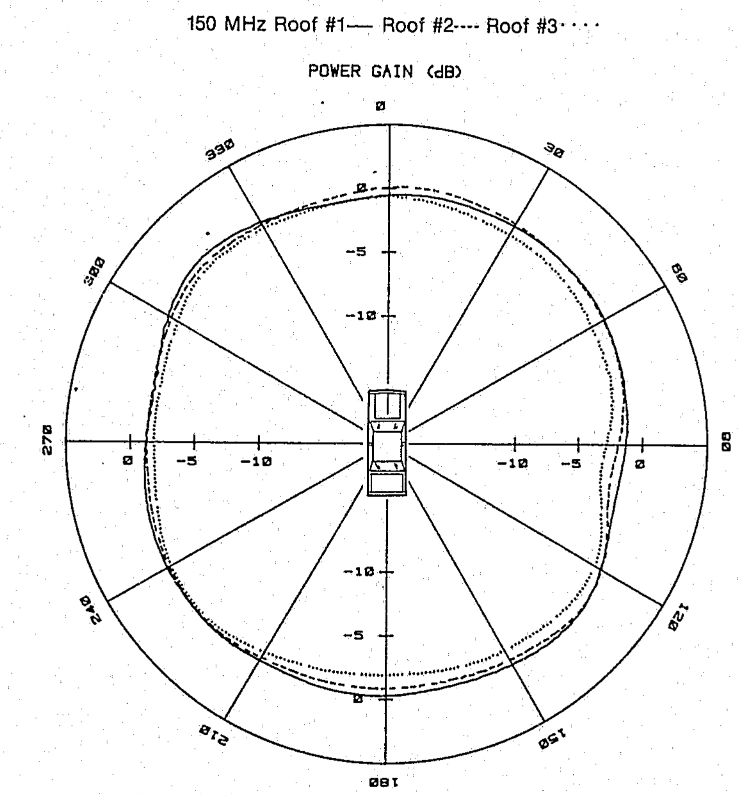

FIGURE 19. *Comparison of the power gain radiation patterns of the 150 MHz mobile antenna measured at roof locations 1, 2, and 3 with lights and siren mounted.*

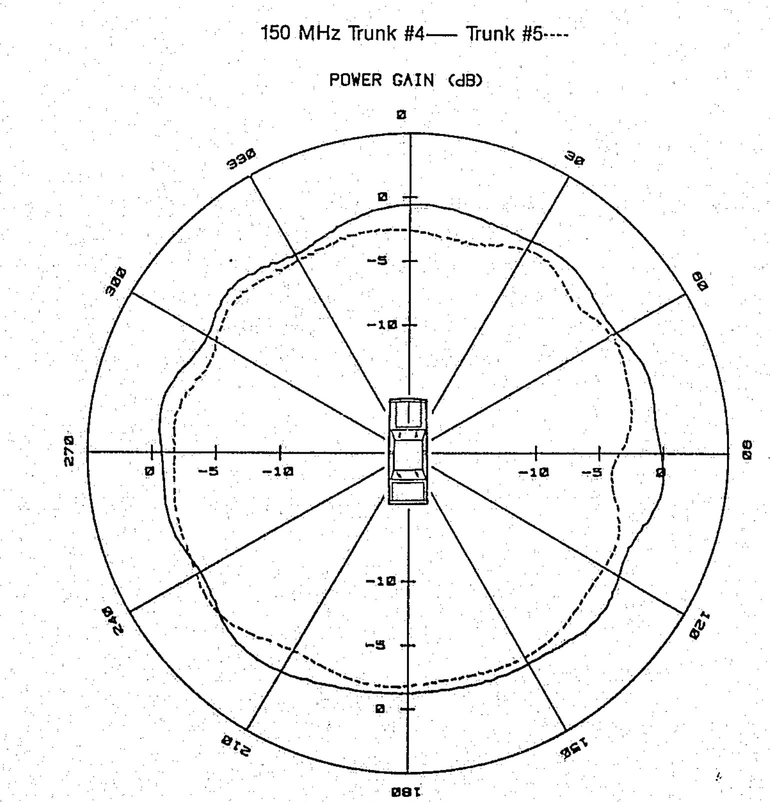

FIGURE 20. *Comparison of the power gain radiation patterns of the 150 MHz mobile antenna measured at trunk locations 4 and 5 with lights and siren mounted.*

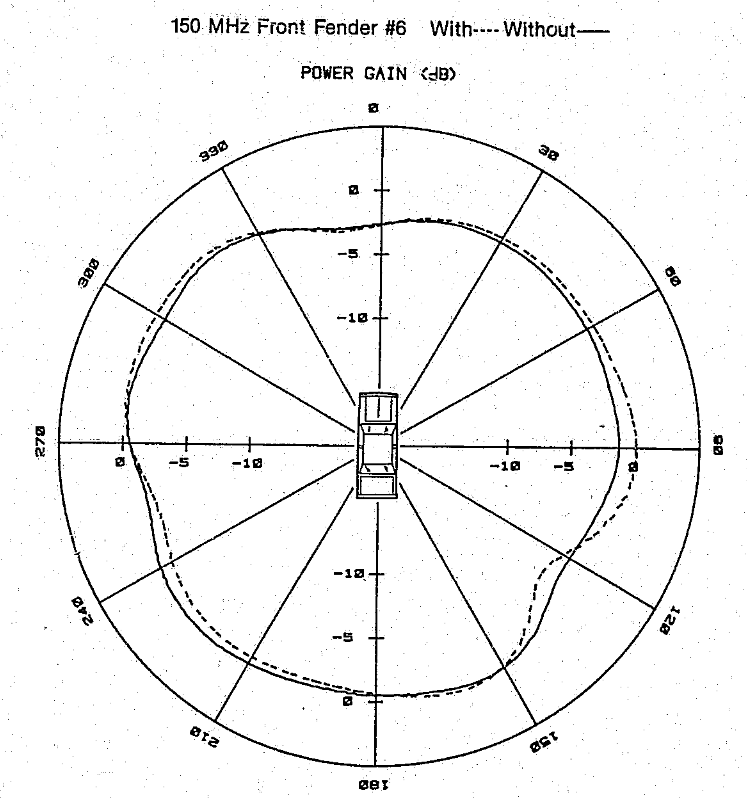

FIGURE 21. *Power gain radiation patterns of the 150 MHz mobile antenna measured at right-front fender location 6 with and without lights and siren mounted.*

4.4 40 MHz Mobile Antenna

Figure 22 shows plots of radiation patterns of the 40 MHz base-loaded mobile antenna measured at roof location 1 with and without the lights and siren mounted. One can see that there is very little distortion of the radiation pattern due to the lights and siren. Figure 23 compares plots of the radiation patterns that were measured at locations 1, 2, and 3 with lights and siren mounted. Again, location 1 offers the best choice for locating this antenna on the roof at 40 MHz with lights and siren mounted. The gain at this location varied between 0.2 and −1.8 dB, respectively.

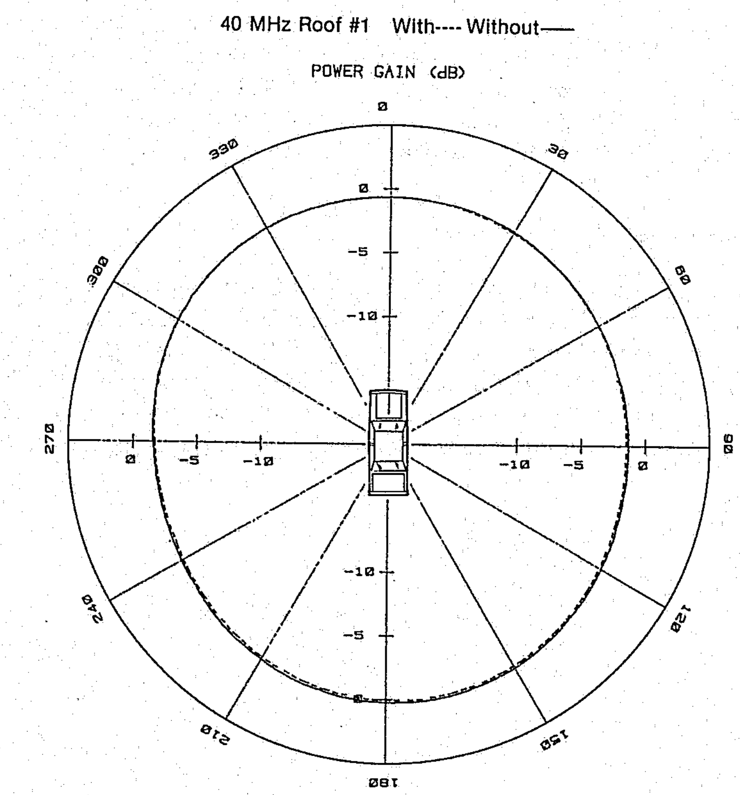

FIGURE 22. *Power gain radiation patterns of the 40 MHz mobile antenna measured at roof location 1 with and without lights and siren mounted.*

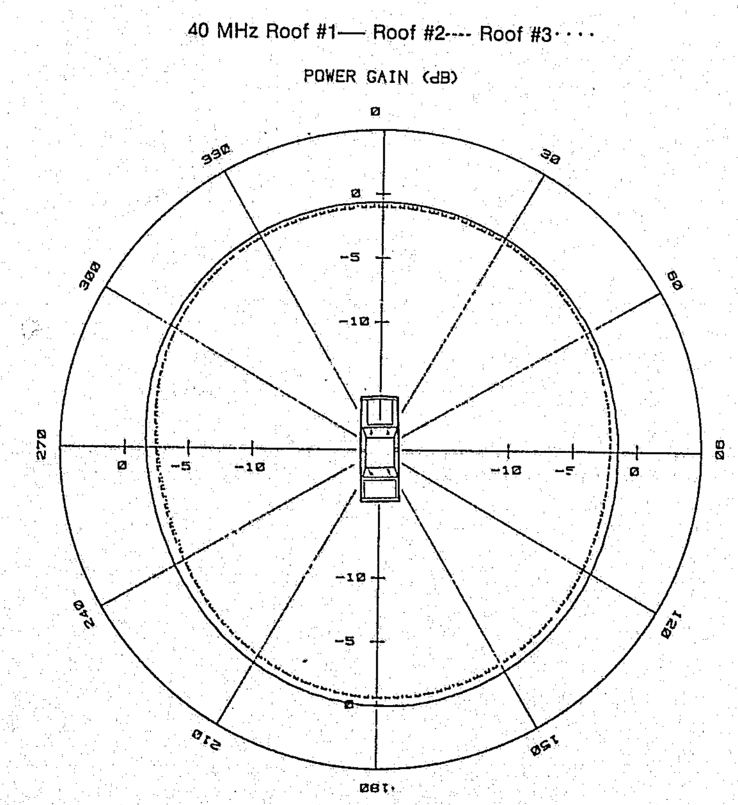

FIGURE 23. *Comparison of the power gain radiation patterns of the 40 MHz mobile antenna measured at roof locations 1, 2, and 3 with lights and siren mounted.*

Figure 24 compares the plots of the radiation patterns of the 40 MHz antenna that were measured at locations 4 and 5 with the lights and siren mounted. The radiation patterns are similar for both locations but not nearly as omnidirectional as those at 150 MHz. Figure 25 shows plots of power gain radiation patterns of the 40 MHz antenna that were measured at location 6 with and without the lights and siren mounted.

4.5 Disguised Antennas

Figures 26, 27, and 28 compare plots of the radiation patterns of three disguised antennas operating at discrete frequencies of 40.27, 162.475, and 416.975 MHz, respectively, with base-loaded mobile antenna counterparts operating at 40, 150, and 460 MHz, respectively. Measurements were taken at location 6 with and without lights and siren mounted, but plots are shown only without the lights and siren mounted. This location is of particular interest to those responsible for providing communications equipment for undercover vehicles.

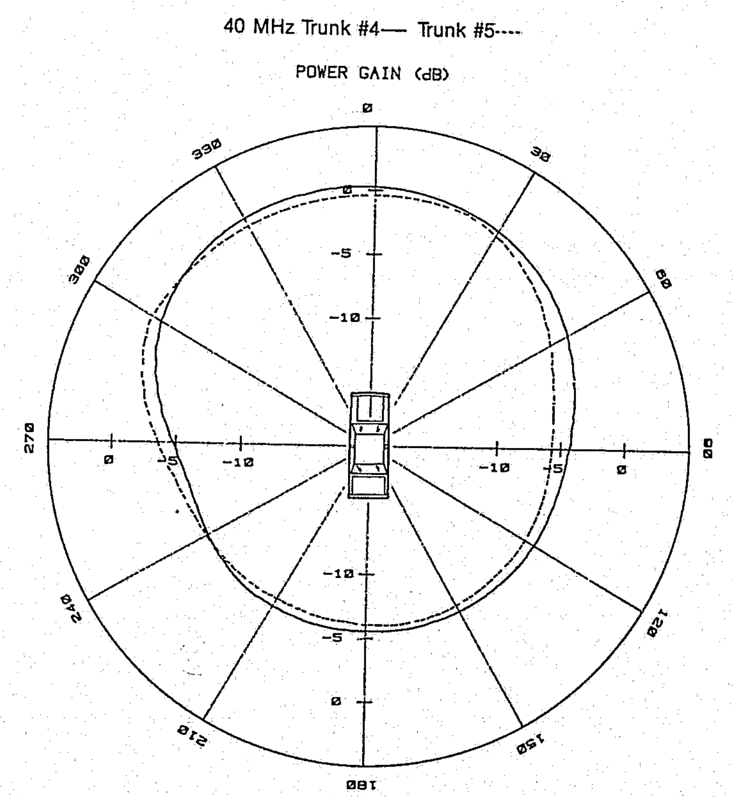

FIGURE 24. *Comparison of the power gain radiation patterns of the 40 MHz mobile antenna measured at trunk locations 4 and 5 with lights and siren mounted.*

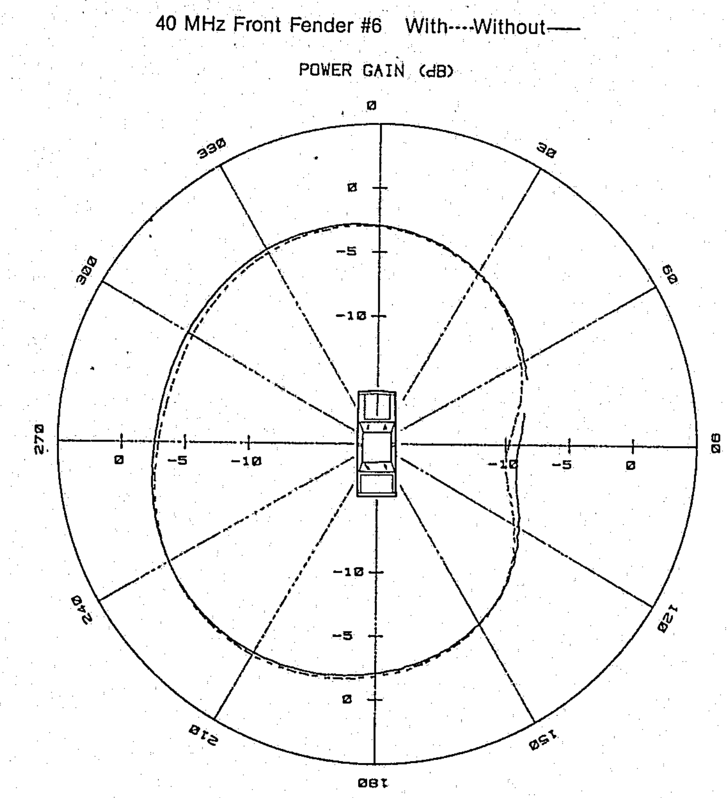

FIGURE 25. *Power gain radiation patterns of the 40 MHz mobile antenna measured at right-front fender location 6 with and without lights and siren mounted.*

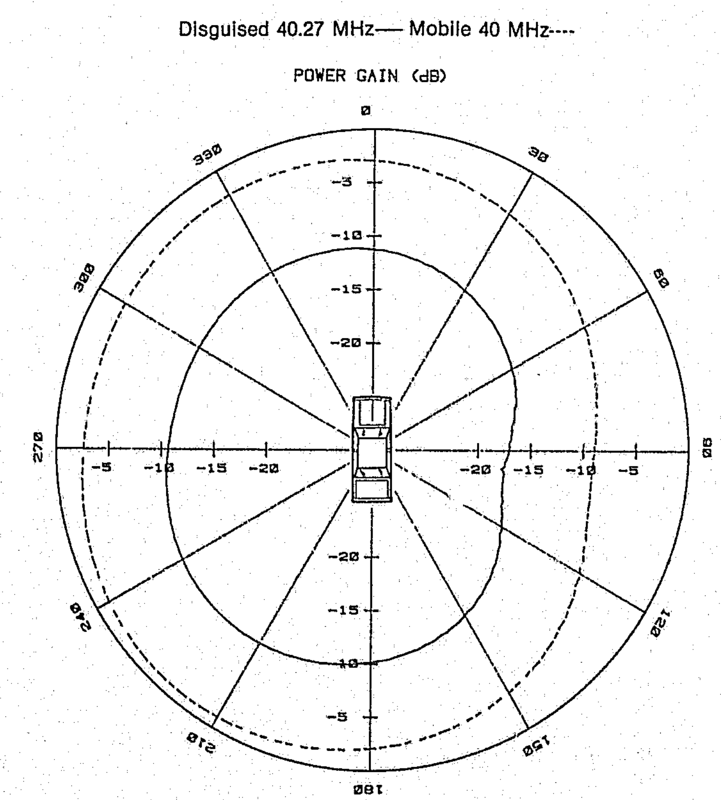

FIGURE 26. *Comparison of the power gain radiation patterns of the 40.27 MHz disguised antenna and the 40 MHz antenna both measured at right-front fender location 6 without lights and siren mounted.*

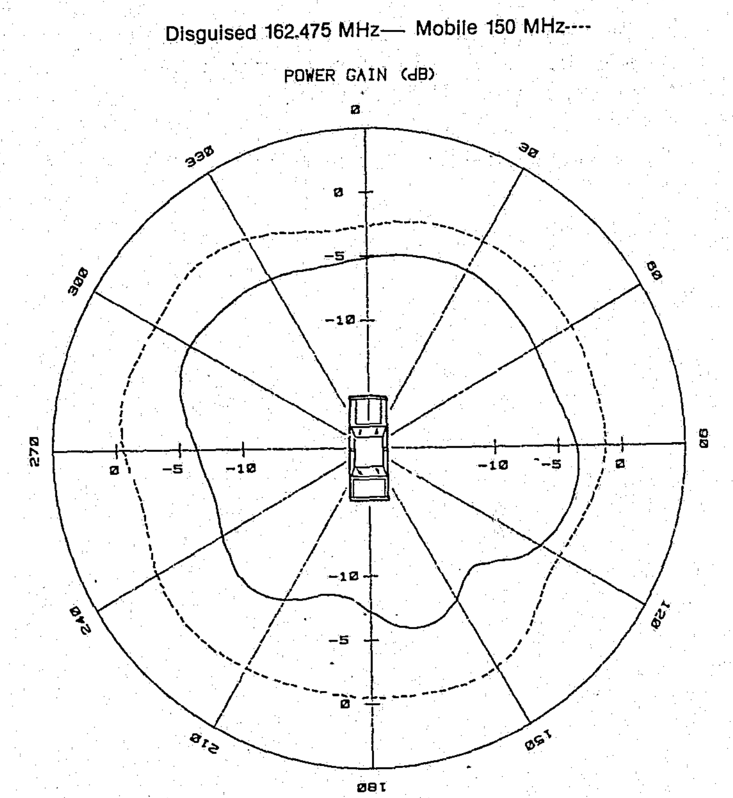

FIGURE 27. *Comparison of the power gain radiation patterns of the 162.475 MHz disguised antenna and the 150 MHz mobile antenna both measured at right-front fender location 6 without lights and siren mounted.*

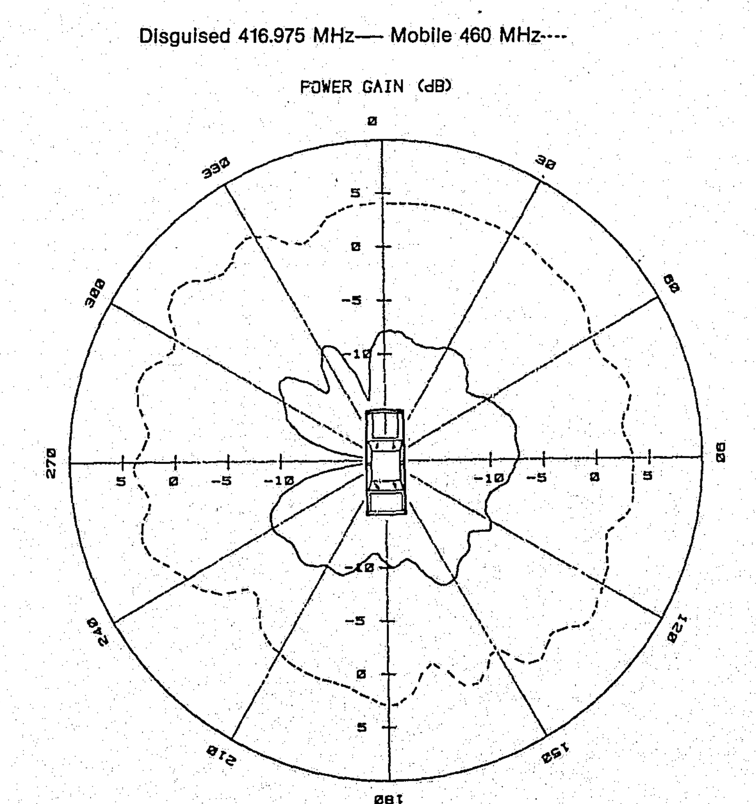

FIGURE 28. *Comparison of the power gain radiation patterns of the 416.975 MHz disguised antenna and the 460 MHz mobile antenna both measured at right-front fender location 6 without lights and siren mounted.*

Figure 29 shows plots of radiation patterns of a 413 MHz slot-type antenna that was mounted in the trunk using the oval aperture normally used for a broadcast radio rear speaker (fig. 1). Radiation pattern measurements of this antenna, normally used in covert operations, were taken with and without lights and siren mounted. The antenna exhibited an interesting radiation pattern that indicates a fairly good reception area in the rear of the vehicle. The two deep symmetrical nulls are characteristic of slot antennas.

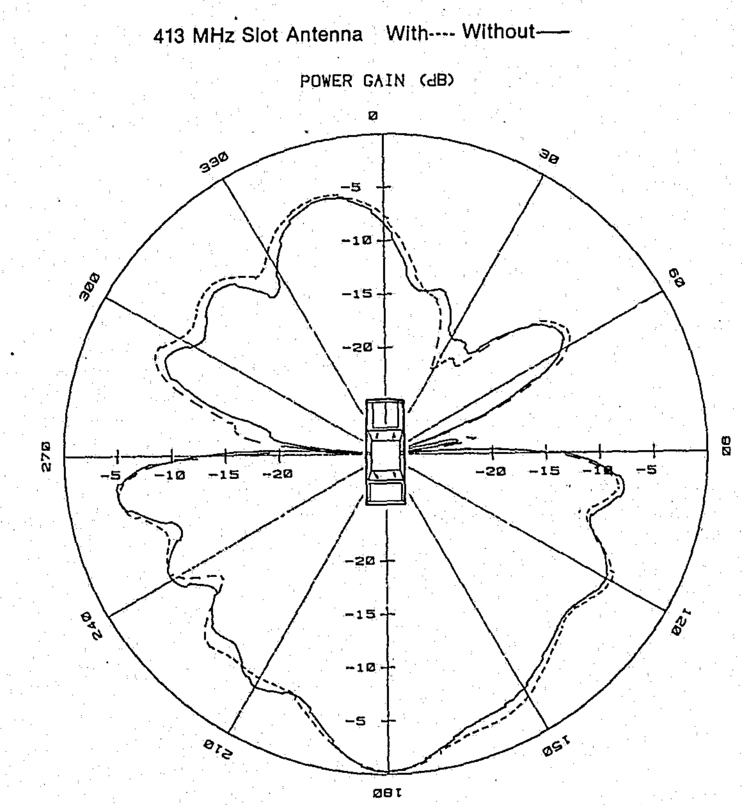

FIGURE 29. *Power gain radiation patterns of the 413 MHz slot antenna measured at the rear-speaker oval aperture with and without lights and siren mounted.*

4.6 Grounding Characteristics

Figure 30 compares plots of the radiation patterns of the 40 MHz antenna measured at location 4, with and without a proper ground of the trunk lid to the rest of the vehicle, with lights and siren mounted. An improved ground connection was made by connecting several places on the trunk lid directly to the vehicle body using copper conducting tape. The solid curve in figure 30 is a plot of the radiation pattern of the mobile antenna without a proper ground connection from the trunk lid to the vehicle body, while the dashed curve is a plot of the radiation pattern with a proper ground. The power gain difference between the two plots varied from 3 dB to about 13 dB. Plots taken at location 5 also exhibited similar grounding characteristics. All previous data given for locations 4 and 5 were taken with the vehicle properly grounded.

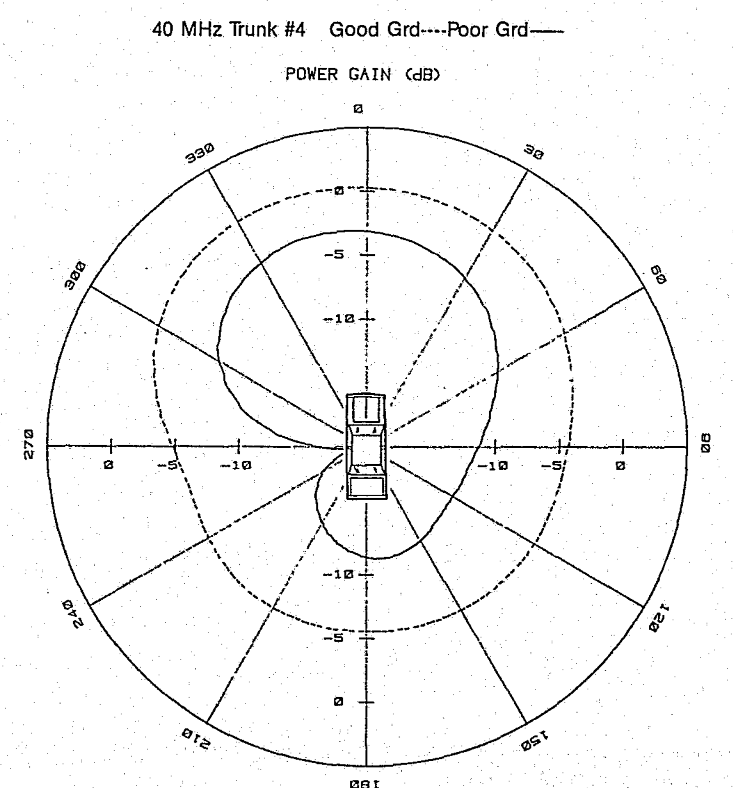

FIGURE 30. *Comparison of the power gain radiation patterns of the 40 MHz mobile antenna measured at trunk location 4 with and without a proper ground connection of the trunk lid with lights and siren mounted.*

Figure 31 compares plots of the radiation patterns of the 40 MHz antenna measured at location 2 with and without a proper ground connection of the lights and siren to the vehicle. The solid curve in figure 31 is a plot of the radiation pattern of the mobile antenna when the lights and siren were not properly grounded to the roof of the vehicle, while the dashed curve is a plot of the radiation pattern with the lights and siren properly grounded. The plots show a degradation of almost 2 dB when the lights and siren were not properly grounded to the vehicle. Again, the data given previously were measured with the lights and siren properly grounded.

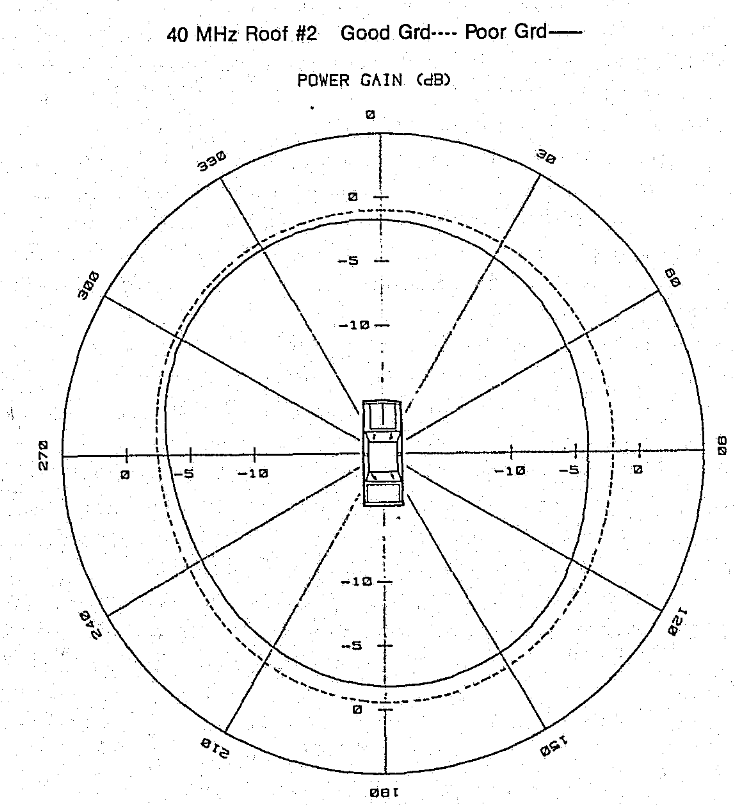

FIGURE 31. *Comparison of the power gain radiation patterns of the 40 MHz mobile antenna measured at roof location 2 with and without a proper ground connection of the lights and siren to the vehicle.*

5. SUMMARY AND CONCLUSIONS

Plots of power gain radiation patterns were obtained for specific mobile and disguised antennas at different frequencies and vehicle locations which allowed antenna performance to be accurately compared between antennas and vehicle locations. The measurements were performed at six different locations on a 1976 four-door sedan, with and without typical lights and siren mounted on the roof. Note, if the same antennas were measured at similar locations on a smaller compact vehicle, the radiation patterns may not have been quite as uniform because of the smaller ground plane [2]. Even though other types of mobile antennas may give some differences in radiation pattern and gain, the roof location gives the most nearly omnidirectional coverage since the vehicle roof provides a more uniform and symmetrical ground plane.

Of the three roof locations, the best choice for mounting the mobile antennas used at 840 and 460 MHz was location 2 (figs. 7 and 14) while the best choice for mounting the mobile antennas used at 150 and 40 MHz was location 1 (figs. 19 and 23). In both situations the second choice, location 1 at the higher two frequencies and location 2 at the lower two frequencies, is not significantly different from the primary choice and should be used if the first choice presents a difficult mounting problem. At the two lower frequencies (40 and 150 MHz), there was little distortion of the radiation pattern due to the lights and siren.

Among the nonroof locations, the best choice for mounting the mobile antennas was trunk location 4. At the higher frequencies of 840 and 460 MHz, there was distortion of the radiation pattern toward the front of the vehicle (figs. 8 and 15) while at 150 and 40 MHz the radiation pattern was more nearly omnidirectional. Also, at 150 MHz, location 4 provides a good alternate location to the roof location.

The least recommended choice for mounting the mobile antennas is location 6 on the right front fender, where the data exhibited more pattern distortion than it did at the other locations. However, this is an ideal location for mounting disguised antennas used in undercover vehicles to aid law enforcement personnel on surveillance.

In summary, the location of the antenna on the vehicle is critical to antenna performance. Further, the lights and sirens near the roof-mounted antenna degraded antenna performance significantly for the higher frequency antennas but to a lesser degree for the lower frequency antennas. Pattern distortion due to positioning the antenna on the car trunk or fender can be readily determined from these power gain measurements. While proper grounding of the lights and siren plus providing an adequate ground plane on the trunk lid for the antennas was critical at 40 MHz, it appeared to have little effect at 150 MHz and none at all above 400 MHz.

6. REFERENCES

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[2] Mobile radio guide. NIJ Report 202-83. National Institute of Justice, U.S. Department of Justice, Washington, DC 20531; 1983 November. pp. 16–21.

[3] Mobile antennas. NILECJ-STD-0205.00. National Institute of Justice, U.S. Department of Justice, Washington, DC 20531; 1974 May.

[4] Standard test procedures for antennas. IEEE Std. 149-1979 (Revision of IEEE Std. 149-1965). Institute of Electrical and Electronics Engineers, Inc., 345 East 47th St., New York, NY; 1979.

[5] Jordan, E. C. Electromagnetic waves and radiating systems. Englewood Cliffs, NJ: Prentice-Hall; 1950. pp. 416–418.

APPENDIX A—TABULAR POWER GAIN DATA

As noted in the body of this report, the antenna power gain measurements were obtained using a calibrated system that automatically plotted the antenna pattern as the vehicle was rotated 360° in the horizontal plane. While the pattern was being plotted, a separate data recorder was used to collect power gain data in azimuth increments of approximately 1°.

Tables 1 through 6 present the maximum and minimum power gain of each antenna recorded in 15° azimuth intervals for each of six antenna locations. The data for antennas operating at 840 and 460 MHz are presented for the antenna alone, and with the lights and siren installed on the vehicle. The 150 and 40 MHz antenna power gain data are presented for measurements taken with the lights and siren installed because the data for the antenna alone are not significant.

Table 7 provides a comparison of the power gain of mobile and disguised antennas mounted on the right front fender, as well as the power gain of a 416.975 MHz slot antenna mounted in the vehicle trunk using the rear speaker opening as the antenna aperture.

Tables 8 and 9 present power gain measurement data for 40 MHz antennas showing the effects of improper trunk lid grounding and improper grounding of the lights and siren when the antenna is roof mounted.

TABLE 1. *Power gain of 840 MHz mobile antenna.*

Azimuth interval (degrees)	*Roof, Location 1 Gain (dB) Max/Min*	*Roof, Location 2 Gain (dB) Max/Min*	*Roof, Location 3 Gain (dB) Max/Min*	*Trunk, Location 4 Gain (dB) Max/Min*	*Trunk, Location 5 Gain (dB) Max/Min*	*Fender, Location 6 Gain (dB) Max/Min*
1–15	4.1/2.8	3.3/2.7	2.2/2.1	−0.3/−7.9	−2.4/−8.4	3.6/1.1
16–30	3.4/2.7	3.1/2.7	2.7/2.2	−5.9/−8.8	0.9/−5.0	3.6/2.2
31–45	3.6/3.2	3.2/3.0	2.7/2.3	−3.0/−5.3	0.9/−2.1	2.6/0.5
46–60	3.8/3.2	3.4/2.9	3.0/2.4	−1.5/−6.6	0.9/−1.1	2.2/1.1
61–75	3.8/3.4	3.4/2.9	3.6/3.1	0.9/−1.6	0.5/−1.1	2.3/1.2
76–90	3.7/3.4	3.7/3.1	3.7/2.8	2.3/0.2	0.6/−0.4	2.0/0.5
91–105	3.7/3.2	3.7/3.3	4.2/3.4	2.2/−0.9	1.5/−0.8	1.9/0.0
106–120	4.2/3.7	4.0/3.7	4.0/3.6	1.4/−0.1	0.6/−1.5	1.7/0.9
121–135	4.1/3.9	3.8/3.6	3.7/3.3	2.1/−0.6	0.8/0.2	3.3/0.6
136–150	3.9/3.4	3.9/2.7	3.8/2.9	1.8/0.3	1.2/0.3	2.7/−0.2
151–165	3.7/3.4	3.9/2.8	3.8/2.9	0.6/−0.8	1.7/0.1	1.0/−4.8
166–180	4.7/3.7	3.9/2.9	3.8/1.0	0.2/−0.7	1.3/0.4	−4.8/−9.3
181–195	4.8/3.6	4.0/2.8	3.8/1.0	−0.1/−1.0	1.6/0.3	−6.7/−9.5
196–210	3.8/3.5	4.0/3.3	3.8/2.8	1.4/−0.1	0.8/−0.7	−9.7/−11.5
211–225	4.0/3.3	3.8/3.1	3.0/2.8	1.4/0.1	−0.4/−1.5	−3.8/−8.8
226–240	4.4/4.1	4.2/3.5	3.6/2.5	0.9/−1.0	0.8/−2.1	−1.1/−3.6
241–255	4.4/3.8	4.3/3.8	3.9/3.5	1.1/−0.2	1.1/−1.0	1.2/−4.2
256–270	3.8/3.4	4.2/3.5	4.3/3.2	2.7/−0.3	0.4/−0.5	0.8/−1.3
271–285	4.0/3.7	3.9/3.5	4.0/2.9	2.7/−2.1	1.9/−0.8	2.2/−0.5
286–300	3.6/3.5	3.8/3.2	3.7/3.4	1.1/−7.0	−0.1/−5.8	2.4/0.4
301–315	3.6/3.0	3.4/2.6	3.6/2.4	−2.0/−4.3	−0.9/−6.4	3.1/0.2
316–330	3.6/3.4	3.0/2.7	2.8/2.4	−3.4/−9.9	−3.3/−4.4	1.8/−2.9
331–345	3.4/3.2	3.0/2.6	2.9/2.7	−2.6/−8.7	−3.5/−9.8	1.5/−0.8
346–360	4.0/3.3	3.4/3.0	2.8/2.3	−1.3/−3.0	−1.2/−10.8	3.0/−0.8

Table 2. *Power gain of 840 MHz mobile antenna with lights/siren installed on vehicle.*

Azimuth interval (degrees)	Roof, Location 1 Gain (dB) Max/Min	Roof, Location 2 Gain (dB) Max/Min	Roof, Location 3 Gain (dB) Max/Min	Trunk, Location 4 Gain (dB) Max/Min	Trunk, Location 5 Gain (dB) Max/Min	Fender, Location 6 Gain (dB) Max/Min
1–15	1.6/−3.7	1.0/−0.2	1.7/−0.5	−2.0/−9.8	−3.0/−8.9	3.4/0.5
16–30	−0.1/−4.4	2.0/−0.4	1.9/1.3	−6.2/−11.4	0.3/−4.7	3.4/1.9
31–45	1.3/0.2	2.8/2.1	2.2/1.5	−2.1/−5.4	1.7/−2.7	2.3/0.5
46–60	2.2/1.2	2.5/1.9	2.0/1.6	−2.1/−5.8	1.6/−2.0	2.0/1.1
61–75	2.0/1.1	3.3/1.8	5.1/2.0	0.3/−1.4	1.4/−0.7	2.5/1.3
76–90	2.6/1.5	4.7/3.5	5.1/2.4	2.7/−0.4	1.2/−1.6	2.0/0.3
91–105	4.9/2.7	4.4/2.5	5.3/2.6	2.4/−1.1	2.0/−1.2	1.7/0.3
106–120	4.9/1.7	5.3/3.5	4.8/3.4	1.2/−0.1	0.6/−2.1	1.8/1.1
121–135	2.5/0.7	4.0/2.1	4.8/2.0	2.0/−0.5	0.8/0.2	2.9/1.3
136–150	3.9/2.7	4.9/3.7	5.1/3.3	1.3/0.5	1.4/0.2	2.9/−0.8
151–165	6.6/4.1	3.6/3.4	2.9/0.9	1.4/−0.9	1.8/−0.3	1.4/−4.4
166–180	7.1/6.7	4.7/3.4	0.7/−2.1	0.8/−1.0	1.6/0.7	−4.5/−8.2
181–195	7.1/7.1	5.2/4.8	2.7/−1.5	0.5/−0.3	1.7/−0.5	−6.5/−10.0
196–210	7.1/4.5	4.8/4.1	3.3/2.6	1.8/0.4	1.0/−1.0	−7.9/−10.4
211–225	4.3/2.9	4.4/2.8	3.8/2.1	1.9/−0.1	0.1/−2.4	−5.6/−9.4
226–240	2.8/1.1	4.4/1.8	4.8/2.2	1.3/−1.4	1.1/−2.7	−2.1/−5.5
241–255	4.0/2.0	5.3/4.1	4.9/4.1	0.8/−0.2	1.1/−1.2	1.5/−4.3
256–270	4.2/3.4	4.7/3.5	4.5/3.3	3.0/0.2	0.5/−0.6	1.2/−1.1
271–285	3.3/2.6	4.7/3.8	4.4/3.9	2.8/−1.9	1.9/−0.9	1.8/0.1
286–300	2.2/0.7	3.7/2.4	4.0/3.3	1.0/−6.5	−0.1/−6.0	2.5/−0.4
301–315	1.8/0.8	2.4/1.9	3.3/2.5	−2.1/−4.4	−1.0/−6.0	3.7/−0.1
316–330	0.8/−0.4	1.8/1.1	2.3/1.5	−3.3/−9.7	−3.5/−5.1	2.4/−3.8
331–345	−0.6/−3.9	1.3/0.3	2.1/0.9	−3.2/−10.8	−3.5/−49.0	2.1/−1.4
346–360	1.7/−2.8	1.6/1.2	2.0/−0.3	−2.8/−6.6	−3.9/−23.5	2.7/−0.7

Table 3. *Power gain of 460 MHz mobile antenna.*

Azimuth interval (degrees)	Roof, Location 1 Gain (dB) Max/Min	Roof, Location 2 Gain (dB) Max/Min	Roof, Location 3 Gain (dB) Max/Min	Trunk, Location 4 Gain (dB) Max/Min	Trunk, Location 5 Gain (dB) Max/Min	Fender, Location 6 Gain(dB) Max/Min
1–15	5.9/5.1	6.2/5.8	5.4/4.6	2.3/1.5	1.8/−1.0	4.3/4.0
16–30	6.2/5.9	6.2/5.8	5.8/5.5	2.4/−0.6	0.6/−1.1	4.3/4.2
31–45	6.1/5.8	5.8/5.4	5.8/5.1	2.1/−1.8	3.6/−0.4	4.3/3.8
46–60	6.1/5.9	5.5/5.4	5.2/4.9	3.0/1.9	3.8/2.6	3.9/2.8
61–75	6.1/5.6	5.6/5.3	6.0/5.3	2.9/1.6	3.7/2.1	4.0/2.6
76–90	6.0/5.7	5.9/5.6	5.9/5.3	3.5/1.7	2.5/2.1	4.0/2.6
91–105	6.1/5.9	6.0/5.7	5.4/5.3	4.8/3.5	3.0/2.3	3.7/2.8
106–120	6.1/5.9	5.9/5.7	5.4/5.2	5.0/3.1	2.1/1.2	3.6/2.1
121–135	5.8/5.4	5.9/5.7	5.2/4.8	4.3/3.2	1.8/1.4	4.4/2.8
136–150	6.1/5.9	6.0/5.7	4.8/4.5	4.1/3.4	1.8/1.1	3.7/1.0
151–165	5.9/5.7	5.8/5.7	4.8/4.3	3.5/3.0	2.1/1.3	2.6/0.6
166–180	5.9/5.7	5.7/5.4	5.8/4.9	4.3/3.6	2.0/0.7	2.9/−0.4
181–195	6.3/5.9	5.8/5.4	5.9/5.1	4.2/3.3	1.8/0.5	2.9/1.4
196–210	6.3/5.8	5.8/5.5	4.9/4.3	3.3/3.1	2.0/1.6	1.4/0.7
211–225	5.9/5.7	5.8/5.5	4.9/4.3	3.8/3.1	3.1/2.0	0.6/−2.4
226–240	6.0/5.6	6.2/5.8	5.1/4.6	3.6/2.0	2.7/1.4	1.9/−2.4
241–255	6.4/6.1	6.0/5.8	5.5/5.2	4.7/2.2	2.9/1.2	4.4/2.1
256–270	6.4/5.9	6.3/6.1	5.7/5.2	4.5/4.1	4.5/2.6	4.0/2.8
271–285	5.9/5.7	6.2/5.7	6.0/5.7	4.4/3.0	4.7/2.9	4.4/2.7
286–300	6.1/5.9	5.7/5.6	6.0/5.6	3.3/2.5	2.8/1.3	4.6/2.7
301–315	6.1/5.9	5.7/5.6	5.5/4.9	3.1/2.3	3.0/0.8	5.5/3.1
316–330	6.0/5.9	5.8/5.7	5.7/5.0	2.2/−0.6	0.4/−1.1	4.6/3.3
331–345	6.2/6.0	6.3/5.9	5.9/5.5	2.0/−0.0	−0.4/−1.2	4.0/1.7
346–360	6.0/5.1	6.2/5.8	5.4/4.6	1.9/1.5	1.4/−0.8	4.1/3.1

Table 4. *Power gain of 460 MHz mobile antenna with lights/siren installed on vehicle.*

Azimuth interval (degrees)	Roof, Location 1 Gain (dB) Max/Min	Roof, Location 2 Gain (dB) Max/Min	Roof, Location 3 Gain (dB) Max/Min	Trunk, Location 4 Gain (dB) Max/Min	Trunk, Location 5 Gain (dB) Max/Min	Fender, Location 6 Gain(dB) Max/Min
1–15	6.0/5.8	6.2/6.0	5.2/4.7	1.9/1.0	1.1/−2.0	4.7/4.2
16–30	5.8/5.0	5.9/4.8	5.2/4.6	2.0/−2.0	1.4/−1.8	4.6/4.3
31–45	5.0/4.4	4.7/3.9	4.5/3.9	2.9/−2.7	3.3/−0.2	4.3/3.6
46–60	5.1/4.5	5.0/4.0	5.5/4.2	3.4/1.3	3.5/2.9	3.6/2.2
61–75	5.4/5.1	5.7/5.1	6.3/5.6	3.0/1.7	3.2/2.2	4.2/2.1
76–90	6.1/5.4	6.3/5.7	6.1/5.2	4.0/2.0	2.4/1.9	4.1/3.4
91–105	6.7/6.2	6.2/5.5	5.2/4.9	4.6/3.7	3.1/2.4	3.4/2.8
106–120	6.6/6.4	5.4/5.0	5.5/5.2	5.0/3.2	2.1/0.8	3.9/2.3
121–135	6.4/6.1	5.6/5.0	5.4/4.7	4.1/3.1	2.1/1.1	4.0/2.3
136–150	6.4/6.0	6.2/5.7	4.6/3.5	4.1/2.9	1.5/1.2	4.6/1.7
151–165	5.9/4.8	6.6/6.2	4.7/3.4	4.5/2.9	1.7/1.5	3.2/1.0
166–180	4.7/4.0	6.5/6.0	6.8/5.0	5.2/4.5	1.6/0.5	0.9/−0.8
181–195	4.6/4.0	6.8/6.0	6.8/4.8	4.9/3.4	2.8/0.6	1.0/−0.1
196–210	5.7/4.7	6.8/6.1	4.6/3.4	3.4/3.1	2.8/0.5	−0.2/−1.4
211–225	6.5/5.7	6.0/5.5	4.9/3.5	3.7/3.1	3.7/1.2	−1.4/−3.0
226–240	6.6/6.3	5.9/5.5	4.9/4.5	3.7/2.1	2.9/1.1	1.0/−2.9
241–255	6.8/6.6	5.8/5.6	5.6/4.9	4.8/2.4	3.2/0.8	3.7/1.0
256–270	6.8/5.8	6.2/5.7	5.5/5.2	4.5/3.7	4.5/2.5	4.8/3.4
271–285	5.7/5.4	6.3/5.9	6.1/5.5	4.4/2.7	4.7/2.6	4.5/2.3
286–300	5.5/5.4	5.8/5.5	6.1/5.8	3.2/2.2	3.0/0.8	4.1/3.6
301–315	5.4/4.8	5.5/4.8	5.8/4.4	3.3/2.0	3.4/0.6	5.0/3.3
316–330	4.9/4.8	4.8/4.6	4.9/4.2	2.6/−1.6	0.1/−1.7	5.7/3.1
331–345	5.6/4.9	5.8/4.8	5.2/4.9	1.8/−1.4	−1.0/−2.0	5.2/1.5
346–360	5.9/5.7	6.1/5.8	5.1/4.7	1.8/0.9	0.8/−1.5	4.0/2.0

Table 5. *Power gain of 150 MHz mobile antenna with lights/siren installed on vehicle.*

Azimuth interval (degrees)	Roof, Location 1 Gain (dB) Max/Min	Roof, Location 2 Gain (dB) Max/Min	Roof, Location 3 Gain (dB) Max/Min	Trunk, Location 4 Gain (dB) Max/Min	Trunk, Location 5 Gain (dB) Max/Min	Fender, Location 6 Gain(dB) Max/Min
1–15	−0.4/−0.5	0.2/0.1	−0.6/−0.9	−0.6/−0.8	−2.7/−3.1	−1.7/−2.6
16–30	−0.3/−0.4	0.1/−0.1	−0.9/−1.1	−0.9/−1.0	−1.6/−3.0	−1.2/−1.6
31–45	−0.2/−0.3	−0.1/−0.3	−1.0/−1.2	−0.6/−0.9	−1.5/−2.4	−0.9/−1.1
46–60	−0.2/−0.4	−0.3/−0.5	−1.2/−1.5	−0.9/−1.3	−1.6/−2.5	−0.9/−0.9
61–75	−0.4/−0.8	−0.5/−0.9	−1.6/−1.8	−0.2/−1.1	−1.5/−2.0	−0.5/−0.8
76–90	−0.9/−1.3	−1.0/−1.9	−1.8/−2.8	−0.1/−0.4	−2.1/−3.4	0.1/−0.5
91–105	−1.3/−1.6	−2.0/−2.3	−2.6/−3.1	0.1/−0.4	−2.9/−4.0	0.1/−0.8
106–120	−0.6/−1.5	−0.5/−2.0	−1.1/−2.4	−0.5/−1.2	−2.1/−2.8	−0.9/−3.1
121–135	0.2/−0.5	−0.0/−0.4	−0.9/−1.1	−0.3/−0.8	−1.9/−2.3	−3.0/−3.9
136–150	0.2/−0.1	−0.1/−0.6	−1.1/−1.4	−0.5/−1.1	−1.6/−1.9	−0.3/−2.8
151–165	−0.1/−0.4	−0.6/−0.9	−1.4/−1.8	−1.0/−1.2	−1.6/−2.0	0.2/−0.2
166–180	−0.3/−0.4	−0.8/−0.9	−1.7/−1.9	−1.2/−1.3	−1.8/−2.0	0.0/−0.6
181–195	−0.2/−0.3	−0.8/−0.8	−1.6/−1.9	−1.0/−1.2	−1.7/−1.8	−0.7/−1.0
196–210	−0.3/−0.4	−0.7/−0.8	−1.1/−1.6	−0.3/−0.9	−1.8/−2.2	−0.8/−1.0
211–225	−0.2/−0.4	−0.3/−0.6	−0.5/−1.1	−0.1/−0.3	−0.9/−2.2	−0.7/−0.8
226–240	−0.2/−0.4	−0.3/−0.5	−0.5/−0.7	−0.5/−1.3	−0.6/−1.0	−0.9/−1.5
241–255	−0.4/−0.7	−0.6/−1.0	−0.8/−1.4	−0.6/−1.3	−1.1/−1.3	−1.6/−2.2
256–270	−0.7/−1.2	−1.0/−1.3	−1.5/−1.9	−0.6/−0.8	−1.3/−1.8	−0.6/−2.1
271–285	−1.3/−1.5	−1.2/−1.3	−1.8/−1.9	−0.4/−0.8	−1.6/−2.0	0.2/−0.5
286–300	−0.2/−1.3	−0.5/−1.2	−1.1/−1.7	−0.7/−1.9	−2.3/−3.0	0.2/0.1
301–315	0.5/−0.2	−0.0/−0.5	−0.4/−1.0	−1.1/−1.8	−2.0/−2.5	0.3/0.2
316–330	0.4/−0.1	−0.0/−0.3	−0.3/−0.6	−1.2/−2.2	−2.2/−2.7	0.2/−0.8
331–345	−0.1/−0.7	−0.3/−0.4	−0.6/−0.8	−1.3/−2.2	−2.4/−2.8	−1.0/−2.6
346–360	−0.5/−0.7	0.1/−0.3	−0.6/−0.8	−0.6/−1.2	−2.4/−2.6	−2.7/−3.0

TABLE 6. *Power gain of 40 MHz mobile antenna with lights/siren installed on vehicle.*

Azimuth interval (degrees)	*Roof, Location 1 Gain (dB) Max/Min*	*Roof, Location 2 Gain (dB) Max/Min*	*Roof, Location 3 Gain (dB) Max/Min*	*Trunk, Location 4 Gain (dB) Max/Min*	*Trunk, Location 5 Gain (dB) Max/Min*	*Fender, Location 6 Gain(dB) Max/Min*
1–15	−0.6/−0.7	−1.0/−1.1	−0.9/−0.9	0.0/0.3	−0.4/−0.4	−3.1/−3.7
16–30	−0.7/−0.9	−1.1/−1.2	−0.9/−1.1	0.0/−0.5	−0.4/−0.9	−3.8/−4.6
31–45	−0.9/−1.0	−1.2/−1.4	−1.1/−1.3	−0.5/−1.2	−1.0/−2.2	−4.6/−5.8
46–60	−1.0/−1.2	−1.4/−1.6	−1.3/−1.6	−1.3/−2.3	−2.3/−3.8	−5.9/−7.2
61–75	−1.2/−1.4	−1.6/−1.9	−1.6/−1.9	−2.4/−3.4	−4.0/−5.1	−7.3/−8.6
76–90	−1.4/−1.5	−1.9/−2.1	−1.9/−2.1	−3.5/−4.3	−5.1/−5.7	−8.7/−9.7
91–105	−1.3/−1.5	−2.0/−2.1	−2.1/−2.2	−4.4/−4.8	−5.7/−5.8	−9.6/−9.9
106–120	−1.0/−1.3	−1.6/−2.0	−1.7/−2.1	−4.8/−4.9	−5.7/−5.8	−7.7/−9.4
121–135	−0.5/−0.9	−1.2/−1.6	−1.2/−1.7	−4.9/−5.1	−5.8/−5.8	−5.5/−7.4
136–150	−0.1/−0.5	−0.8/−1.1	−0.8/−1.2	−5.1/−5.2	−5.8/−5.8	−3.8/−5.3
151–165	0.1/−0.1	−0.5/−0.7	−0.6/−0.8	−5.3/−5.4	−5.8/−5.9	−2.7/−3.7
166–180	0.2/0.0	−0.5/−0.6	−0.6/−0.7	−5.4/−5.6	−5.9/−6.1	−1.8/−2.6
181–195	0.0/−0.2	−0.6/−0.8	−0.7/−0.9	−5.5/−5.6	−6.1/−6.2	−1.2/−1.8
196–210	−0.2/−0.6	−0.9/−1.3	−0.9/−1.4	−5.4/−5.5	−6.1/−6.2	−0.9/−1.2
211–225	−0.7/−1.1	−1.4/−1.9	−1.4/−2.0	−5.4/−5.5	−5.9/−6.1	−0.8/−0.9
226–240	−1.2/−1.6	−1.9/−2.4	−2.0/−2.5	−5.5/−5.7	−5.6/−5.8	−0.9/−1.3
241–255	−1.6/−1.8	−2.4/−2.6	−2.6/−2.8	−5.7/−5.9	−5.0/−5.6	−1.4/−2.1
256–270	−1.7/−1.8	−2.4/−2.6	−2.6/−2.8	−4.8/−5.8	−3.7/−5.0	−2.2/−2.9
271–285	−1.3/−1.7	−1.9/−2.4	−2.1/−2.5	−2.9/−4.6	−1.7/−3.6	−3.0/−3.3
286–300	−0.9/−1.3	−1.4/−1.8	−1.4/−1.9	−1.1/−2.8	−0.4/−1.6	−3.3/−3.4
301–315	−0.7/−0.9	−1.1/−1.4	−1.1/−1.4	−0.2/−1.0	−0.4/−0.4	−3.1/−3.2
316–330	−0.6/−0.7	−1.0/−1.1	−0.9/−1.0	0.3/−0.1	−0.4/−0.4	−2.8/−3.0
331–345	−0.6/−0.6	−1.0/−1.0	−0.9/−0.9	0.4/0.3	−0.4/−0.4	−2.8/−2.8
346–360	−0.6/−0.7	−1.0/−1.0	−0.8/−0.9	0.4/0.3	−0.4/−0.4	−2.8/−3.1

TABLE 7. *Comparison of the power gain of mobile and disguised antennas at location 6 (right front fender) and the power gain of a slot antenna mounted in the vehicle trunk without lights/siren installed.*

Azimuth interval (degrees)	*40 MHz mobile Gain (dB) Max/Min*	*40.27 MHz disguised Gain (dB) Max/Min*	*150 MHz mobile Gain (dB) Max/Min*	*162.475 MHz disguised Gain (dB) Max/Min*	*460 MHz mobile Gain (dB) Max/Min*	*416.975 MHz disguised Gain (dB) Max/Min*	*413 MHz slot Gain (dB) Max/Min*
1–15	−3.0/−3.6	−11.3/−11.9	−1.9/−2.7	−4.6/−5.1	4.3/4.0	−7.8/−8.7	−8.9/−14.5
16–30	−3.6/−4.5	−12.0/−12.8	−1.5/−1.8	−4.1/−4.5	4.3/4.2	−8.0/−8.8	−13.8/−17.5
31–45	−4.6/−5.6	−12.8/−13.7	−1.4/−1.5	−4.1/−4.4	4.3/3.8	−7.8/−8.9	−14.5/−17.8
46–60	−5.7/−6.9	−13.8/−14.8	−1.4/−1.5	−4.4/−4.7	3.9/2.8	−8.8/−9.9	−10.1/−13.8
61–75	−6.9/ND[a]	−14.9/−16.0	−1.4/−1.5	−4.6/−4.8	4.0/2.6	−7.3/−8.5	−11.5/−40.3
76–90	−8.3/−8.9	−16.1/−17.1	−1.3/−1.5	−3.6/−4.6	4.0/2.6	−7.2/−7.5	−13.7/−35.3
91–105	−8.8/−9.1	−17.1/−17.6	−1.3/−2.1	−3.3/−3.5	3.7/2.8	−7.5/−9.1	−7.5/−12.4
106–120	−7.2/−8.7	−15.8/−17.2	−2.1/−2.7	−3.4/−4.4	3.6/2.1	−8.5/−9.7	−6.3/−10.0
121–135	−5.4/−7.0	−13.9/−15.7	−1.7/−2.8	−4.6/−7.1	4.4/2.8	−8.2/−9.5	−6.4/−7.5
136–150	−3.8/−5.2	−12.2/−13.7	−0.1/−1.5	−6.3/−7.6	3.7/1.0	−7.2/−8.7	−4.5/−7.1
151–165	−2.9/−3.8	−11.0/−12.1	−0.0/−0.2	−5.4/−6.1	2.6/0.6	−7.0/−9.9	−3.0/−4.4
166–180	−2.1/−2.8	−10.2/−10.9	−0.3/−0.5	−5.5/−7.2	2.9/−0.4	−10.0/−10.6	−0.3/−2.8
181–195	−1.5/−2.0	−9.5/−10.1	−0.5/−0.6	−7.3/−8.3	2.9/1.4	−9.8/−11.2	−0.3/−4.2
196–210	−1.1/−1.4	−9.1/−9.5	−0.2/−0.6	−6.4/−8.1	1.4/0.7	−8.5/−9.5	−4.5/−5.9
211–225	−1.0/−1.1	−9.0/−9.1	−0.0/−0.2	−5.6/−6.3	0.6/−2.4	−7.6/−8.6	−5.1/−7.3
226–240	−1.0/−1.3	−9.0/−9.4	−0.0/−0.5	−5.6/−6.5	1.9/−2.4	−7.4/−8.2	−6.8/−9.6
241–255	−1.4/−1.9	−9.4/−10.0	−0.6/−1.5	−6.5/−7.1	4.4/2.1	−7.5/−10.8	−6.8/−9.7
256–270	−2.0/−2.6	−10.0/−10.6	−0.5/−1.5	−6.3/−7.1	4.0/2.8	−11.4/−26.3	−4.7/−12.8
271–285	−2.6/−2.9	−10.7/−11.0	−0.1/−0.5	−4.6/−6.3	4.4/2.7	−12.4/−27.8	−14.3/−30.5
286–300	−2.8/−2.9	−11.0/−11.0	−0.2/−0.6	−3.7/−4.5	4.6/2.7	−8.8/−11.9	−7.6/−13.0
301–315	−2.7/−2.8	−10.9/−11.0	−0.2/−0.5	−3.7/−4.2	5.5/3.1	−7.5/−9.5	−8.0/−9.8
316–330	−2.5/−2.7	−10.8/−10.9	−0.2/−1.0	−4.2/−4.7	4.6/3.3	−8.1/−11.6	−8.1/−11.9
331–345	−2.5/−2.6	−10.8/−11.0	−1.1/−2.5	−4.7/−5.3	4.0/1.7	−7.9/−14.1	−5.4/−9.3
346–360	−2.6/−3.0	−11.0/−11.3	−2.6/−2.8	−5.1/−5.4	4.1/3.1	−7.9/−13.8	−5.4/−8.4

[a] ND—No data

TABLE 8. *The effects of improper grounding of the lights/siren on the power gain of a 40 MHz antenna mounted at roof location 2.*

Azimuth interval (degrees)	*Proper ground Gain (dB) Max/Min*	*Improper ground Gain (dB) Max/Min*
1–15	−1.0/−1.1	−2.0/−1.8
16–30	−1.1/−1.2	−2.1/−2.5
31–45	−1.2/−1.4	−2.5/−2.9
46–60	−1.4/−1.6	−3.0/−3.5
61–75	−1.6/−1.9	−3.5/−3.9
76–90	−1.9/−2.1	−3.9/−4.0
91–105	−2.0/−2.1	−3.8/−4.0
106–120	−1.6/−2.0	−3.1/−3.7
121–135	−1.2/−1.6	−2.5/−3.1
136–150	−0.8/−1.1	−2.0/−2.4
151–165	−0.5/−0.7	−1.8/−1.9
166–180	−0.5/−0.6	−1.7/−1.8
181–195	−0.6/−0.8	−1.8/−2.1
196–210	−0.9/−1.3	−2.1/−2.6
211–225	−1.4/−1.9	−2.7/−3.2
226–240	−1.9/−2.4	−3.2/−3.6
241–255	−2.4/−2.6	−3.6/−3.7
256–270	−2.4/−2.6	−3.2/−3.6
271–285	−1.9/−2.4	−2.6/−3.2
286–300	−1.4/−1.8	−2.0/−2.5
301–315	−1.1/−1.4	−1.6/−1.9
316–330	−1.0/−1.1	−1.5/−1.6
331–345	−1.0/−1.0	−1.5/−1.6
346–360	−1.0/−1.0	−1.6/−1.7

TABLE 9. *The effects of improper trunk lid grounding on the power gain of a 40 MHz antenna mounted at trunk location 4.*

Azimuth interval (degrees)	*Proper ground Gain (dB) Max/Min*	*Improper ground Gain (dB) Max/Min*
1–15	0.3/0.0	−3.2/−3.7
16–30	0.0/−0.5	−3.8/−4.8
31–45	−0.5/−1.2	−4.9/−6.4
46–60	−1.3/−2.3	−6.5/−8.3
61–75	−2.4/−3.4	−8.5/−10.0
76–90	−3.5/−4.3	−10.1/−11.3
91–105	−4.4/−4.8	−11.4/−12.0
106–120	−4.8/−4.9	−12.0/−12.3
121–135	−4.9/−5.1	−12.1/−12.3
136–150	−5.1/−5.2	−11.6/−12.1
151–165	−5.3/−5.4	−11.2/−11.6
166–180	−5.4/−5.6	−11.2/−11.4
181–195	−5.5/−5.6	−11.4/−12.0
196–210	−5.4/−5.5	−12.1/−13.1
211–225	−5.4/−5.5	−13.2/−14.4
226–240	−5.5/−5.7	−14.5/−16.0
241–255	−5.7/−5.9	−16.3/−18.3
256–270	−4.8/−5.8	−16.1/−18.7
271–285	−2.9/−4.6	−10.4/−15.6
286–300	−1.1/−2.8	−6.7/−10.0
301–315	−0.2/−1.0	−4.5/−6.5
316–330	0.3/−0.1	−3.4/−4.4
331–345	0.4/0.3	−3.0/−3.3
346–360	0.4/0.3	−3.0/−3.2

END