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Susceptibility of Emergency Vehicle Sirens to External Radiated Electromagnetic Fields

NIJ Report–200-85

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ABOUT THE TECHNOLOGY ASSESSMENT PROGRAM

The Technology Assessment Program is sponsored by the Office of Development, Testing, and Dissemination of the National Institute of Justice (NIJ), U.S. Department of Justice. The program responds to the mandate of the Justice System Improvement Act of 1979, which created NIJ and directed it to encourage research and development to improve the criminal justice system and to disseminate the results to Federal, State, and local agencies.

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The program operates through:

The *Technology Assessment Program Advisory Council* (TAPAC) consisting of nationally recognized criminal justice practitioners from Federal, State, and local agencies, which assesses technological needs and sets priorities for research programs and items to be evaluated and tested.

The *Law Enforcement Standards Laboratory* (LESL) at the National Bureau of Standards, which develops voluntary national performance standards for compliance testing to ensure that individual items of equipment are suitable for use by criminal justice agencies. The standards are based upon laboratory testing and evaluation of representative samples of each item of equipment to determine the key attributes, develop test methods, and establish minimum performance requirements for each essential attribute. In addition to the highly technical standards, LESL also produces user guides that explain in nontechnical terms the capabilities of available equipment.

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James K. Stewart, Director
National Institute of Justice

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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: $(T_C \times 9/5)+32=T_F$
Temperature: $(T_F-32)\times 5/9=T_C$

SUSCEPTIBILITY OF EMERGENCY VEHICLE SIRENS TO EXTERNAL RADIATED ELECTROMAGNETIC FIELDS

Ramon L. Jesch*

National Bureau of Standards, Boulder, CO 80303

This report provides the results of an exploratory study to determine the susceptibility of electronic sirens to interference from typical communications equipment such as the transmitters and antennas likely to be operated in and around a law enforcement vehicle.

Tests were performed using five sirens and communications equipment operating at frequencies representing the frequency bands of 25 to 50, 150 to 174, 400 to 512, and 806 to 866 MHz. The sirens were mounted on top of a vehicle equipped with transmitters and roof-mounted antennas and subjected to levels of field strength generated by mobile transmitting equipment having output levels up to 100 W. The control units of the sirens were also subjected to various levels of field strength inside a transverse electromagnetic (TEM) cell or an anechoic chamber to determine their susceptibility to electromagnetic fields.

Key words: communication equipment; field strength; sirens; susceptibility; transmitter.

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. The communication equipment utilized by law enforcement agencies operate over a broad frequency range. Transmitters are used at selected frequencies from about 25 to 900 MHz, and mobile transmitters with output powers of 100 W are commonplace. The use of several items of electronic equipment in close proximity to each other may result in degraded communications system performance as a consequence of electromagnetic interference (EMI). Performance is also affected by less identifiable sources of interference, such as automotive ignition systems, vehicle warning lights and sirens, and the mobile operating environment.

Because of concern regarding the effect of electromagnetic radiation on other equipment, a program was undertaken by the Law Enforcement Standards Laboratory (LESL) of the National Bureau of Standards (NBS) to develop standards that will minimize degradation in communications system performance caused by electromagnetic interference from all sources that affect such systems. The first phase of this program, which was undertaken at the request of the National Institute of Justice (NIJ), was to study and measure the field strength levels that are generated by typical mobile and personal transmitters used by law enforcement personnel, either in open space or inside and around a vehicle. The results of that work were discussed in NIJ report 200-83 [1][1]. The second phase of this program was to expand the scope of the measurements to include other interference sources such as emergency vehicle sirens, rotating warning lights and vehicle emissions. Prior to commencing the second phase effort, a decision was made to concentrate on vehicle sirens, their potential to interfere with typical police communications, and their susceptibility to interference from typical communications equipment (transmitter and associated antenna) likely to be operated in and around a law enforcement vehicle. This report contains the results of

*Electromagnetic Fields Division, Center for Electronics and Electrical Engineering, National Engineering Laboratory.
[1] Numbers in brackets refer to references in section 4.

susceptibility tests conducted on sirens and their control units to determine possible substandard performance. The sirens were mounted on top of a vehicle equipped with roof-mounted antennas using a transmitter inside the vehicle. The siren control units were also subjected to various levels of field strength inside a TEM cell or an anechoic chamber.

Several years ago LESL conducted a research program to develop standards for vehicle emergency warning devices, including sirens and warning lights. Previous NIJ reports [2,3] and NBS special publications [4,5] addressed the subject of sirens and warning light systems in an attempt to identify and quantify the physical parameters of these devices and their effectiveness in enabling police to perform their duties with efficiency and safety. An NIJ standard [6] has been developed to establish performance requirements and methods of test for electronic and electromechanical sirens used on law enforcement vehicles.

2. SUSCEPTIBILITY TESTS

2.1 Energy Sources and Instrumentation

Five electronic sirens, consisting primarily of a signal generator and a loudspeaker, were obtained from different manufacturers and were each mounted, in turn, on top of a production American hatchback vehicle (fig. 1) equipped with roof-mounted antennas and investigated for their susceptibility to those levels of field strength generated by mobile transmitting equipment having output powers up to 100 W. Tests for susceptibility to external radiated electromagnetic fields were conducted at frequencies of 40.27, 162.475, 416.975, and 823 MHz using mobile transmitting equipment having output power levels of 80, 100, 100, and 40 W, respectively. Figure 2 shows the four transmitters mounted on a rack in the back of the vehicle. The interconnecting coaxial cables used with the antennas and the transmitters were routed beneath the headliner and as close as possible to the vehicle body, which was metallic. No tests were made on a vehicle having other than a metallic roof. The control units for the sirens were mounted underneath the right-hand dashboard near the floor (fig. 3). The tests were conducted in a remote wooded area where the audible output of the sirens would not disturb other personnel.

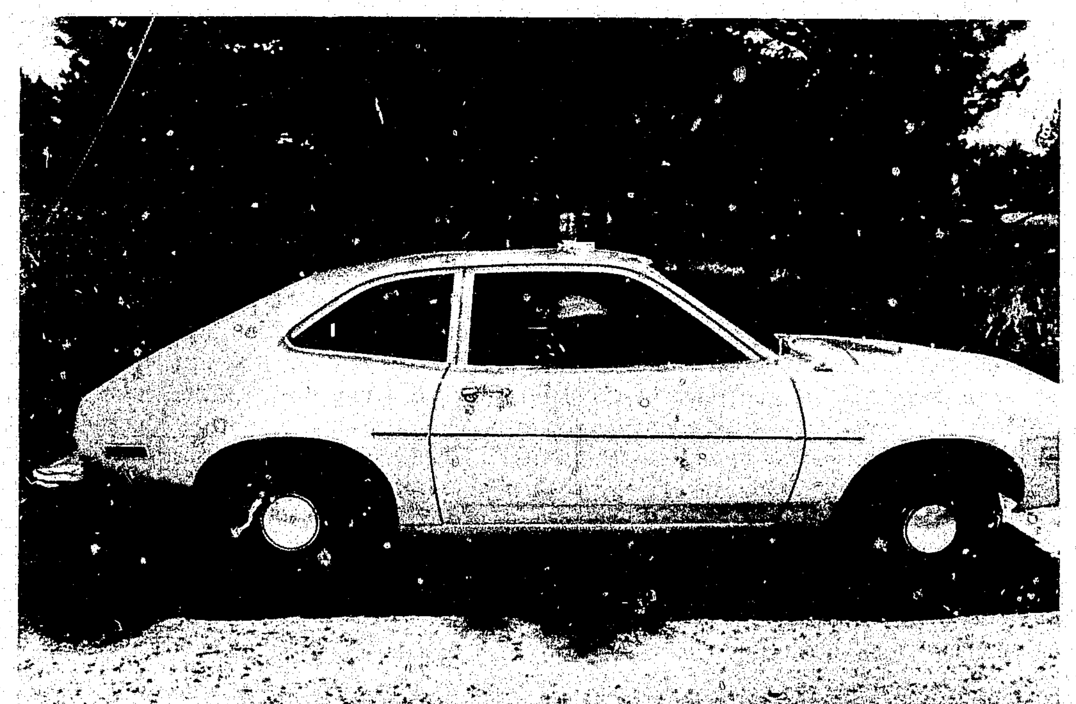

FIGURE 1. *Antenna and siren mounted on vehicle roof.*

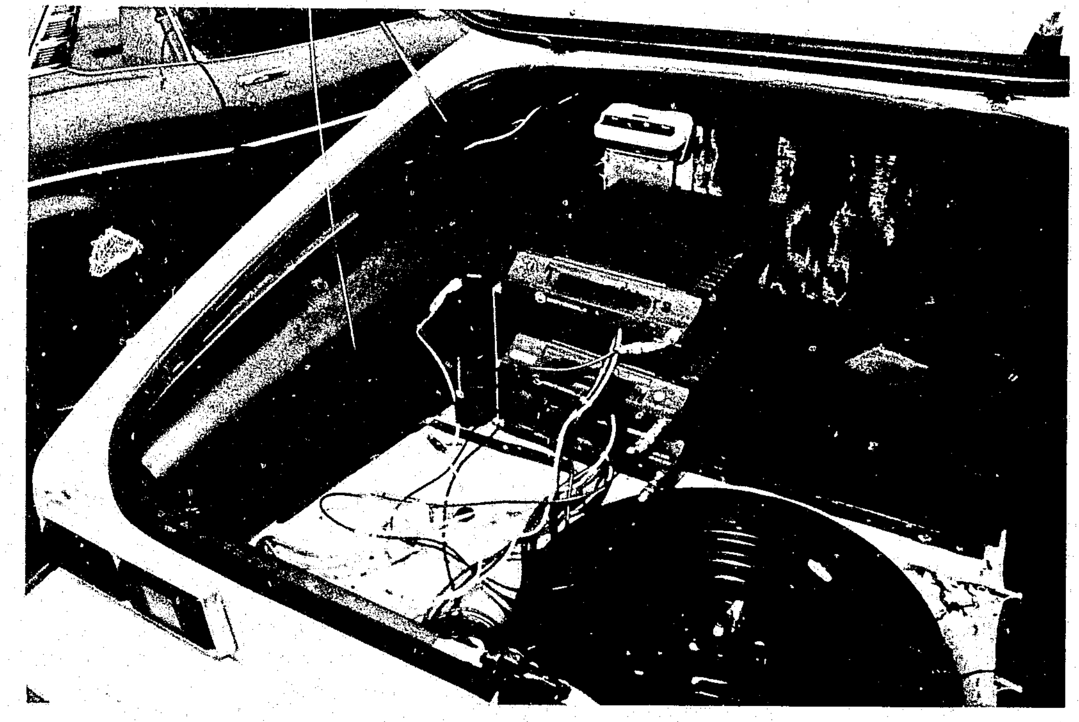

FIGURE 2. *Transmitters used for the susceptibility tests.*

FIGURE 3. *Mounting position of control unit for siren.*

2.2 Measurement Conditions

Five siren operating modes were used for the susceptibility tests as follows:

1. The *Manual* operational mode of a siren that produces a rising frequency (pitch) until either the apex is reached or the control is released. The operator can produce a wailing sound in this mode of operation by alternately closing and releasing a momentary contact switch.
2. The *High-Low* operational mode of a siren that produces a pattern of alternating high and low tones at nominal cycling rates of 40 to 60 cycles per minute (c/m).
3. The *Wail* operational mode of a siren that produces a tonal pattern of slow, automatic increases and decreases in frequency at a nominal cycling rate that ranges from 15 to 30 c/m.
4. The *Yelp* operational mode of a siren that produces a tonal pattern of rapid, automatic increases and decreases in frequency at a nominal cycling rate of 160 to 240 c/m.
5. The *Public Address* operational mode of a siren that automatically mutes the siren when the mobile radio is being used.

Each siren was mounted, in turn, on top of the vehicle approximately 30 cm (12 in) forward of the roof-mounted transmitter antenna. At each of the four designated frequencies and output power levels of the mobile transmitting equipment, tests were conducted using each of the five siren operating modes. This was done by an operator either speaking into or keying the microphone of the mobile radio system inside the vehicle (fig. 4). Simultaneously, the operator and one other party listened to the audible output of the siren and speaker of the mobile radio system while switching through the five siren operating modes. Any changes in the audible characteristics of the siren in the different modes or noises in the speaker of the mobile radio system were easily heard and distinguished by both parties.

FIGURE 4. *Operator speaking into the mobile radio system microphone.*

The siren control units were also tested inside a TEM cell [7] or an anechoic chamber [8] by subjecting the units to varying levels of electric field strength. The TEM cell was used to test the siren control units in the 25–50 MHz and the 150–174 MHz frequency bands while the anechoic chamber was used for the 400–512 MHz and the 806–866 MHz frequency bands. The siren control units were each placed, in turn, inside the TEM cell or anechoic chamber and operated over the above frequency bands while varying the levels of electric field strength from approximately 0 up to 150 V/m. Concurrently, an operator listened to the audible output from the siren while switching through the five siren operating modes.

3. MEASUREMENT RESULTS[2]

Table 1 shows the type of susceptiblity of each of the five sirens to interference from the transmitter and associated antennas at frequencies of 40.27, 162.475, 416.975, and 823 MHz, as determined by the two listeners, with transmitter output power levels of 80, 100, 100, and 40 W, respectively. Although identified only by number, the sirens tested were typical of those used by the law enforcement community.

TABLE 1. *Siren susceptibility test results at selected frequencies.*

	Frequency—MHz			
Siren	40.27	162.475	416.975	823
1	*	*	B	*
2	*	A	B	*
3	*	*	*	*
4	*	A	*	*
5	*	A	*	*

* – No effect.
A – In the public address operational mode, engine ignition and alternator noise were heard on the mobile radio speaker.
B – In the wail operational mode, there was a slight tonal variation.

In addition to the caveat in footnote 2, it should be noted that the table 1 results apply only to the actual measurement conditions and the type of vehicle used. For example, as noted in section 2.1, the test automobile is a hatchback type; the same transmitters mounted in a different type of vehicle with the same antennas and sirens mounted on the roof may produce different results.

For these particular tests, the siren/control unit systems operating in two of the frequency bands, i.e., 150–174 MHz and 400–512 MHz, appeared to be more susceptible to EMI, with vehicle noise predominating at 162.475 MHz and a tonal variation at 416.975 MHz. The peak sound level of the siren output also varied at the time of tonal variation, but there was no correlation between these results, i.e., degraded output did not vary consistently with the variation in tone. There appears to be no ready explanation as to why the tonal quality varied slightly on two of the sirens in the wail operational mode but not in the other operational mode. Moreover, there is no rationale for the fact that engine ignition and alternator noise could be heard on the mobile radio speaker during operation of three of the sirens. Some improvement was noted when a by-pass capacitor was placed on the speaker lines to the siren and the power supply leads to the siren control unit. A quick visual inspection showed that some of the siren control units were not as well shielded as the others, which could account for part of the noise problem.

When the siren control units were subjected to various levels of field strength inside the TEM cell or the anechoic chamber, there was no noticeable susceptibility of any control units to levels of field strength below about 65 V/m at any frequency band. This is a more severe operating environment than that normally encountered inside a vehicle as reported in [1]. For example, the electric field strength levels between the dashboard and the floor area

[2] These results are intended to be indicative, not definitive. Therefore, statistical estimates of measurement uncertainties and details of the measurement configurations are not provided.

where the siren control units were mounted varied between 34–37 V/m at 40.27 MHz, 17–45 V/m at 162.475 MHz, 10–20 V/m at 416.975 MHz, and 7–15 V/m at 823 MHz during the testing chronicled in [1]. This leads to the conclusion that the variation in siren output was not due primarily to the susceptibility of the control unit.

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