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MAY 1974

LAW ENFORCEMENT STANDARDS PROGRAM

MOBILE ANTENNAS

U.S. DEPARTMENT OF JUSTICE
Law Enforcement Assistance Administration
National Institute of Law Enforcement and Criminal Justice

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NILECJ STANDARD FOR MOBILE ANTENNAS

A Voluntary National Standard Promulgated by the National Institute of Law Enforcement and Criminal Justice.

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NILECJ Standard for Mobile Antennas

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FOREWORD

Following a Congressional mandate* to develop new and improved techniques, systems, and equipment to strengthen law enforcement and criminal justice, the National Institute of Law Enforcement and Criminal Justice (NILECJ) has established the Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards. LESL's function is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

In response to priorities established by NILECJ, 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 guidelines, state-of-the-art surveys and other reports.

This document, NILECJ–STD–0205.00, *Mobile Antennas,* is a law enforcement equipment standard developed by LESL and approved and issued by NILECJ. Additional standards, as well as other documents will be issued under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equipment, investigative aids, vehicles and clothing.

This equipment standard is a technical document, consisting of performance and other requirements together with a description of test methods. Equipment which can meet these requirements is of superior quality and is suited to the needs of law enforcement agencies. Purchasing agents can use the test methods described in this standard to determine firsthand whether a particular equipment item meets the requirements of the standard, or they may have the tests conducted on their behalf by a qualified testing laboratory. Law enforcement personnel may also reference this standard in purchase documents and require that any equipment offered for purchase meet its requirements and that this compliance be either guaranteed by the vendor or attested to by an independent testing laboratory.

The necessary technical nature of this NILECJ standard, and its special focus as a procurement aid, make it of limited use to those who seek general guidance concerning mobile antennas. The NILECJ Guideline Series is designed to fill that need. We plan to issue guidelines to this as well as other law enforcement equipment as soon as possible, within the constraints of available funding and the overall NILECJ program.

The guideline documents to be issued are highly readable and tutorial in nature in contrast to the standards, which are highly technical, and intended for laboratory use by technical personnel. The guidelines will provide, in nontechnical language, information for purchasing agents and other interested persons concerning the capabilities of equipment currently available. They may then select equipment appropriate to the performance required by their agency. Recommendations for the development of particular guidelines should be sent to us.

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*Section 402(b) of the Omnibus Crime Control and Safe Streets Act of 1968, as amended.

NILECJ standards are subjected to continuing review. Technical comments and recommended revisions are invited from all interested parties. Suggestions should be addressed to the Program Manager for Standards, National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice, Washington, D.C. 20530.

LESTER D. SHUBIN, *Manager*
Standards Program

NILECJ STANDARD for MOBILE ANTENNAS

1. PURPOSE AND SCOPE

The purpose of this document is to establish minimum performance requirements and methods of test for mobile antennas mounted on vehicles used by law enforcement agencies. This standard deals with those characteristics which determine the suitability and effectiveness of these antennas for law enforcement use.

2. CLASSIFICATION

For the purposes of this standard, antennas are classified by their operating frequency and their directional pattern.

2.1 Operating Frequency

2.1.1 Type I

Antennas which operate primarily in the 400-512 MHz band.

2.1.2 Type II

Antennas which operate primarily in the 150-174 MHz band.

2.1.3 Type III

Antennas which operate primarily in the 25-50 MHz band.

2.2 Directional Pattern

2.2.1 Omnidirectional Antenna

2.2.2 Directional Antenna

3. DEFINITIONS

The principal terms used in this document are defined in this section. Additional definitions relating to law enforcement communications are given in LESP-RPT-0203.00, Technical Terms and Definitions Used with Law Enforcement Communications Equipment (Radio Antennas, Transmitters, and Receivers).

3.1 Dipole Antenna, Resonant Half-Wavelength

A straight radiator (usually energized at the center) whose diameter is small compared to its length and whose electrical length is equal to one-half the wavelength of the energizing signal. The radiator supports a line current distribution such that a current node exists at each of the ends, producing maximum radiation in the plane normal to its axis.

3.2 Directional Pattern (Radiation Pattern)

A characteristic of antennas which describes the transmitting or receiving properties of the antenna as a function of space coordinates. Cross sections in which directional patterns are frequently given are vertical planes, horizontal planes, or the principal electric and magnetic polarization planes. Radiation properties may include radiation intensity field strength, phase, and polarization.

3.3 Monopole Antenna, Resonant Quarter-Wavelength

An antenna which utilizes an image plane to produce a directional pattern approximating that of an electric dipole antenna and whose electrical length is equal to one-fourth the wavelength of the exciting signal.

3.4 Power Rating

The maximum continuous wave power which can be applied to the antenna in accordance with the standard duty cycle without degrading its performance beyond specified limits.

3.5 Radiation Intensity

The power radiated from an antenna per unit solid angle.

3.6 Relative Gain

The ratio of the radiation intensity of the antenna in a given direction to the radiation intensity of a reference antenna in the same direction with the same net power input to both antennas.

3.7 Voltage Standing Wave Ratio (VSWR)

The ratio of the maximum voltage to the minimum voltage in the standing wave pattern that appears along a lossless 50-ohm transmission line with the antenna as the termination of the transmission line.

4. REQUIREMENTS

4.1 User Information

The information supplied to the user by the manufacturer or distributor shall include the following:

(a) Operating frequencies
(b) Relative antenna gain
(c) Directional pattern
(d) VSWR
(e) Antenna power rating
(f) Antenna material composition

4.2 Test Sequence

Each antenna tested shall be subjected to the shock test, vibration test, and antenna power test, and shall then be tested for conformance with paragraphs 4.6, 4.7, and 4.8.

4.3 Shock Stability

No fixed part shall become loose nor shall any movable part be shifted in position or adjustment when the antenna is subjected to the shock test described in paragraph 5.3.1.

4.4 Vibration Stability

No fixed part shall become loose nor shall any movable part be shifted in position or adjustment when the antenna is subjected to the vibration test described in paragraph 5.3.2.

4.5 Antenna Power Rating

The antenna shall not be physically damaged by the test described in paragraph 5.3.3.

4.6 Relative Antenna Gain

The relative antenna gain, measured in accordance with paragraph 5.3.4, shall be within 1.0 decibel (or 10% of the maximum relative gain in decibels, whichever is greater) of the specified value.

4.7 Directional Pattern

4.7.1 Omnidirectional Antenna

When the directional pattern of the antenna is measured in accordance with paragraph 5.3.5, the variation shall be within 1.0 decibel throughout a 360° variation in azimuthal angle.

4.7.2 Directional Antenna

When the directional pattern of the antenna is measured in accordance with paragraph 5.3.5, the variation from the specified pattern shall be within 1.0 decibel (or 10% of the maximum relative antenna gain in decibels, whichever is greater) throughout the horizontal beamwidth of the specified major lobe.

4.8 VSWR

The VSWR of the antenna, measured in accordance with paragraph 5.3.6, shall be less than 1.5 referenced to a 50-ohm system.

5. TEST METHODS

5.1 Standard Test Conditions

All measurements, unless otherwise specified, shall be performed under standard test conditions.

5.1.1 Standard Radiation Test Site

The standard radiation test site shall be located on level ground which has uniform electrical characteristics (i.e., ground constants). Reflecting objects (especially large metal objects), trees, buildings, and other objects which would perturb the electromagnetic fields to be measured should be no closer than 90 meters (295 ft) to any test equipment or equipment under test. All utility lines and any control circuits between test positions should be buried underground to a depth of 1 meter (approximately 3.3 ft). The ambient electrical noise level shall be as low as possible and shall be carefully monitored to insure that it does not interfere with the test being performed. Preferably, the test site should be equipped with a remotely controlled turntable located at ground level.

5.1.2 Standard Duty Cycle

The standard duty cycle shall be 2 min with rated power applied to the antenna followed by 3 min with no power applied.

5.1.3 Test Frequencies

Tests shall be conducted at the operating frequencies specified in paragraph 4.1 (a).

5.2 Test Equipment

The test equipment described in this section is limited to that equipment which is the most critical in making the required measurements. All other test equipment shall be of comparable quality.

5.2.1 Field Strength Meter

The field strength meter, consisting of an antenna and a well-shielded calibrated receiver which operate over the frequency range of the antenna under test, shall have a resolution of at least 0.2 decibel. The receiver should be located near the receiving antenna to keep the length of the cable between the antenna and the receiver as short as possible.

5.2.2 Reference Antenna

The reference antenna shall consist of a resonant quarter-wavelength monopole constructed of silver-plated brass tubing 0.318 cm (0.125 in) in diameter and mounted on a ground plane as described in paragraph 5.3.4.1 or 5.3.4.2. The length of the monopole at each test frequency shall be calculated using the following formula, where L is the length of the monopole and λ is the test wavelength, both in centimeters.

$$L = \left[1 - \frac{27.08}{120 \left[\ln \left(\frac{\lambda}{.318} \right) - 1 \right]} \right] \frac{\lambda}{4}$$

Examples of reference antenna monopole lengths calculated using this formula are given in table 1. Refer to appendix A for a comparison of the gain of the reference antenna to that of an isotropic radiator.

TABLE 1.—*Examples of reference antenna monopole lengths using equation from paragraph 5.2.2*

Resonant frequency (MHz)	Reference antenna length (cm)
40.0	187.5
160.0	44.9
460.0	15.45

5.2.3 Power Meter

The power meter shall measure both incident and reflected power and have a measurement range from 1 milliwatt to 10 watts. The uncertainty of the power measured shall be less than 5 percent.

5.2.4 Impedance Matching Unit

The impedance matching unit shall provide a conjugate impedance match between the antenna and the rf signal source. The insertion loss of the matching unit shall be less than 0.2 decibel.

5.3 Measurement Techniques

All measurement equipment shall be allowed to warm up until the system has achieved sufficient stability to perform the measurements within the uncertainties required. For tests which require the use of the standard duty cycle, provisions should be made to avoid drift due to switching the signal source completely off.

5.3.1 Shock Test

The antenna shall be mounted on a stationary supporting structure. A rigid metal rod shall be mounted on a movable apparatus driven by a piston or motor capable of moving the rod at 16.09 km/h (10 mi/h) at the time it strikes the antenna. 1500 blows shall be administered to the antenna major axis at a point two thirds of the length of the antenna above the mounting surface [1].

5.3.2 Vibration Test

The antenna shall be vibrated in a plane perpendicular to its major axis with a simple harmonic motion having an amplitude of 0.76 mm (0.03 in) [total excursion of 1.52 mm (0.06 in)] while the frequency is varied slowly between 10 and 60 Hz.

5.3.2.1 The frequency at which the antenna has its most severe resonance shall be noted and designated f. The antenna shall then be vibrated in the same plane with the same amplitude while the frequency is varied uniformly from 0.9 f to 1.1 f and back to 0.9 f. The cycle shall be accomplished in 5 min and shall be repeated continually for 4 h.

5.3.2.2 If no resonance is found, the antenna shall be vibrated in the same plane with the same amplitude while the frequency is varied uniformly from 10 to 60 Hz, and back to 10 Hz. The cycle shall be accomplished in 5 min and shall be repeated continually for a period of 8 h [1].

5.3.3 Antenna Power Test

The test antenna shall be mounted on the ground plane and positioned above the ground as described in paragraph 5.3.4. The test equipment shall be connected as shown in figure 1. Rated power shall be applied in accordance with the standard duty cycle for 8 hours and the relative gain, directional pattern and VSWR shall then be measured as described in paragraphs 5.3.4, 5.3.5 and 5.3.6, respectively.

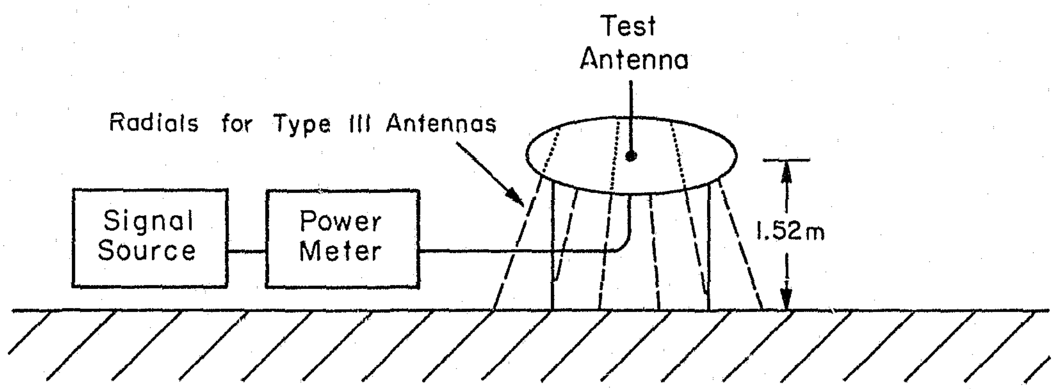

FIGURE 1. *Antenna power test measurement setup.*

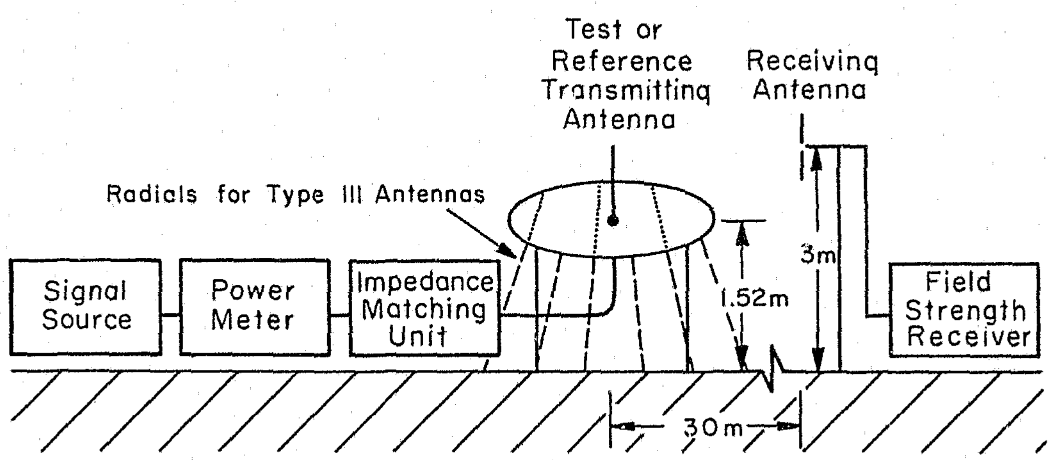

FIGURE 2. *Relative antenna gain measurement setup.*

5.3.4 Relative Antenna Gain Test

Although relative antenna gain is defined in terms of radiation intensity, the measurement procedure described herein uses a field strength measurement technique to determine the value of this characteristic.

5.3.4.1 Type I and Type II Antennas

The antenna under test shall be center mounted (±1 cm) on, and perpendicular to, a circular aluminum ground plane with a diameter of 1.47 meters (58.0 in), which is 1.52 meters (60.0 in) above the earth, parallel to it and electrically insulated from it. The signal source, power meter, and impedance matching unit shall be connected to the antenna as shown in figure 2 and as close to the antenna as possible. The midpoint of the receiving antenna shall be 3.0 meters (9.84 ft) above the earth at a horizontal distance of 30.0 meters (98.4 ft) from the transmitting antenna. The receiving antenna shall be oriented for the same polarization as the transmitting antenna.

The signal source shall be adjusted for an output of approximately 1 watt and the matching unit adjusted for maximum power into the test antenna. The signal source shall then be adjusted for a reading of 1 watt on the power meter and the field strength measured by the field strength receiver recorded in decibels.

The test antenna shall then be replaced with the reference antenna, the procedure repeated, and the measured field strength again recorded in decibels. The measured field strength from the test antenna minus the measured field strength from the reference antenna represents the gain of the test antenna relative to the reference antenna.

5.3.4.2 Type III Antennas

The measurement technique and equipment shall be the same as that described in paragraph 5.3.4.1 with the exception of the ground plane. The ground plane for both the reference antenna and the antenna under test shall be modified as follows:

Six conducting radial elements, each 2.5 meters (98.4 in) in length, shall be electrically attached to the plane, equally spaced around its perimeter. The radials shall be constructed of approximately 6.35 mm (0.25 in) diameter copper or aluminum material and shall be extended outward from the ground plane to the ground, taking care that the radials are electrically insulated from the earth.

5.3.5 Directional Pattern Test

5.3.5.1 Type I and Type II Antennas

The test antenna and field strength meter shall be arranged as described in paragraph 5.3.4.1 with the exception of the impedance matching unit which is not required for this measurement. Power shall be applied to the test antenna and the field strength measured and recorded. The azimuthal angle for this first measurement shall be taken as 0°. The test antenna shall then be rotated horizontally 45° and the field strength again measured and recorded. This procedure shall be repeated until the test antenna has been rotated 360°. The field strength at 360° should agree with the field strength measured at 0° within 0.5 dB for the pattern measurements to be considered valid. The difference between the maximum and minimum field strengths recorded represents the variation in the directional pattern. If the test antenna is not omnidirectional, horizontal rotations of the antenna shall be made in increments of 10 degrees from the center of the major lobe to measure its pattern.

5.3.5.2 Type III Antennas

The measurement procedure shall be the same as that described in paragraph 5.3.5.1 with the exception that the ground plane shall be modified as described in paragraph 5.3.4.2.

5.3.6 Voltage Standing Wave Ratio (VSWR) Test

Although VSWR is defined in terms of voltage, the measurement procedure described herein uses a power measurement technique to determine VSWR.

5.3.6.1 Type I and Type II Antennas

The test antenna shall be mounted on the ground plane and positioned above the ground as described in paragraph 5.3.4.1. The signal source and power meter shall be connected as shown in figure 1, using as short a cable as possible between the power meter and the antenna. The insertion loss of this cable shall be 0.5 dB or less.

The incident power delivered to the antenna and the reflected power from the antenna shall be measured with the power meter. The VSWR shall then be calculated from the following relationship, where P_i is the incident power in watts and P_r is the reflected power in watts.

$$VSWR = \frac{\sqrt{P_i} + \sqrt{P_r}}{\sqrt{P_i} - \sqrt{P_r}}$$

The power delivered to the antenna is arbitrary except that it should be greater than 25 times the minimum power that can be measured on the power meter but less than the power rating of the antenna.

5.3.6.2 Type III Antennas

The measurement procedure shall be the same as that described in paragraph 5.3.6.1 with the exception that the ground plane shall be modified as described in paragraph 5.3.4.2.

APPENDIX A — Isotropic Radiator Comparison

To express the gain of the test antenna relative to an isotropic radiator, the gain of the reference antenna given below should be added to the relative antenna gain of the test antenna. The reference antenna was calibrated by NBS in terms of NBS standard antennas [2,3,4,5].

For type I and II antennas, the reference antenna has a gain over average ground relative to an isotropic radiator as follows:

Frequency (MHz)	Gain relative to an isotropic radiator (dB)
150	−0.1
156	0.0
174	−0.5
400	+1.3
450	+0.7
475	0.0

Relative antenna gain can readily be measured within 0.1 dB; however, the numerical value obtained may vary by as much as 1.0 dB due to variations in the environment, principally the dielectric constant and the conductivity of the ground.

The gain of the reference antenna relative to an isotropic radiator has not been determined for type III antennas. When this information becomes available, this appendix will be amended.

APPENDIX B — References

[1] EIA Standard RS-329-1, "Minimum Standards for Mobile Communication Antennas, Part II—Vehicular Antennas" (August 1972).

[2] Taggart, H. E., and Workman, J. L., "Calibration Principles and Procedures for Field Strength Meters (30 Hz to 1 GHz)," NBS Tech. Note 370 (March 1969).

[3] Green, F. M., "NBS Field-Strength Standards and Measurements (30 Hz to 100 MHz)," Proceedings IEEE, Vol. 55, No. 6, pp. 970-981 (June 1967).

[4] Taggart, H. E., "Field Strength Calibration Techniques at the National Bureau of Standards," IEEE Trans. Vol. EMC-7, No. 2 (June 1965).

[5] McMullin, T. J., "Gain Antennas for Mobile Application," presented at IEEE Vehicular Communications Conference, Cleveland, Ohio, December 3-4, 1964.
[6] Fitzgerrell, R. G., "Gain Measurements of Vertically-Polarized Antennas Over Imperfect Ground," IEEE Trans. Antennas and Propagation, Vol. AP-15, No. 2 (March 1967).
[7] Berry, L. A., and Chrisman, M., "Linear High Frequency Antennas Over a Finitely Conducting Spherical Earth," ESSA Tech. Report IER 8-ITSA 8 (September 1966).
[8] Ma, M. T., and Walters, L. C., "Power Gains for Antenna Over Lossy Plane Ground," ESSA Tech. Report ERL 104-ITS 74 (April 1969).
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