U.S. Department of Justice
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Law Enforcement and Corrections Standards and Testing Program

Mobile Antennas

NIJ Standard-0205.02

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The Law Enforcement and Corrections Standards and Testing Program is an applied research effort that determines the technological needs of justice system agencies, sets minimum performance standards for specific devices, tests commercially available equipment against those standards, and disseminates the standards and the test results to criminal justice agencies nationwide and internationally.

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Mobile Antennas

NIJ Standard-0205.02

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October 1997

National Institute of Justice

Jeremy Travis
Director

The technical effort to develop this standard was conducted under Interagency Agreement No. 94-IJ-R-004, Project No. 96-007.

This standard was formulated by the Office of Law Enforcement Standards (OLES) of the National Institute of Standards and Technology (NIST) under the direction of A. George Lieberman, Program Manager for Communications Systems, and Kathleen M. Higgins, Director of OLES. Revision of this standard was performed at the National Telecommunications and Information Administration, Institute for Telecommunications Sciences by John M. Vanderau. The preparation of this standard was sponsored by the National Institute of Justice, David G. Boyd, Director, Office of Science and Technology.

FOREWORD

This document, NIJ Standard-0205.02, Mobile Antennas, is an equipment standard developed by the Office of Law Enforcement Standards of the National Institute of Standards and Technology. It is produced as part of the Law Enforcement and Corrections Standards and Testing Program of the National Institute of Justice. A brief description of the program appears on the inside front cover.

This standard is a technical document that specifies performance and other requirements equipment should meet to satisfy the needs of criminal justice agencies for high quality service. Purchasers can use the test methods described in this standard to determine whether a particular piece of equipment meets the essential requirements, or they may have the tests conducted on their behalf by a qualified testing laboratory. Procurement officials may also refer to this standard in their purchasing documents and require that equipment offered for purchase meet the requirements. Compliance with the requirements of the standard may be attested to by an independent laboratory or guaranteed by the vendor.

Because this NIJ standard is designed as a procurement aid, it is necessarily highly technical. For those who seek general guidance concerning the selection and application of law enforcement equipment, user guides have also been published. The guides explain in nontechnical language how to select equipment capable of the performance required by an agency.

NIJ standards are subjected to continuing review. Technical comments and recommended revisions are welcome. Please send suggestions to the Director, Office of Science and Technology, National Institute of Justice, U.S. Department of Justice, Washington, DC 20531.

Before citing this or any other NIJ standard in a contract document, users should verify that the most recent edition of the standard is used. Write to: Director, Office of Law Enforcement Standards, National Institute of Standards and Technology, Gaithersburg, MD 20899.

David G. Boyd, Director
Office of Science and Technology
National Institute of Justice

NIJ STANDARD FOR MOBILE ANTENNAS

CONTENTS

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 radio
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	lb×0.4535924=kg
ft×0.3048=m	lbf×4.448222=N
ft·lbf×1.355818=J	lbf/ft×14.59390=N/m
gr×0.06479891=g	lbf·in×0.1129848=N·m
in×2.54=cm	lbf/in^2×6894.757=Pa
kWh×3 600 000=J	mph×1.609344=km/h
	qt×0.9463529=L

Temperature: $(T_{°F}-32)\times 5/9=T_{°C}$

Temperature: $(T_{°C}\times 9/5)+32=T_{°F}$

NIJ STANDARD
FOR
MOBILE ANTENNAS

1. PURPOSE AND SCOPE

The purpose of this document is to establish minimum performance requirements and methods of test for antennas that are mounted on police vehicles or other mobile platforms used by law enforcement agencies. Whereas the antennas under test must meet all the rf electrical performance specifications cited in this document at ambient conditions, the environmental performance specifications stated herein should be selectively applied according to the anticipated operating environment of the antenna. That is, the antenna need only comply with those environmental specifications not waived by the procuring agency. This standard is a revision of NIJ Standard-0205.01, dated May 1989. This revision incorporates the latest recommended methods and procedures of industry standards related to communications antennas and environmental test procedures.

2. CLASSIFICATION

2.1 Operating Frequency

2.1.1 Type I

Antennas for use in the 25 MHz to 50 MHz band.

2.1.2 Type II

Antennas for use in the 150 MHz to 174 MHz band.

2.1.3 Type III

Antennas for use in the 406 MHz to 512 MHz band.

2.1.4 Type IV

Antennas for use in the 806 MHz to 930 MHz band.

2.2 Directional Pattern

2.2.1 Omnidirectional Antennas

2.2.2 Directional Antennas

3. DEFINITIONS

The principal terms used in this document are defined in this section. These terms comply with accepted industry definitions specified in ANSI/IEEE STD 145-1993, IEEE Standard Definitions of Terms for Antennas. Other terms are defined within this section and EIA/TIA-329B-1, Minimum Standards for Communications Antennas, Part II—Vehicular Antennas.

3.1 Ambient Conditions

Ambient conditions of temperature and humidity are defined as any combination of prevailing weather conditions of temperature between 13° to 35 °C (55° to 95 °F) and relative humidity between 25 to 85 percent.

3.2 Antenna Power Rating

The maximum continuous-wave power that can be continuously applied to an antenna without degrading its performance.

3.3 Dipole Antenna, Resonant Half-Wavelength

A straight metallic radiator, usually energized at its center, whose length is slightly less than one-half wavelength[1] of the energizing signal and whose diameter is small compared to its length. The current goes to zero at the ends of the antenna. The maximum radiation intensity lies in a plane normal to the axis of the antenna.

3.4 Effective Antenna Volume

The effective antenna volume is the actual volume occupied by the radiating part of the antenna plus one-half wavelength all the way around, taking into account all appropriate conditions of the antenna under test. In certain applications, the supporting structure is in the rf field and shall be included in the effective antenna volume.

3.5 Isotropic Radiator

A hypothetical antenna that radiates or receives equally in all directions.

3.6 Major Lobe (Main Lobe)

The radiation lobe that contains the direction of maximum radiation.

3.7 Pattern Recorder

A device that records the amplitude of the output signal from an antenna and receiver and displays the amplitude as a function of the spatial orientation of the antenna. This device may collect and store tabular data or graphics information originating from a network analyzer or similar rf measurement device, and be capable of graphically plotting or displaying measured data or presenting the data in tabular format.

3.8 Polarization

In a given direction from the antenna, the orientation of the electric field vector of the wave radiated from the antenna, or the orientation of the electric field vector of the wave incident upon the antenna that produces the maximum voltage at the antenna terminals.

3.9 Quiet Zone

That region of an antenna test range illuminated by an electromagnetic wave from the source antenna where the amplitude taper (ripple) is less than 0.25 dB and phase taper (ripple) is less than 22.5°. The quiet zone must totally enclose the effective antenna volume of the antenna under test.

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[1] Dipole antennas in free space which are exactly one-half wavelength long exhibit an impedance which has an inductive component and is represented by a complex number 73+j42.5 Ω; the imaginary part of the complex number indicates the inductive effects. The reactance of the antenna depends on the length and diameter (in wavelengths) of the antenna in a complicated fashion involving sine integral functions and cosine integral functions. By shortening the antenna slightly, the inductive component can be made equal to zero. When there is no inductive or capacitive component of impedance, then the antenna is said to be resonant. Shortening the antenna from one-half wavelength to bring it into resonance also lowers the radiation resistance from 73 Ω to a value closer to 50 Ω; this further improves the impedance match and VSWR between the antenna and the 50 Ω coaxial cable transmission line.

3.10 Radiation Pattern (Antenna Pattern)

The spatial presentation of the distribution of the magnitude of the electric or magnetic field strengths, or of the power density, of an electromagnetic wave radiated from an antenna, as a function of the physical (angular) orientation of the antenna from some predefined reference orientation. Alternatively, the spatial presentation of the voltage induced at the antenna terminals by an electromagnetic wave incident upon an antenna as a function of incidence angle and incident wave polarization relative to the antenna.

3.10.1 Radiation Pattern Cut

Any path on an imaginary surface surrounding an antenna over which a radiation pattern is obtained. For far field patterns, the surface is that of a sphere. Typically, the radiation pattern cuts are "principal plane cuts" which are orthogonal "great circle cuts" that intersect through the peak of the main antenna lobe.

3.11 Relative Antenna Gain

The ratio of the power received by the antenna under test to the power received by a reference antenna oriented in the same direction, with the same incident power density, frequency, and polarization.

3.12 Scale Ratio

The ratio of operating frequency of a scale model antenna to the operating frequency of the full size antenna.

3.13 Standard Gain Unit

The reference unit used to measure relative antenna gain. The reference unit is usually either decibels relative to an isotropic antenna (dBi) or decibels relative to a lossless resonant half-wavelength dipole antenna (dBd). Gain expressed in dBi is related to gain expressed in dBd as follows:

$$G_{dBi} = G_{dBd} + 2.15 \tag{1}$$

3.14 Standing Wave Ratio (SWR) or Voltage Standing Wave Ratio (VSWR)

The ratio of maximum to minimum rf voltage (or current) appearing along a transmission line. This quantity indicates how well energy is coupled into an antenna.

4. REQUIREMENTS

4.1 Minimum Performance

The antenna shall meet or exceed all the requirements of this standard as given below and summarized in table 4.1-1. These performance requirements meet or exceed those specified in TIA/EIA STD 329-B-1.

TABLE 4.1-1. *Minimum performance standards for mobile antennas.*

Antenna Characteristic	*Minimum Requirement*
Rated Power Output	No physical damage
Relative Antenna Gain	± 1.5 dB of the relative gain specified in the major lobe, ± 5 dB in minor lobes
Radiation Pattern	± 1.5 dB of the radiation pattern specified in the major lobe, ± 5 dB in minor lobes
Voltage Standing Wave Ratio	1.5 or less

4.2 User Information

The following information shall be supplied to the purchaser by the antenna manufacturer, system integrator, or distributor, and shall include the following:

(a) Operating frequency range
(b) Antenna power rating
(c) Relative antenna gain vs operating frequency in standard gain units
(d) Polarization
(e) Vertical (elevation plane) principal plane radiation pattern cut
(f) Horizontal (azimuthal plane) principal plane radiation pattern cut
(g) Nominal impedance
(h) Voltage standing wave ratio vs operating frequency
(i) Connector type
(j) Ice load rating
(k) Physical dimensions
(l) Weight
(m) Antenna material composition
(n) Operating, installation, and maintenance instructions
(o) Rf radiation hazard zone
(p) Certification of compliance with this standard

4.3 Environmental

Mobile station antennas shall be capable of withstanding the physical environment of the climatic regions in which they exist, as defined in MIL STD 210C. Test methods described in MIL STD 810E shall be employed by the manufacturer on representative sample lots to assure compliance with the following requirements. The applicable environmental tests performed and required performance parameters are influenced by the theater of operations in which the candidate antenna system is to be deployed. Whereas the antennas under test must meet all the rf electrical performance specifications cited in this document at ambient conditions, the environmental performance specifications stated herein should be selectively applied according to the anticipated operating environment of the antenna. That is, the antenna need only comply with those environmental specifications not waived by the procuring agency.

4.3.1 High Temperature/Solar Radiation

Antennas shall withstand sustained ambient temperatures as specified in table 4.3.1-1 as determined in accordance with section 5.4.1.

TABLE 4.3.1-1. *High temperature/solar radiation performance requirements.*

Region	*Temperature*	*Solar Radiation*
CONUS, AK, HI, US territories except southwestern United States	43 °C (110 °F)	1120 W/m^2
Southwestern United States	49 °C (120 °F)	1120 W/m^2

4.3.2 Low Temperature

Antennas shall withstand sustained ambient temperatures as specified in table 4.3.2-1 as determined in accordance with section 5.4.2.

TABLE 4.3.2-1. *Low temperature performance requirements.*

Region	*Temperature*
CONUS, HI, US territories and southern coastal regions of Alaska	–32 °C (–25 °F)
Southwestern inland regions of Alaska	–46 °C (–50 °F)
Northeastern and Central Alaska	–51 °C (–60 °F)

4.3.3 Blowing Rain

Electrical performance and structural integrity of antennas can be compromised by the penetration of rain into/inside housings, connectors, radomes, matching networks, and other antenna system components, with consequent freezing, corrosion, and other adverse effects. Antennas, antenna systems, and related components shall be resistant to moisture penetration when subjected to the rainfall rates specified in table 4.3.3-1 as determined in accordance with section 5.4.3.

TABLE 4.3.3-1. *Rainfall performance requirements.*

Duration	*Rainfall Rate*	*Ambient Temperature*	*Windspeed*
1 h	15 cm/h (5.9 in/h)	24 °C (75 °F)	35 knots

4.3.4 Humidity

Detrimental effects induced by high humidity environments may manifest themselves in various ways, for example, the oxidation of metals, electrical shorts due to condensation, and degradation of electrical properties in insulating materials. Antennas, antenna systems, and related components shall be capable of withstanding repeated sustained relative humidities of 100 percent at the high and low temperature extremes cited in sections 4.3.1 and 4.3.2 without degradation of electrical performance or structural integrity as determined in accordance with section 5.4.4.

4.3.5 Salt Fog

Antenna systems located in coastal areas are subject to the corrosive effects of salt air, resulting in the oxidation of metals, electrical shorts due to condensation, and degradation of electrical properties in insulating materials. Antennas, antenna systems, and related components shall be capable of withstanding repeated sustained exposure to salt fog environments as determined in accordance with section 5.4.5.

4.3.6 Sand and Dust

Penetration and accumulation of sand or dust (including fine particulate blowing snow) particles into connectors, seals, housings, etc., can result in abrasion of electrical connections, failure of insulators, intermittent short circuits, etc. These effects can be detrimental to the desired and necessary electrical performance of antenna systems. Antennas, antenna systems, and related components shall be capable of withstanding the effects of repeated exposure to sand and dust/blowing snow as determined in accordance with section 5.4.6.

4.3.7 Icing/Freezing Rain

Icing and freezing rain greatly increases the structural weight and wind velocity loads while adding no structural integrity to the antenna. Mobile antennas deployed in areas prone to ice build-up such as the New England states, mid-Atlantic states, northern mid-west and northwest states, shall be capable of withstanding 13 mm (1/2 in) radial glaze ice when subjected to 50 knot winds.

4.4 Antenna Power Rating

The antenna shall meet the requirements of sections 4.5 through 4.7 immediately after being subjected to the test described in section 5.4. The antenna shall not be physically damaged by this test.

4.5 Relative Antenna Gain

The relative antenna gain, measured in accordance with section 5.5, shall be within ± 1.5 dB of the relative gain specified by the manufacturer in accordance with section 4.2.c.

4.6 Radiation Pattern

4.6.1 Vertical (Elevation Plane) Pattern

The vertical radiation pattern, measured in accordance with section 5.6.1, shall be within ± 1.5 dB of the vertical (elevation plane) radiation pattern specified by the manufacturer in accordance with section 4.2.e.

4.6.2 Horizontal (Azimuthal Plane) Pattern

The horizontal radiation pattern, measured in accordance with section 5.6.2, shall be within ± 1.5 dB of the horizontal (azimuthal plane) radiation pattern specified by the manufacturer in accordance with section 4.2.f. For omnidirectional antennas, the horizontal radiation pattern shall be within ± 1.5 dB throughout a 360° range in azimuth.

4.7 Voltage Standing Wave Ratio

The VSWR of the antenna, measured in accordance with section 5.7, shall be 1.5 or less, referenced to a 50 Ω system.

4.8 Radiation Hazard

Radiation hazard zones shall be identified by measurements performed in conformance with the provisions of ANSI/IEEE C95.3-1991. Radiation hazard zones are those volumes of space surrounding the antenna where the electromagnetic power density and/or field strengths exceed the industry recognized limits of ANSI/IEEE C95.1-1991. The radiation hazard zone shall be determined when transmitting at the antenna's fully rated power output. For single radiating frequencies, permissible limits of exposure are 1 mW/cm^2 for type II antennas and ranging from about 1.4 mW/cm^2 to about 3.5 mW/cm^2 for type III and type IV antennas. For type I antennas, permissible limits of exposure are expressed in field strength rather than power density, and range from about 61.4 V/m to about 80 V/m electric field strength. For multiple frequencies radiating simultaneously, the contribution from each must be derated appropriately in accordance with the provisions of ANSI/IEEE C95.1.

Of particular importance for mobile antennas is the field strength and power density inside the passenger compartment areas of motor vehicles, maritime vessels, and aircraft. The surrounding metal structure of the host vehicle may induce "hot spots" where field strength and power density may intensify due to specular reflections of the electromagnetic wave from the host vehicle and is dependent on the mounting location of the antenna and geometry of the vehicle. Special care must be taken to ensure that passenger compartments are adequately probed to ensure that no rf radiation hazard to personnel exists.

Radiation hazard is not considered an "environmental" specification in the spirit of section 4.3 and consequently cannot be selectively applied or waived as can individual environmental specifications in that section. Radiation hazard compliance is mandatory. Refer to ANSI/IEEE Standards C95.1-1991 and C95.2-1991 for recognized exposure levels and detailed test procedures.

5. TEST METHODS

5.1 Standard Test Conditions

Unless otherwise specified, perform all rf/electrical performance measurements at the standard test frequencies under standard test conditions and ambient environmental conditions. Allow all measurement equipment to warm up to achieve sufficient measurement stability to perform accurate and repeatable measurements.

5.1.1 Standard Test Frequencies

The standard test frequencies shall be three frequencies, one in the 0 to 10th percentile, one in the 45th to 55th percentile, and one in the 90th to 100th percentile of the operating frequency range. Standard test frequencies for multiband antennas (e.g., 150 MHz/450 MHz bands) shall consist of standard test frequencies for each continuous band of operation that the antenna is capable.

5.1.2 Standard Radiation Test Site

A standard radiation test site shall be used to measure relative gain and radiation patterns. The standard radiation test site shall conform to the accepted industry standards and design principles stated in ANSI/IEEE STD 149-1979 (R1990) section 4.

Outdoor ranges shall be free of large reflecting (especially metallic) objects, trees, electric/telephone poles and overhead wires, fences, buried wires or pipes, buildings, or other objects which could perturb the illuminating electromagnetic field for a minimum of 50 λ or 100 m (328 ft), whichever is greater, from source and test antennas and with unobstructed view between source and test antennas. Buried utility lines or control cables should be at least 0.3 m (1 ft) beneath the surface. In most cases, the ground should be level and exhibit uniform conductivity and permittivity characteristics. An exception to this policy is in the case of an elevated range over irregular terrain (ANSI/IEEE STD 149-1979 (R1990) section 4.3.1) where the source and test antennas are affixed to support structures located on adjacent mountain peaks or hilltops. For such ranges, however, additional design considerations are necessary to ensure that any points of specular reflection are sufficiently suppressed so as not to perturb the illuminating line-of-sight electromagnetic field.

In any case, the amplitude and phase tapers of the wavefront illuminating the test antenna must be less than 0.25 dB and 22.5° throughout the effective antenna volume of the antenna under test. Measured field probe data of the test range shall be available to show compliance with these constraints. Site power delay profiles shall exhibit no multipath components. For all types of outdoor ranges, the ambient rf noise levels should be carefully monitored to ensure that they are at least 14 dB lower than the amplitude of the minimum measured signal strength.

Indoor ranges (anechoic chambers) are suitable for higher frequency measurements, typically to as low as 800 MHz, depending on the physical size of the chamber. Several different chamber designs are typical: rectangular, tapered, and compact range. Design characteristics of these indoor ranges are summarized in ANSI/IEEE 149-1979 (R1990), section 4.5.4.

5.1.3 Standard Test Range

Outdoor test ranges may be of the following types: elevated range over flat surface, elevated range over irregular terrain, elevated range with diffraction fences, ground reflection range, slant range, or compact range. Indoor test ranges may be of the following types: rectangular, tapered, pyramidal, and may incorporate compact range design features. Figures 5.1.3.1 through 5.1.3.9 depict these various types of ranges.

The test site shall consist of an elevated metal ground plane having a surface flatness within ±0.5 cm (200 mils) for type III and type IV antennas and ±1 cm (400 mils) for type I and type II antennas. The dimensions of the ground plane shall be at least .9 m × 4.7 m (12 in × 16 in) for type I antennas. If no type I measurements are to be performed, the ground plane may be scaled by a factor of $25/f_{lowest}$ where f_{lowest} is measured in MHz. The ground plane shall be extended by the addition of 16 equally spaced radials about its periphery, each approximately 0.25 λ and loaded with 240 Ω resistors. See figures 5.1.3.10 and 5.1.3.11.

5.2 Instrumentation

The instrumentation described in this section is limited to the equipment that is most critical in making the required measurements.

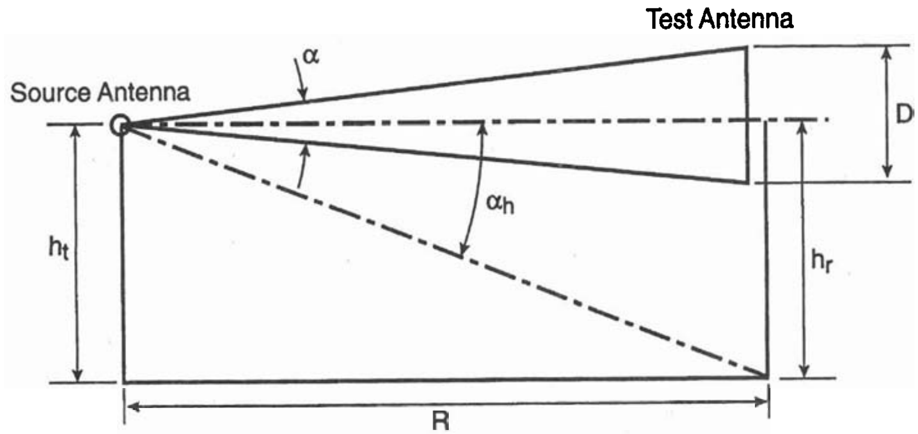

FIGURE 5.1.3.1. *Elevated range over flat surface, reprinted from IEEE Std 149-1979 (R1990) Copyright© 1979, IEEE[2]. All rights reserved. Used with permission.*

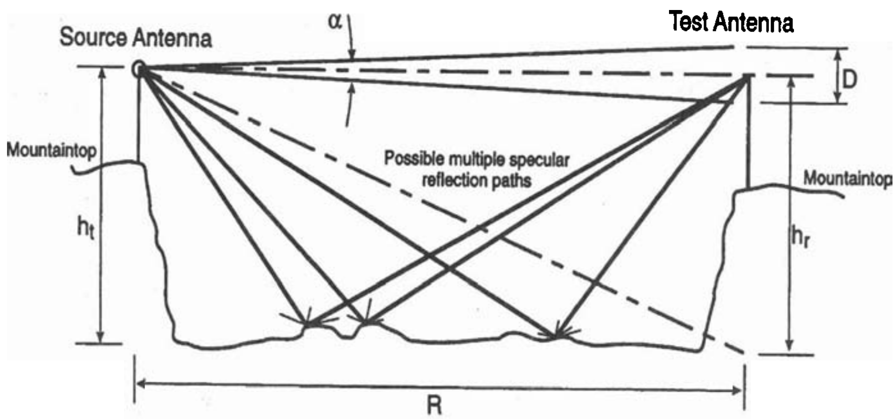

FIGURE 5.1.3.2. *Elevated range over irregular terrain. Minimize specular reflections by situating specular rays in nulls or highly suppressed sidelobes of the antenna patterns, or by other suitable technologies.*

5.2.1 Signal Source

Frequency stability of at least 10^{-5} is usually acceptable, but for more precise measurements, frequency stability of 10^{-6} or better may be necessary. Phase noise shall not exceed – 120 dBc/Hz at 12.5 kHz or greater offset, where "dBc" is "decibels relative to carrier power." Transmitter power shall be sufficient to ensure that the minimum measurable specified signal exceeds the ambient noise level by at least 14 dB.

5.2.2 Receiver

The receiver shall exhibit frequency stability equal to that of the transmitter, and shall be phase-locked to the transmitter. A vector network analyzer may serve as suitable alternative to a dedicated phase-locked measurement receiver and signal source. Input VSWR should not exceed 1.05 over the measurement frequency bands of interest and the receiver's frequency and power measurements capability shall be accurate to within 6 percent of true value. The receiver's frequency and power measurement accuracy shall be traceable to NIST calibration standards.

5.2.3 Antenna Pattern Recorder

The antenna pattern recorder shall be such that it can reproduce patterns to within ± 0.2 dB accuracy. The recorder should be of automated data acquisition design, however, so long as results can be displayed in tabular and graphical form to within the required accuracy, manual collection systems are acceptable.

[2] Figure 5.1.3.1 reprinted from IEEE Std 149-1979 (R1990), "IEEE Standard Test Procedures for Antennas," Copyright© 1979 by the Institute of Electrical and Electronics Engineers, Inc. The IEEE disclaims any responsibility or liability resulting from the placement and use in the described manner. Information is reprinted with the permission of the IEEE.

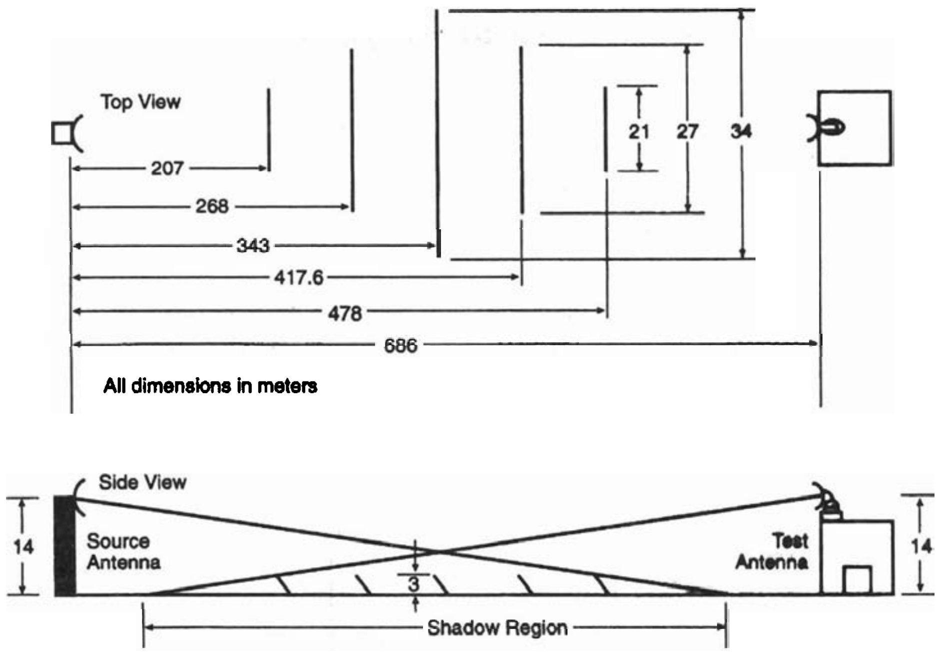

FIGURE 5.1.3.3. *Example of 686-meter elevated range with diffraction fences, reprinted from IEEE Std 149-1979 (R1990) Copyright© 1979, IEEE.*[3] *All rights reserved. Used with permission. Diffraction fences are metallic screens, typically with serrated top edges which are strategically placed to scatter the electromagnetic energy, that would normally be reflected from the range surface towards the antenna under test, away from it.*

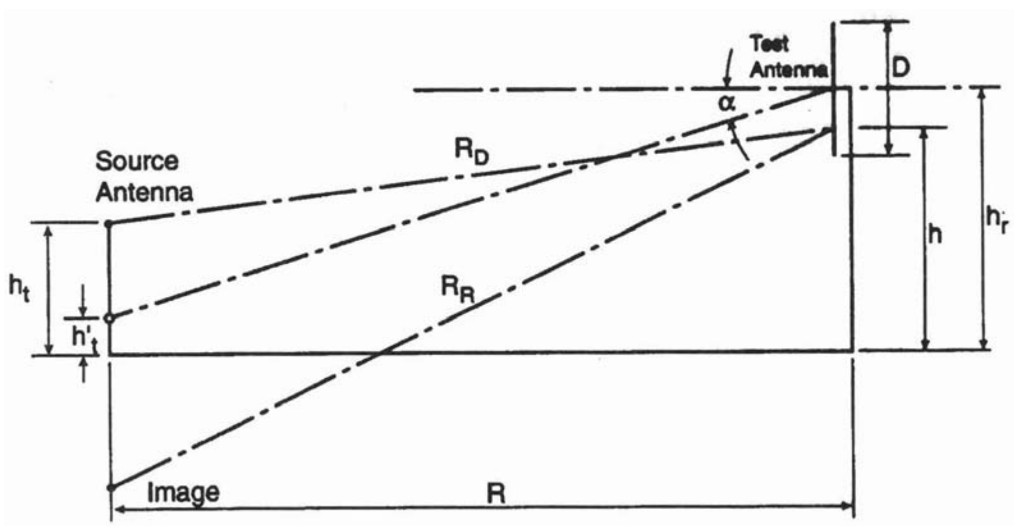

FIGURE 5.1.3.4. *Ground reflection range, reprinted from IEEE Std 149-1979 (R1990) Copyright© 1979, IEEE.*[4] *All rights reserved. Used with permission.*

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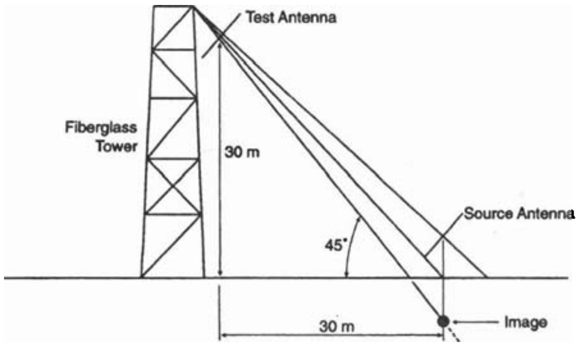

FIGURE 5.1.3.5. *Slant range, reprinted IEEE Std 149-1979 (R1990) Copyright© 1979, IEEE.*[5] *All rights reserved. Used with permission.*

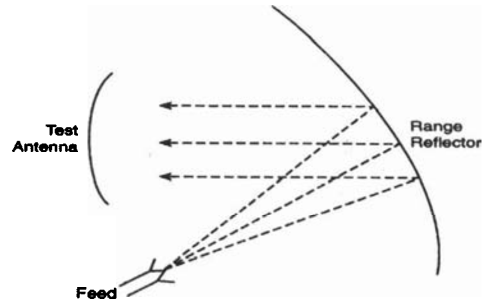

FIGURE 5.1.3.6. *Compact range, reprinted from IEEE Std 149-1979 (R1990) Copyright© 1979, IEEE.*[6] *All rights reserved. Used with permission. Range reflector collimates beam to minimize phase taper. Allows smaller range distance to antenna under test than standard ranges.*

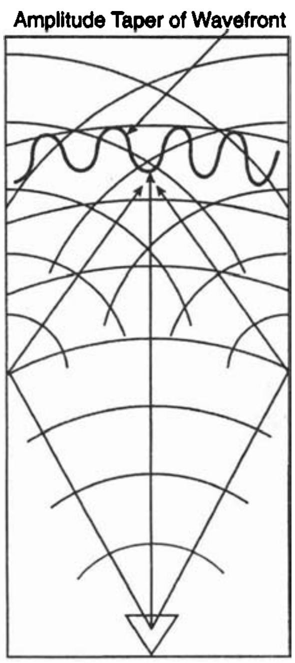

FIGURE 5.1.3.7. *Rectangular anechoic chamber, reprinted from IEEE Std 149-1979 (R1990) Copyright© 1979, IEEE.*[7] *All rights reserved. Used with permission.*

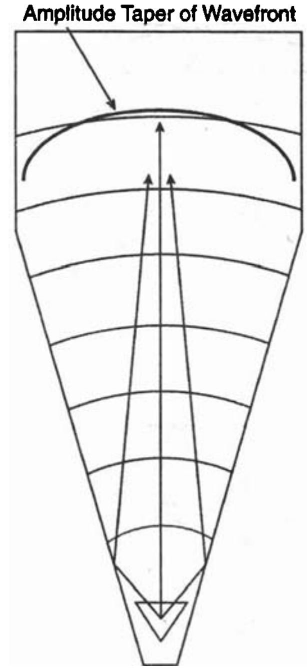

FIGURE 5.1.3.8. *Tapered anechoic chamber, reprinted from IEEE Std 149-1979 (R1990) Copyright© 1979, IEEE.*[8] *All rights reserved. Used with permission.*

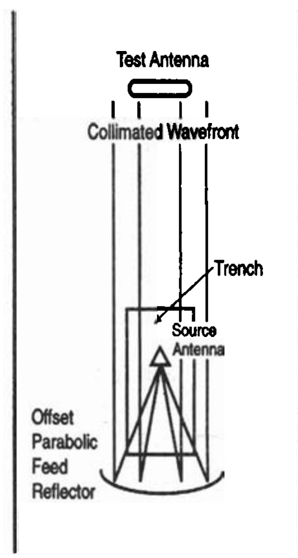

FIGURE 5.1.3.9. *Compact range anechoic chamber. See Fig. 5.1.2.6 for plan review.*

[5] Figure 5.1.3.5 reprinted from IEEE Std 149-1979 (R1990), "IEEE Standard Test Procedures for Antennas," Copyright© 1979 by the Institute of Electrical and Electronics Engineers, Inc. The IEEE disclaims any responsibility or liability resulting from the placement and use in the described manner. Information is reprinted with the permission of the IEEE.

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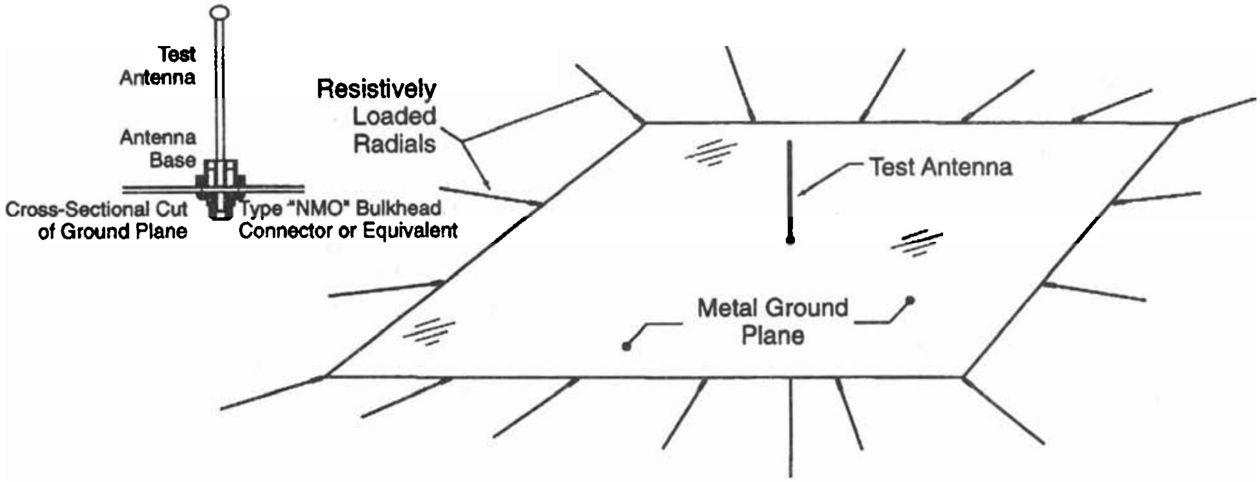

FIGURE 5.1.3.10. *Whip antenna affixed to ground plane.*

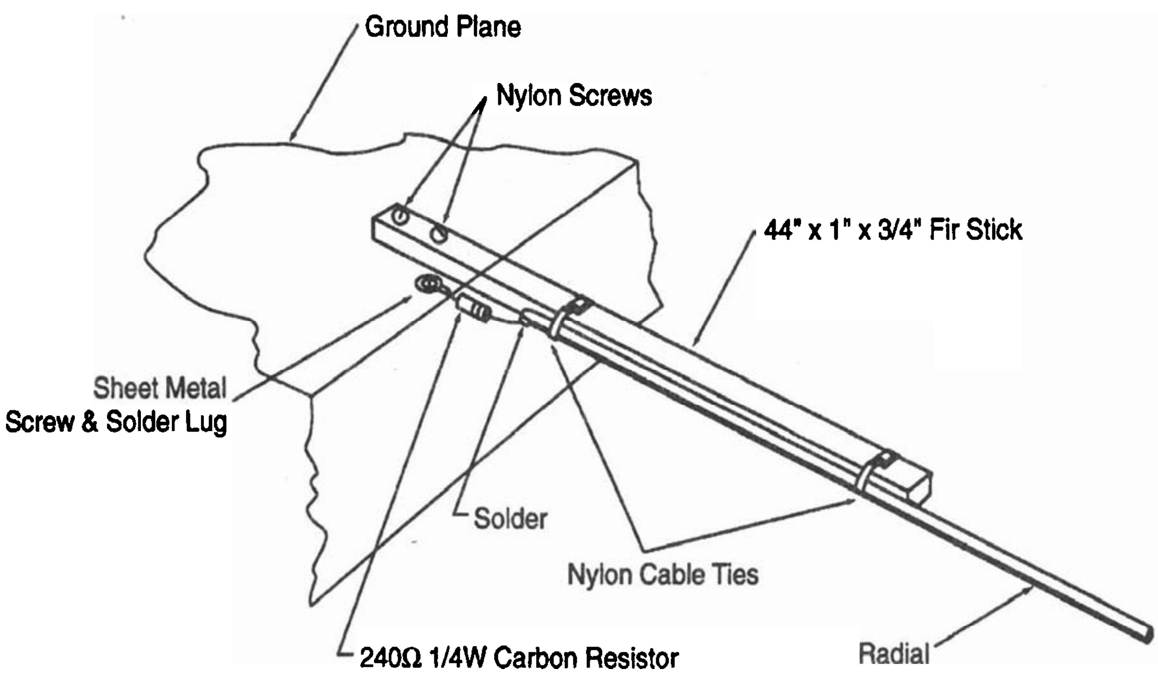

FIGURE 5.1.3.11. *Detail of resistively loaded radials extended from ground plane.*

5.2.4 Power Meter

The power meter shall measure forward and reflected power in a 50 Ω system with full-scale uncertainty of 5 percent or less. It may be a through-line directional power meter, or two power meters attached to a directional coupler, or as part of a vector network analyzer.

5.2.5 Reference Antennas

To determine the realized gain of the antenna under test (AUT), subtract the measured relative gain (in dB) of the standard (STD) monopole reference antenna from the measured relative gain (in dB) of the antenna under test, then add the appropriate gain number from the following tables to that intermediate result, i.e.:

$$G_{AUT(dBi)} = G_{AUT(rel)} - G_{STD(rel)} + G_{STD(dBi)} \qquad (2)$$

Tables 5.2.5-1 through 5.2.5-5 summarize the gain characteristics of the standard monopole reference antenna. These gain figures include the effects of VSWR mismatch.

TABLE 5.2.5-1. *Gain characteristics for 2.4-meter length/1.0 cm diameter Type I standard reference monopole antenna.*

Frequency (MHz)	*Gain (dBi)*
25	0.6
26	2.0
27	3.1
29	4.6
31	4.5
33	3.6
35	2.4

TABLE 5.2.5-2. *Gain characteristics for 1.72-meter length/1.0 cm diameter Type I standard reference monopole antenna.*

Frequency (MHz)	*Gain (dBi)*
35	0.4
36	1.4
37	2.3
38	3.1
41	4.6
44	4.5
47	3.5
50	2.5

TABLE 5.2.5-3. *Gain characteristics for 0.445-meter length/0.48 cm diameter Type II standard reference monopole antenna.*

Frequency (MHz)	*Gain (dBi)*
150	3.7
152	4.0
155	4.3
157	4.5
159	4.6
162	4.7
164	4.7
166	4.6
169	4.5
171	4.4
174	4.2

TABLE 5.2.5-4. *Gain characteristics for 0.156-meter length/0.48 cm diameter Type III standard reference monopole antenna.*

Frequency (MHz)	*Gain (dBi)*
400	3.2
417	3.8
434	4.2
453	4.3
491	4.1
512	3.6

TABLE 5.2.5-5. *Gain characteristics for 0.0845-meter length/0.48 cm diameter Type IV standard reference monopole antenna.*

Frequency (MHz)	*Gain (dBi)*
806	4.3
821	4.3
85	4.3
851	4.3
866	4.2

5.3 Rf Performance Tests

5.3.1 Standing Wave Ratio (Voltage Standing Wave Ratio)

Voltage standing wave ratio may be determined by measuring the forward and reflected power and solving the following equation:

$$\mathrm{VSWR} = (\sqrt{P_f} + \sqrt{P_r}) / (\sqrt{P_f} - \sqrt{P_r}) \tag{3}$$

where P_f is the forward measured power and P_r is the reverse, or reflected measured power. Many network analyzers have provision for measuring and directly displaying VSWR in Cartesian or polar (Smith Chart) form. If the line loss between the antenna under test and the measurement device exceeds 0.5 dB, the measured VSWR must be corrected to compensate for the line loss, which will otherwise make the antenna appear to have superior VSWR than it really has. Ideally, the measurement device should be located as close as possible to the antenna feed point.

5.3.2 Relative Antenna Gain Test

Relative antenna gain of the antenna under test is determined by illuminating a standard gain reference antenna with an electromagnetic wave of a particular frequency, power, and polarization and measuring its voltage or power delivered to a measurement device. This value is compared to that measured after replacing the standard gain reference antenna with the antenna under test and illuminating it under the same conditions of frequency, power, and polarization as before. See section 5.2.5.

5.3.3 Radiation Pattern Test

The basic procedure for performing radiation pattern measurements is fully described in ANSI/IEEE STD 149-179 (R1990) in various sections. The technique is illustrated in figure 5.3.3.1. Essentially, the source and test antennas are securely affixed to their respective supporting structures in such a way that their mutual polarization is as desired, usually co-polarized. As the antenna under test is rotated about its axis (see fig. 5.3.3.1), a line-of-sight ray originating from the source antenna traces out a path along an imaginary sphere which surrounds the test antenna and rotates with it. This defines the plane of the radiation pattern cut. The voltage or power response of the antenna under test at each angular orientation is mapped to a radial distance as a function of the angle in this plane. This gives an indication of the antenna pattern, or radiation pattern, which shows the response of the antenna to an electromagnetic wave incident from some prescribed direction.

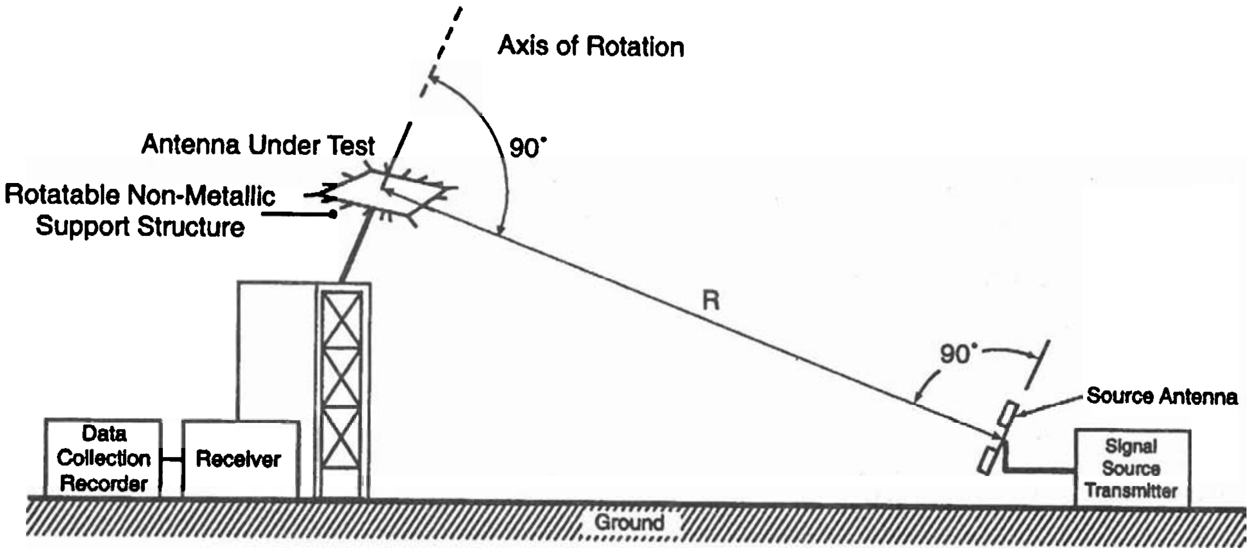

FIGURE 5.3.3.1. *Example of an azimuth plane radiation pattern measurement at a slant range.*

5.3.4 Rated Power Test

Affix the antenna to its host platform or mock-up thereof at a suitable standard radiation test site. Measure antenna VSWR at each standard test frequency to establish a performance baseline. Apply rated full continuous wave power at each of the standard test frequencies for a minimum of 4 h per frequency. At the conclusion of each application of full rated power, measure VSWR to determine performance degradation, if any. VSWR should read within ±5 percent of performance baseline. Visually inspect the antenna for physical damage.

5.4 Environmental Test Methods

Procedures for conducting the environmental tests described below are detailed in MIL STD 810E under the applicable methods identified herein. Where *in situ* "operational" environmental testing of an item is impractical because of the size and/or cost of its host platform, the test items may be installed on mock-ups of its host platform. For example, vehicular antennas might be mounted on ground planes simulating a vehicle roof, or base station antennas might be mounted on partial tower sections.

In order to establish baseline performance characteristics, and also to reject defective items before committing the effort to perform environmental performance tests, rf electrical performance tests shall be conducted at ambient test conditions (sec. 3.14) prior to exposing the test items to the environmental tests specified herein. At the conclusion of each environmental test, rf electrical performance tests shall be conducted at ambient conditions to ensure that the test item has not endured degradation of rf electrical performance.

Whereas the antennas under test must meet all the rf electrical performance specifications cited in this document at ambient conditions, the environmental performance specifications stated herein should be selectively applied according to the anticipated operating environment of the antenna. That is, the antenna need only comply with those environmental specifications not waived by the procuring agency. The test methods described below provide industry-recognized, standardized, and measurable techniques to quantify antenna performance against various environmental stress factors.

5.4.1 High Temperature/Solar Radiation

Use MIL STD 810E, Method 505, Procedure II. Test item shall be subjected to a minimum of three test cycles. Applied temperature and radiance variation within an individual cycle shall conform to those listed in table 505.3-1 (Basic Hot) and figure 505.3-2 of MIL STD 810E. If the antenna system will be deployed in the southwestern United States, the temperature/radiance conditions specified table 505.3-1 (Hot-Dry) and figure 505.3-2 of MIL STD 810E shall apply instead. All performance tests are waived during high temperature/solar radiation cycling except VSWR, which shall be conducted at each temperature step of each cycle. At the conclusion of the temperature cycling, visually inspect the test items for physical damage or degradation.

5.4.2 Low Temperature

Use MIL STD 810E, Method 502.3, Procedure II. Test item shall be subjected to a minimum of three test cycles. Applied temperature and humidity variation within an individual cycle shall conform to those listed in tables X (Ambient) (CONUS and Alaska coastal regions) or XII (Ambient) (southwestern Alaska) of MIL STD 210C. For deployment in northeastern regions of Alaska, the test item shall be subjected to the constant temperature specified in section 4.3.2 for a like period of time. All performance tests are waived during low temperature exposure except VSWR, which shall be conducted at each temperature step of each cycle. At the conclusion of the low temperature testing, visually inspect the test items for physical damage or degradation.

5.4.3 Blowing Rain

Use MIL STD 810E, Method 506.3, Procedure I. Test item shall be subjected to conditions specified in section 4.3.3 table 4.3.3-1 above. All performance tests are waived during blowing rain exposure except VSWR, which shall be conducted just prior to cessation of this test. At the conclusion of blowing rain testing, visually inspect the test items for physical damage, leakage, or degradation.

5.4.4 Humidity

Use MIL STD 810E, Method 507.3, Procedure III. All performance tests are waived during aggravated humidity exposure except VSWR, which shall be conducted during the fifth and tenth humidity cycles of this test. At the conclusion of humidity testing, visually inspect the test items for physical damage, leakage, or degradation.

5.4.5 Salt Fog

Use MIL STD 810E, Method 509.3, Procedure I. Cycle the test article to alternating 24 h periods of salt fog exposure and standard ambient drying for a minimum of four 24 h periods. All performance tests are waived during salt fog exposure. At the conclusion of salt fog testing, visually inspect the test items for physical damage, corrosion, or degradation.

5.4.6 Sand and Dust

Use MIL STD 810E, Method 510.3, Procedures I and II. All performance tests are waived during sand and dust exposure. At the conclusion of salt fog testing, visually inspect the test items for physical damage, erosion of surfaces, or degradation.

5.4.7 Icing/Freezing Rain

Use MIL STD 810E, Method 521.1, Procedure I. All performance tests are waived during icing exposure. At the conclusion of icing testing, visually inspect the test items for physical damage.

5.4.8 Vibration

Use MIL STD 810E, Method 514.3, Procedure I. Depending on host platform, use test conditions I-3.4.1 (propeller aircraft), I-3.4.3 (helicopter), I-3.4.7 (ground mobile), or I-3.4.8 (marine). All performance tests are waived during vibration testing. At the conclusion of vibration testing, visually inspect the test items for physical damage.

5.4.9 Shock

Whip antennas and other antennas which protrude from the host vehicle more than 30 cm (12 in) shall be firmly affixed to a stationery supporting structure. The antenna shall be repetitively subjected to striking action 30 cm (12 in) above its mounting base by a piston or motor driven impact arm to simulate shock conditions which might be expected when, for example, driving under a low clearance obstruction at a speed of 16 kph (10 mph). The required number of blows shall be 1500. Figure 5.4.9.1 illustrates a possible test fixture for administering this test.

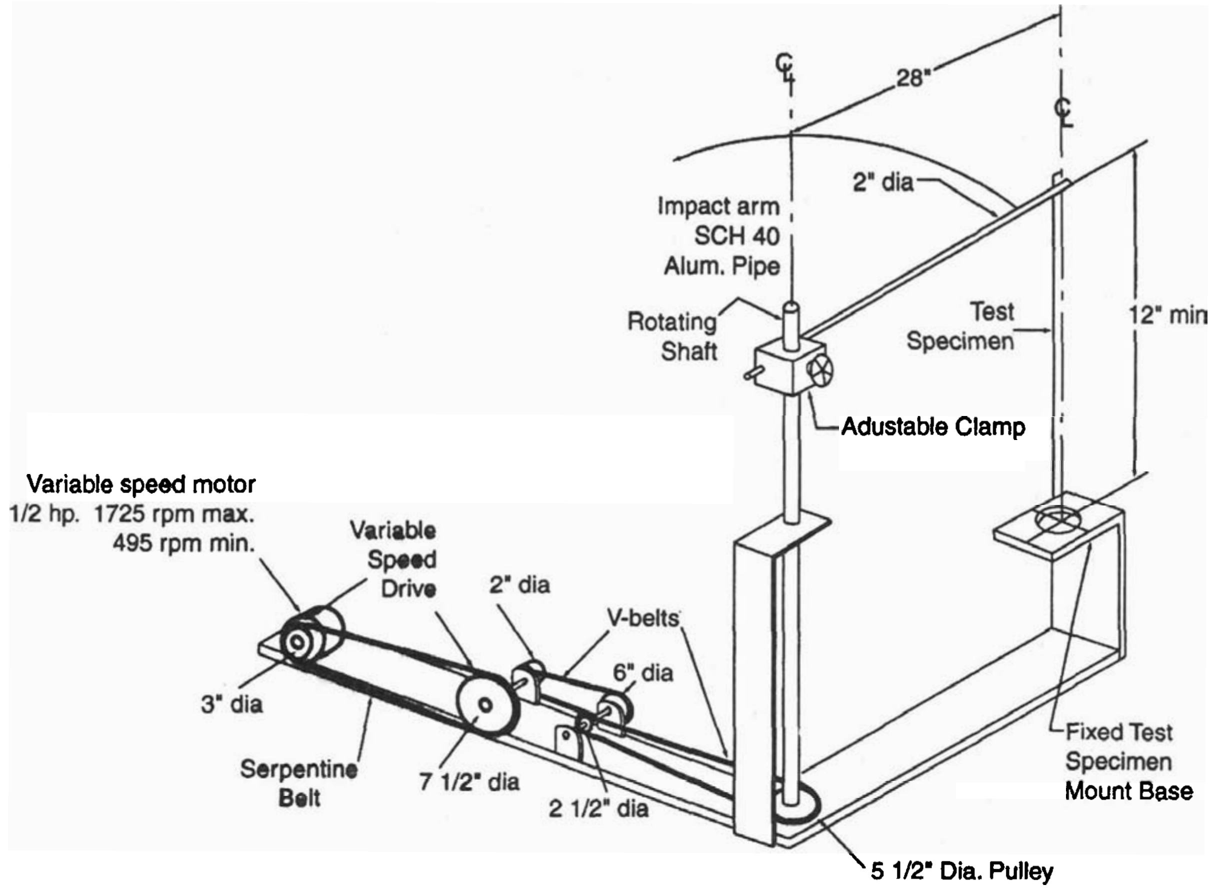

FIGURE 5.4.9.1. *One possible test fixture design for administering shock test. Reproduced under written permission of the copyright holder (Telecommunications Industry Association).*

5.5 Radiation Hazard

Radiation hazard is not considered an "environmental" test in the spirit of section 5.4 and consequently cannot be selectively applied or waived as can individual environmental tests in that section. Determination of the spatial boundaries of the radiation hazard zone when the antenna is operated at its fully rated output power is a mandatory requirement. Refer to ANSI/IEEE Standards C95.1-1991 and C95.3-1991 for permissible exposure levels and detailed test procedures.

APPENDIX A – REFERENCES

[1] NIJ Standard-0205.01, Standard for Mobile Antennas, May 1989, National Institute of Justice.

[2] ANSI/IEEE 145-199, IEEE Standard Definitions of Terms for Antennas.

[3] ANSI/IEEE 149-1979 (R1990), IEEE Standard Test Procedures for Antennas.

[4] ANSI/IEEE C95.1-1991, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

[5] ANSI/IEEE C95.3-1991, IEEE Standard Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields—RF and Microwave.

[6] TIA/EIA 222-F,[9] Structural Standards for Steel Antenna Towers and Antenna Supporting Structures.

[7] TIA/EIA 29-B-1,[10] Minimum Standards for Communications Antennas, Part II–Mobile Antennas.

[8] MIL STD 210C, Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment.

[9] MIL STD 810E, Environmental Test Methods and Engineering Guidelines.

[10] Federal Communications Commission Report and Order 96-26 (1996 Aug. 1), "Guidelines for Evaluating the Environmental Effects of Radio Frequency Radiation."

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[9] To purchase the complete text of any TIA document, call Global Engineering Documents at 1-800-854-7179 or send a facsimile to 1-303-397-2740.

[10] Ibid.

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