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NOVEMBER 1977

LAW ENFORCEMENT STANDARDS PROGRAM

FIXED AND BASE STATION ANTENNAS

STANDARD

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

LAW ENFORCEMENT STANDARDS PROGRAM

NILECJ STANDARD FOR FIXED AND BASE STATION ANTENNAS

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

NOVEMBER 1977

U.S. DEPARTMENT OF JUSTICE
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NATIONAL INSTITUTE OF LAW ENFORCEMENT AND CRIMINAL JUSTICE

Blair G. Ewing, Acting Director

LAW ENFORCEMENT ASSISTANCE ADMINISTRATION

James M. H. Gregg, Acting Administrator

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NILECJ STANDARD
FOR
FIXED AND BASE STATION ANTENNAS

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FOREWORD

Following a Congressional mandate[1] 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-0204.00, Fixed and Base Station Antennas, is a law enforcement equipment standard developed by LESL and approved and issued by NILECJ. Additional standards 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.

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 necessarily 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 fixed and base station antennas. The NILECJ Guideline Series fills 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 being 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 provide, in non-technical 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.

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. 20531.

Lester D. Shubin
Program Manager for Standards
National Institute of Law
Enforcement and Criminal Justice

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

NILECJ STANDARD for FIXED AND BASE STATION ANTENNAS

1. PURPOSE AND SCOPE

The purpose of this document is to establish minimum performance requirements and methods of test for antennas that are used at base stations or other fixed sites by law enforcement agencies.

2. CLASSIFICATION

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

2.1 Operating Frequency

2.1.1 Type I

Antennas for use in the 400-512 MHz band.

2.1.2 Type II

Antennas for use in the 150-174 MHz band.

2.1.3 Type III

Antennas for use 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 communication are given in LESP-RPT-0203.00 [7].

3.1 Antenna Power Rating

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

3.2 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 approximately one-half the wavelength of the energizing signal. The radiator supports a line current distribution such that a current node (zero net current) exists at each of the ends, producing maximum radiation in the plane at the center of the antenna and normal to its longitudinal axis.

3.3 Directional Pattern (Radiation Pattern)

The transmitting or receiving properties of an antenna as a function of direction. Directional patterns are frequently given in vertical and horizontal planes.

3.4 Effective Antenna Volume

The volume occupied by an antenna plus one-half wavelength in all directions when it is rotated through 360° as required by a particular test.

3.5 Isotropic Radiator

A hypothetical antenna radiating or receiving equally in all directions.

3.6 Pattern Recorder

A device that records the amplitude of the output signal from an antenna and receiver combination as a function of the antenna orientation.

3.7 Polarization

The orientation of the electric-field vector of the wave radiated by an antenna. Alternatively, the orientation of the electric-field vector of an incident wave which results in maximum available power at the antenna terminals.

3.8 Relative Antenna Gain

The ratio of the radiation intensity of an antenna in a given direction to the radiation intensity of a reference antenna in the same direction, with the same power input to both antennas. If the reference antenna is a loss-less half-wave dipole antenna, the gain is expressed in decibels relative to the dipole antenna, dBd.

3.9 Scale Ratio

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

3.10 Standing Wave Ratio (SWR)

The ratio of the maximum to the minimum voltage or current appearing along a transmission line.

3.11 Wind Velocity Rating

The maximum wind velocity that an antenna assembly can withstand without physical damage.

4. REQUIREMENTS

4.1 Performance Requirements

The antenna shall meet or exceed all the requirements of this standard as given below and summarized in table 1.

4.2 User Information

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

a. Operating frequency range
b. Antenna power rating
c. Relative antenna gain vs. operating frequency
d. Polarization
e. Vertical radiation pattern
f. Horizontal radiation pattern
g. Nominal impedance

Table 1. Minimum Performance Requirements for Fixed and Base Station Antennas

Antenna Characteristic	Minimum Requirement
Rated Power Operation	No physical damage
Relative Antenna Gain	± 1.0 dB of max relative gain
Radiation Pattern	± 1.0 dB or 10% of max relative gain, whichever is greater
Standing Wave Ratio	1.5 or less
Wind Velocity Rating	See table 2

h. SWR vs. operating frequency
i. Connector type
j. Wind velocity rating
k. Physical dimensions
l. Weight
m. Antenna material composition
n. Operating, installation and service instructions.
o. Certification of compliance with this standard.

4.3 Rated Power Operation

The antenna shall meet the requirements of paragraphs 4.4, 4.5, and 4.6 immediately after being subjected to the test described in paragraph 5.4. In addition, the antenna shall not be physically damaged by the test.

4.4 Relative Antenna Gain

The relative antenna gain, measured in accordance with paragraph 5.5, shall be within 1.0 decibel of the maximum relative gain specified by the manufacturer in accordance with paragraph 4.2.c.

4.5 Radiation Pattern

4.5.1 Vertical Pattern

The vertical radiation pattern, measured in accordance with paragraph 5.6.1, shall be within 1.0 decibel (or 10 percent of the maximum relative gain in decibels, whichever is greater) of the radiation pattern specified by the manufacturer in accordance with paragraph 4.2.e.

4.5.2 Horizontal Pattern

The horizontal radiation pattern shall be measured in accordance with paragraph 5.6.2. For omnidirectional antennas, the horizontal radiation pattern variation shall be within 1.0 decibel throughout a 360° variation in azimuthal angle. For directional antennas, the horizontal radiation pattern shall be within 1.0 decibel (or 10 percent of the maximum relative gain in decibels, whichever is greater) of the pattern specified by the manufacturer in accordance with paragraph 4.2.f.

4.6 Standing Wave Ratio

The SWR of the antenna, measured in accordance with paragraph 5.7, shall be 1.5 or less referenced to a 50-ohm system.

4.7 Wind Velocity Rating

The antenna shall be capable of withstanding wind velocities of 114 kilometers per hour (71 miles per hour), without ice loadings. If mounted more than 90 meters (295 feet) above the ground or if located in zones B or C (see figure 1), the antenna shall be capable of withstanding the appropriate wind velocity, as listed in table 2.

4.8 Materials

The materials used in the antenna and in auxiliary items such as support members, feed harnesses, connectors and mounting hardware shall provide a high strength-to-weight ratio and good resistance to corrosion.

Table 2. Wind Velocity Rating [2]

Antenna Base Height Above Ground	Wind Loading Zone A	Wind Loading Zone B	Wind Loading Zone C
	Wind Velocity km/hr (mi/hr)		
Less than 90 m (295 ft)	114 (71)	132 (82)	145 (90)
90–200 m (295–656 ft)	123 (76.5)	144 (89.5)	161 (100)
More than 200 m (656 ft)	145 (90)	168 (104)	193 (120)

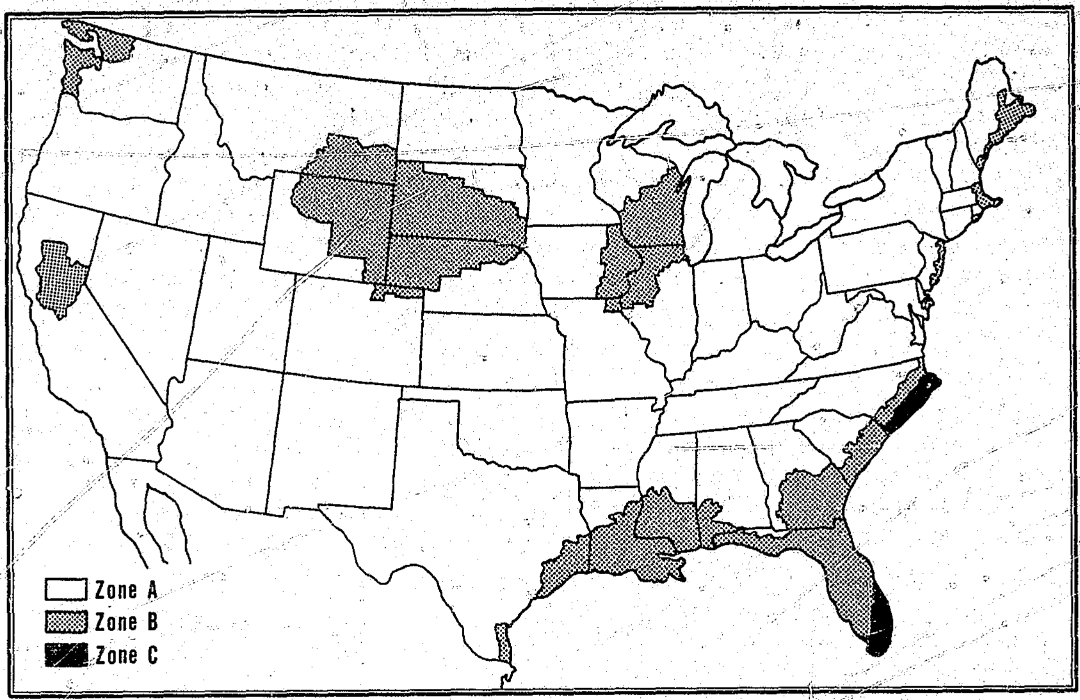

Figure 1. Location of wind loading zones based on 50 year mean recurrence interval.

5. TEST METHODS

5.1 Standard Test Conditions

Unless otherwise specified, perform all measurements at the standard test frequencies under standard test conditions. Allow all measurement equipment to warm up until the system has achieved sufficient stability to perform accurate measurements.

5.1.1 Standard Test Frequencies

The standard test frequencies shall be three frequencies, one each at the low end, middle and high end of the operating frequency range (4.2.a).

5.1.2 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 measuring instrument or the equipment under test. All utility lines and any control circuits within the test site should be buried underground to a depth of 0.3 meter (approximately 1.0 ft). The ambient electrical noise level shall be carefully monitored to insure that it does not interfere with the test being performed. The ambient noise level should be 14 dB or more below the signal levels being measured.

5.1.3 Standard Test Range

Either a slant range, a ground level range or an elevated range may be used to measure relative antenna gain and/or vertical and horizontal radiation patterns. In each, the distance between the two antennas, R, shall be ten wavelengths or $2\ d^2/\lambda$ (where d is the largest dimension, in meters, of the antenna under test, and λ is the free space wavelength, in meters, of the test frequency), whichever is greater. After turning on the signal source, the resultant electromagnetic field shall be probed over the effective antenna volume of the antenna to be tested to insure that the field strength variation is less than ±3/4 decibel. If a slant range is used, the source antenna shall be positioned within a few centimeters of the ground, and the antenna under test shall be located about 20-30 meters (66-99 feet) above ground level. If a ground level range is used, both antennas shall be positioned close to the ground such that the first maximum of the interference pattern of the source antenna and its image shall be placed at the center of the test antenna. If an elevated test range is used, both the antenna under test and the source antenna shall be elevated sufficiently such that the reflected signal from the source antenna is negligible at the center of the antenna under test when the major lobes of both antennas are aligned.

5.2 Test Equipment

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

5.2.1 Receiver

The receiver shall be well-shielded, capable of operating over the frequency range of the antenna under test and shall be calibrated such that it can measure voltages of 1 to 10 mV with an accuracy of 6 percent and a resolution of 2 percent. It shall have an input impedance of 50 ohms and an SWR of 1.05 or less.

5.2.2 Antenna Pattern Recorder

The stability of the antenna pattern recorder shall be such that it can reproduce patterns to within 0.2 dB.

5.2.3 Reference Antenna

The standard reference antenna shall be a self-resonant half-wavelength dipole whose antenna gain is 2.1 dB relative to an isotropic radiator.

5.2.4 Source Antenna

The source antenna shall be capable of radiating both vertically and horizontally polarized fields, not necessarily at the same time.

5.2.5 Power Meter

The power meter shall measure both forward and reflected power in a 50-ohm system with a full-scale uncertainty of 5 percent or less. It may be a through-line directional wattmeter, or directional couplers with power meters on the side arms.

5.3 Scale Model Measurements

Accurate radiation pattern and relative antenna gain measurements are difficult to obtain for type III antennas because of the antenna size. For type III antennas, scale model techniques may be used, provided certain precautions are observed. The scale model shall be constructed to the following accuracy:

$$L_s = (L \pm 1\%)/R$$

where R is the scale ratio, L_s is any significant linear dimension of the scale model, and L is the corresponding linear dimension of the full-size antenna. The scale ratio shall not exceed 6. The parts of the scale model shall be constructed of the same materials as the corresponding parts of the full-size antenna. If the supporting tower or mast is an electrically essential part of the antenna or affects the electrical performance of the antenna, it also shall be constructed to scale.

5.4 Rated Power Operation Test

If authorized by the Federal Communications Commission to do so, mount the antenna on an outside range at a temperature of at least 20° C (68° F) and apply rated power (paragraph 4.2.b) for four hours at one of the standard test frequencies. If not authorized to transmit at rated power into free space, place the antenna in a chamber that will provide 60 decibels or more of shielding and perform the same test.

5.5 Relative Antenna Gain Test

Mount the source antenna and the antenna under test in accordance with paragraph 5.1.3 so that their maximum transmitting/receiving lobes are positioned for horizontally polarized signals, and connect the equipment as shown in figure 2. Tune the signal source to one of the standard test frequencies, and adjust its output until a convenient reading is obtained on the pattern recorder. Position and align both antennas for the maximum indication on the pattern recorder and record this reading, P_A, in decibels. Do not adjust the signal source for the remainder of this test. Remove the antenna under test and replace it with the reference antenna. Position and align the reference antenna for the maximum received signal and record the reading, P_R, in decibels. The relative antenna gain in the direction of maximum radiation is $P_A - P_R$, in decibels relative to a dipole, dBd. Repeat for each of the other two standard test frequencies.

5.6 Radiation Pattern Tests

5.6.1 Vertical Pattern Test

Use the same measurement setup as described in paragraph 5.5 and figure 2. Align and position both the source and test antennas for maximum signal strength. Adjust the signal source for full scale indication on the pattern recorder. Do not adjust either the pattern recorder or the signal source for the remainder of this test. Obtain the vertical radiation pattern of the antenna under test by rotating it through 360° in the plane defined by its major axis and that of the source antenna. The starting and ending points on the pattern record should be the same. If they are not, repeat the measurement. Repeat for each of the other two standard test frequencies.

5.6.2 Horizontal Pattern Test

Position the two antennas as shown in figure 3, with their major axes parallel to each other in a vertical plane and perpendicular to the imaginary line that connects their midpoints. Adjust the signal source and the pattern recorder controls so that the pattern recorder indicates full scale. Do not make adjustments for the remainder of this test. Rotate the antenna under test through 360° about its major axis to obtain the horizontal radiation pattern of the antenna under test. The starting and ending points on the pattern record should be the same. If they are not, repeat the measurement. Repeat for each of the other two standard test frequencies.

5.7 Standing Wave Ratio Test

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

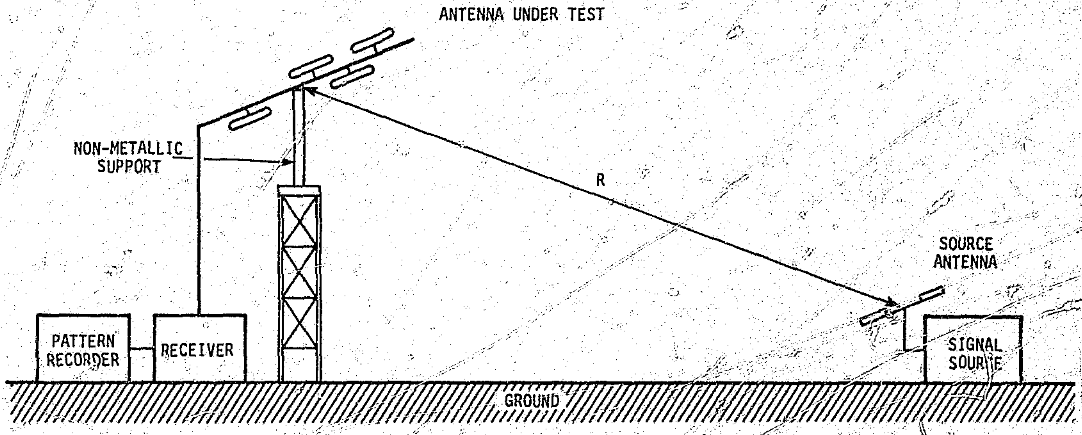

Figure 2. Test setup for measuring relative antenna gain and vertical radiation pattern.

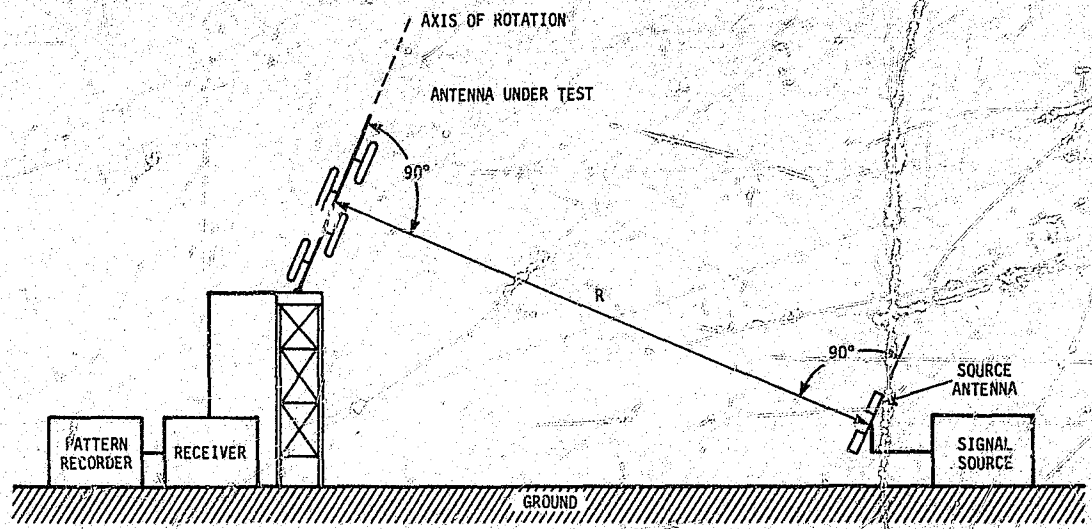

Figure 3. Test setup for measuring horizontal radiation pattern.

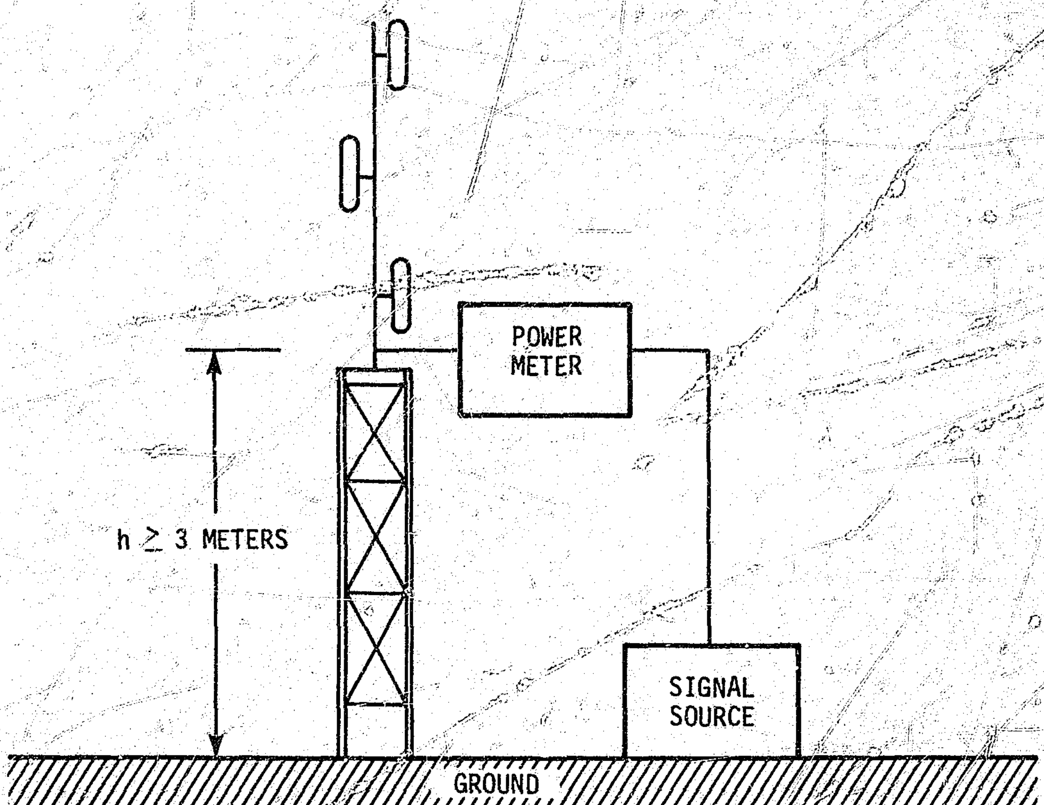

Figure 4. Test setup for measuring SWR.

Mount the antenna under test on a tower in the same manner in which it is normally used with its base at least 3 meters (10 feet) above ground. This is important for mountings where the antenna supporting structure is in the field of the antenna. Connect the measuring instruments as shown in figure 4. Place the power meter very near the antenna input terminals. If the line loss in the rf transmission line connecting the power meter to the antenna input terminals exceeds 0.5 dB, correct the measured SWR to eliminate the effect of the line loss.

Use the power meter to measure the incident power delivered to the antenna and the reflected power from the antenna. Calculate the SWR from the following relationship, where P_i is the incident power in watts and P_r the reflected power in watts.

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

APPENDIX A. BIBLIOGRAPHY

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