

# **American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz**

**Accredited Standards Committee On Electromagnetic Compatibility, C63**

accredited by the

**American National Standards Institute**

secretariat

**Institute of Electrical and Electronics Engineers, Inc.**

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**Abstract:** Uniform methods of measurement of radio noise emitted from low-voltage electrical and electronic equipment, including digital and other information technology equipment, in the frequency range of 9 kHz to 40 GHz are set forth. Both unintentional and certain intentional radiators are included. Methods for the measurement of radiated and powerline conducted radio noise are covered and may be applied to any such equipment unless otherwise specified by individual equipment requirements.

**Keywords:** conducting ground plane, conducted emission testing, digital equipment, electric field measurement, information technology equipment, intentional radiators, line impedance stabilization network, low-voltage electrical equipment, low-voltage electronic equipment, magnetic field measurement, normalized site attenuation, periodic intentional radiators, powerline conducted radio noise, radiated emission testing, radio-noise emissions, radio-noise power, site attenuation, unintentional radiators.

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## Foreword

(This foreword is not a part of C63.4-1992, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.)

Almost from the beginning of radio broadcasting, the electric utility companies were faced with the problem of radio noise. In 1924 the National Electric Light Association appointed a committee to study the subject. The manufacturers of electric power equipment had encountered similar problems, and in 1930, a subcommittee of the NEMA Codes and Standards Committee was set up. The following year the EEI-NEMA-RMA Joint Coordination Committee on Radio Reception was organized.

The Joint Coordination Committee issued a number of reports, among which was Methods of Measuring Radio Noise, 1940. This report included specifications for a radio-noise and field-strength meter for the frequency band 0.15 MHz to 18 MHz. The report recommended procedures for measuring radio-noise voltage (conducted noise) from low- and high-voltage apparatus, making noise field-strength measurements near overhead powerlines, determining broadcast field strengths, and collecting data upon which to base tolerable limits for radio noise.

During World War II, the needs of the armed services for instruments and methods for radio-noise measurement, particularly at frequencies higher than the broadcast band, became pressing and, in 1944, work on developing suitable specifications was begun by a special subcommittee of ASA Sectional Committee C63, Radio-Electrical Coordination. This special subcommittee developed a wartime specification that became Army-Navy Specification JAN-I-225 issued in 1945 and later approved as C63.1-1946, American War Standard-Method of Measuring Radio Interference of Electrical Components and Completed Assemblies of Electrical Equipment for the Armed Forces from 150 KHz to 20 Mhz.

In 1951, ASA Sectional Committee C63, through its Subcommittee No. 1 on Techniques and Developments, started work on improving and extending measurement methods, taking into account methods mentioned in the 1940 report and those in current military specifications. In the course of this work, Subcommittee No. 1 developed the standard C63.4-1963, Radio-Noise Voltage and Radio-Noise Field Strength, 0.015 to 25 Mhz, Low-Voltage Electric Equipment and Nonelectric Equipment. Work continued within the subcommittee on developing methods of measurement above 25 Mhz and the subsequent inclusion of these measurement methods in future revisions of C63.4-1963.

The standard C63.4-1963 was reaffirmed in 1969, and work within the subcommittee was accelerated to produce a draft standard that would make use of the experience gained by several years' use of the standard, to extend its coverage to embrace a broader frequency range and to incorporate newer measurement techniques that had been developed within the USA and by the International Special Committee on Radio Interference (CISPR) as set forth in CISPR Publications 14 and 16. The revised standard was published in 1981.

Although many improvements had been made in standard C63.4 in the several revisions, the reproducibility of measurements of radiated interference from one test site to another had not been completely satisfactory. In 1982 a concerted effort was organized in Subcommittee No. 1 of the American National Standards Committee C63 to determine how the technique could be improved. Evidence showed that the variability was due, in part, to inadequate (1) control of site ground plane conductivity, flatness, site enclosures, effects of surrounding objects, and certain other site construction features, (2) accounting for antenna factors, associated cabling, and balun and device under test characteristics and (3) consideration of mutual coupling effects between the device under test and the receiving antenna and their images in the ground plane. Accordingly, standard C63.4 was further revised in 1988 and standards C63.5, C63.6, and C63.7 were prepared to provide additional information.

In late 1988 and in 1989 the importance of including additional details on test procedures to provide proper evaluation of complex systems, such as information technology equipment and systems, was recognized. Measurements on such systems can be quite sensitive to the exact configuration of equipment units and interconnecting cables. The 1991 edition was the result of a major effort on the part of the members of the Committee and various other participating individuals.

Work on a further revision began during 1991 to provide for the testing of intentional as well as unintentional radiators. Thus these are covered in the present document. The following members of the C63 Committee served as task group leaders on this revision:

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# American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

## 1. Introduction

### 1.1 Scope

This standard sets forth uniform methods of measurement of radio-frequency (RF) signals and noise emitted from both unintentional and intentional emitters of RF energy in the frequency range 9 kHz to 40 GHz. Methods for the measurement of radiated and ac powerline conducted radio noise are covered and may be applied to any such equipment unless otherwise specified by individual equipment requirements.

These methods cover measurement of certain devices that deliberately radiate energy, such as intentional emitters, but does not cover licensed transmitters. This standard is not intended for certification/approval of avionic equipment or for industrial, scientific, and medical (ISM) equipment.

These methods apply to the measurement of individual units or systems comprised of multiple units. Additional methods may be added to this standard to fulfill future requirements as needed. The methods used for validation of test sites, such as open area sites and absorber-lined rooms for frequencies in the range of 30 to 1000 MHz, are contained in this standard. Further work on absorber-lined room validation is under consideration. An effort has been made, wherever possible, to harmonize the measurement procedures contained herein with those in effect internationally.

### 1.2 Applications

The procedures contained herein are to be used for determining compliance of a wide variety of equipment with applicable standards for that equipment. They may be used, for example, to test small hand-held electronic devices such as portable computers or garage door openers, as well as to test larger equipment units such as electronically controlled gas station pumps or ensembles of computers such as might be found serving a banking or insurance center. Other procedures may be used in certain instances provided the methods used yield results that are expected to be the same as the results that would be obtained using the procedures contained in this standard. In the event of any dispute, the results of tests performed in accordance with the procedures described herein will prevail over the results of tests performed using other methods. Any persons contemplating using other procedures may want to determine, before performing the alternate procedures, that those alternate procedures are acceptable to the appropriate agency or procuring organization requiring the testing.

This standard, having rather broad applicability, contains clauses that may be selectively incorporated in a specific product requirement. Any procurement or regulatory requirement should contain the following information:

- 1) Limits and frequency ranges for both ac powerline conducted and radiated measurements
- 2) For radiated measurements, limits and test distances
- 3) A specific affirmative statement if any or all of the following are required:
  - a) Radiated magnetic field strength measurements below 30 MHz (see 8.2.1)
  - b) Radiated electric field strength measurements below 30 MHz (see 8.2.2)
  - c) Use of the absorbing clamp as a substitute for measuring radiated field strength (see Section 9)
  - d) Use of a 5  $\mu$ H  $\lambda/8$ -impedance stabilization network (LISN) (see 4.1.2)
  - e) Current rather than voltage measurements (see 4.1.4)
  - f) Relaxation of the limits for clicks (transients) (see Section 14)
  - g) Artificial hand (see 5.7)
- 4) Any requirements concerning the test facilities or test procedures used if the facilities or procedures do not fully comply with the requirements contained herein

Where dimension/distance tolerances are not specified, nominal tolerances are assumed, based upon good engineering practice.

Wherever the word *shall* is used in this document, it is considered to be mandatory. The word *should* is advisory only.

### 1.3 How to Use this Document

This document addresses a broad range of criteria applicable to the testing of a variety of devices and equipment. All sections may not be applicable to all items subject to testing. The nature of this document is to specify general conditions that are applicable to all equipment covered under its scope and to supplement these general conditions with specific requirements for individual equipment types where appropriate. The specific requirements take precedence over those outlined in the general sections. See Appendix J for guidance in applying this document to specific types of equipment by category.

## 2. References

The following references shall form a part of this standard to the extent that they are referenced herein. When American National Standards and IEEE Standards are superseded by a revision, the version specified in this document shall apply.

[1] ANSI C63.2-1987, American National Standard for Instrumentation—Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz—Specifications.<sup>1</sup>

[2] ANSI C63.5-1988, American National Standard for Calibration of Antennas Used for Radiated Emissions Measurements.

[3] ANSI C63.6-1988, American National Standard Guide for the Computation of Errors in Open-Area Test Site Measurements.

[4] ANSI C63.7-1988, American National Standard Guide for Construction of Open Area Test Sites for Performing Radiated Emission Measurements.

<sup>1</sup>C63 publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 USA or from the Sales Department, American National Standards Institute, 11 West 42nd St., New York, NY 10036 USA.

- [5] CISPR Publication 14 (1985), Limits and Methods of Measurement of Radio Interference Characteristics of Household Electrical Appliances, Portable Tools and Similar Electrical Apparatus.<sup>2</sup>
- [6] CISPR Publication 16 (1987), CISPR Specifications for Radio Interference Measuring Apparatus and Measurement Methods, 2nd ed.
- [7] CISPR Publication 22 (1985), Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment. (See also [B3].)<sup>3</sup>
- [8] EIA 378 (Aug., 1970), Measurement of Spurious Radiation from FM and TV Broadcast Receivers in the Frequency Range of 100 to 1000 MHz—Using the EIA Laurel Broadband Antenna.<sup>4</sup>
- [9] FCC 47 CFR Part 15, Radio Frequency Devices (1990).<sup>5</sup>
- [10] IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronics Terms—4th ed. (ANSI)<sup>6</sup>
- [11] IEEE Std 139-1988, IEEE Recommended Practice for the Measurement of Radio Frequency Emission from Industrial, Scientific, and Medical (ISM) Equipment Installed on User's Premises (ANSI).
- [12] IEEE Std 149-1979 (Reaff 1990), Test Procedures for Antennas (ANSI).
- [13] IEEE Std 187-1990, IEEE Standard on Radio Receivers: Open Field Method of Measurement of Spurious Radiation from FM and Television Broadcast Receivers (ANSI).
- [14] IEEE Std 213-1987 IEEE Standard Procedure for Measuring Conducted Emissions in the Range of 300 kHz to 25 MHz from Television and FM Broadcast Receivers to Power Lines (ANSI).
- [15] IEEE Std 291-1991, IEEE Standard Methods for Measuring Electromagnetic Field Strength of Sinusoidal Continuous Waves, 30 Hz to 30 GHz.
- [16] IEEE Std 474-1973 (Reaff 1982), IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz (ANSI).
- [17] MIL-STD-45662, Military Standard Calibration Systems Requirements.<sup>7</sup>
- [18] Hewlett Packard Co. Application Note 150-2, "Spectrum Analysis—Pulsed RF."<sup>8</sup>

<sup>2</sup>CISPR publications are available from the International Electrotechnical Commission, 3 rue de Varembe, Case Postale 131, CH-1211, Geneve 20, Switzerland/Suisse. In the US, CISPR publications are available from the Sales Department, American National Standards Institute.

<sup>3</sup>Bracketed numbers preceded by B correspond to those of the Bibliography in Section 15.

<sup>4</sup>EIA publications are available from Global Engineering, 1990 M Street NW, Washington, DC 20036 USA.

<sup>5</sup>For information on how to purchase FCC publications, contact the Superintendent of Documents, US Government Printing Office, Washington, DC 20402 USA.

<sup>6</sup>IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331 USA.

<sup>7</sup>MIL publications are available from the Director, US Navy Publications and Printing Service, Eastern Division, 700 Robbins Avenue, Philadelphia, PA 19111 USA.

<sup>8</sup>This publication can be ordered from Regional Sales Assistance, Hewlett-Packard Co., 1212 Valley House Drive, Rohnert Park, CA 94928-4999 USA.

### 3. Definitions And Acronyms

#### 3.1 Definitions

The definitions in IEEE Std 100-1988 [10]<sup>9</sup>, unless otherwise noted below, apply throughout this document. Definitions in particular product standards or in applicable regulations take precedence.

**accessory:** Any device associated with another device that adds to the convenience or effectiveness of the latter.

**ambient level:** The values of radiated and conducted signal and noise existing at a specific test location and time when the test sample is not activated.

**antenna factor:** A factor that, when properly applied to the meter reading of the measuring instrument, yields the electric field strength in volts/meter or the magnetic field strength in amperes per meter.

NOTES:

1 — This factor includes the effects of antenna effective length and mismatch and may include transmission line losses.

2 — The factor for electric field strength is not necessarily the same as the factor for the magnetic field strength.

3 — The antenna factor as determined in ANSI C63.5-1988 [2] is very nearly equal to the free-space antenna factor.

**antenna transfer switch:** A device used to alternate between the reception of over-the-air RF signals via connection to an antenna and the reception of RF signals received by any other method.

**broadcast receiver:** A device designed to receive transmissions from a licensed station on frequencies that are authorized for commercial or public broadcasting.

**click:** A disturbance of a duration less than a specified value when measured under specified conditions.

NOTE — For the specified values and conditions, guidance may be found in International Special Committee on Radio Interference (CISPR) Publications 14 (1985) [5], 16 (1987) [6], and 22 (1985) [7].

**conducted emissions test site:** A site meeting specified requirements suitable for measuring radio interference voltages and currents emitted by an equipment under test (EUT).

**conducting ground plane:** A conducting fiat surface or plate that is used as a common reference point for circuit returns and electric or signal potentials, and that reflects electromagnetic waves.

**digital device:** An information technology equipment (ITE), which falls into the class of unintentional radiators, that uses digital techniques and generates and uses timing signals or pulses at a rate in excess of 9000 pulses per second.

**(electromagnetic) disturbance:** Any electromagnetic phenomenon that may degrade the performance of a device, piece of equipment, or system, or adversely affect living or inert matter.

NOTE — An electromagnetic disturbance may be a noise, an unwanted signal, or a change in the propagation medium itself.

**(electromagnetic) emission:** The phenomenon by which electromagnetic energy emanates from a source.

**equipment under test (EUT):** A device or system used for evaluation that is representative of a product to be marketed.

**floor-standing equipment:** Equipment designed to be used directly in contact with the floor, or supported above the floor on a surface designed to support both the equipment and the operator (e.g., a raised computer floor).

**host:** A device to which other devices (peripherals) are connected and which generally controls those devices.

<sup>9</sup>The numbers in brackets correspond to those of the references in Section 2; when preceded by B, they correspond to those of the Bibliography in Section 15.

**incidental radiator:** A device that produces RF energy during the course of its operation, although the device is not intentionally designed to generate or emit RF energy. Examples of incidental radiators are dc motors, mechanical light switches, etc.

**information technology equipment (ITE):** Unintentional radiator equipment designed for one or more of the following purposes:

- (1) Receiving data from an external source (such as a data input line or via a keyboard);
- (2) Performing some processing functions of the received data (such as computation, data transformation or recording, filing, sorting, storage, transfer of data);
- (3) Providing a data output (either to other equipment or by the reproduction of data or images).

NOTE — This definition includes electrical/electronic units or systems that predominantly generate a multiplicity of periodic binary pulsed electrical/electronic waveforms and e. re designed to perform data processing functions such as word processing, electronic computation, data transformation, recording, filing, sorting, storage, retrieval and transfer, and reproduction of data as images.

**intentional radiator:** A device that intentionally generates and emits RF energy by radiation or induction.

**interface cable:** An interconnecting cable or wire used in an ITE system to carry information.

**line impedance stabilization network (LISN):** A network inserted in the supply mains lead of apparatus to be tested that provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages and that may isolate the apparatus from the supply mains in that frequency range. *Syn:* artificial mains network.

NOTE — An LISN unit may contain one or more individual LISN circuits.

**low-voltage electrical and electronic equipment:** Electrical and electronic equipment with operating input voltages of up to 600 Vdc or rms ac.

**normalized site attenuation (NSA):** Site attenuation divided by the antenna factors of the radiating and receiving antennas (all in linear units).

**peripheral device:** A digital accessory that feeds data into or receives data from another device (host) that, in turn, controls its operation.

**personal computer:** A system containing a host and a limited number of peripherals designed to be used in the home or in small offices, which enables individuals to perform a variety of computing or word processing functions or both, and which typically is of a size permitting it and its peripherals to be located on a table surface.

NOTE — Other definitions given in product standards or applicable regulations may take precedence.

**powerline conducted radio noise:** Radio noise produced by equipment operation, which exists on the powerline of the equipment and is measurable under specified conditions.

NOTE — It may enter a receptor, such as ITE, by direct coupling or by subsequent radiation from some circuit element.

**radiated emissions test site:** A site meeting specified requirements suitable for measuring RF fields radiated by an EUT.

**radiated radio noise:** Radio-noise energy in the form of an electromagnetic field including both the radiation and induction components of the field.

**radio noise:** An electromagnetic noise that may be superimposed upon a wanted signal and is within the RF range. For the purposes of this standard, an electromagnetic disturbance of a sinusoidal character is also considered radio noise.

**restricted band:** A band of frequencies in which intentional radiators are not permitted to operate.

NOTE — For FCC application of this standard, see [9].

**site attenuation:** The ratio of the power input of a matched, balanced, lossless, tuned dipole radiator to that at the output of a similarly matched, balanced, lossless, tuned dipole receiving antenna for specified polarization, separation, and heights above a flat reflecting surface. It is a measure of the transmission path loss between two antennas.

NOTE — The above is the classical definition of site attenuation. In this document, it is extended to cover broadband antennas as well as tuned dipole antennas.

**system:** An arrangement of interconnected devices and their cables designed to perform a particular function or functions.

**tabletop device:** A device designed to be placed and normally operated on the raised surface of a table, e.g., most personal computers.

**TV interface device:** An unintentional radiator that produces or translates in frequency a radio carrier modulated by a video signal derived from an external or internal signal source, and which feeds the modulated RF energy by conduction to the antenna terminals or other nonbaseband input connections of a television broadcast receiver.

**unintentional radiator:** A device that generates RF energy for use within the device, or sends RF signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction.

## 3.2 Acronyms

|       |                                                       |
|-------|-------------------------------------------------------|
| CISPR | International Special Committee on Radio Interference |
| CSTD  | cable system terminal devices                         |
| CW    | continuous wave                                       |
| EIA   | Electronic Industries Association                     |
| EUT   | equipment under test                                  |
| FCC   | Federal Communications Commission                     |
| ISM   | industrial, scientific, and medical                   |
| ITE   | information technology equipment                      |
| LISN  | line impedance stabilization network                  |
| NIST  | National Institute of Standards and Technology        |
| NSA   | normalized site attenuation                           |
| NTSC  | National Television Systems Committee                 |
| RC    | resistor-capacitor                                    |
| RF    | radio frequency                                       |
| VCR   | video cassette recorder                               |
| VITS  | vertical interval test signal                         |
| VSWR  | voltage standing-wave ratio                           |

## 4. Measurement Instrumentation

### 4.1 General

Use of proper measurement instrumentation is critical to obtaining accurate, reproducible results. Various measuring accessories that may be needed depend upon the particular measurements to be performed as indicated below.

#### 4.1.1 Measuring Instruments

Measurements of radiated and ac powerline conducted radio noise shall be made with a measuring instrument conforming to ANSI C63.2-1987 [1] or with a spectrum analyzer. Where there is disagreement on the results of a test, data obtained with equipment conforming to ANSI C63.2-1987 shall take precedence.

#### 4.1.1.1 Reference Receiver

The reference receiver for measurements of radiated and ac powerline conducted radio noise is a measuring instrument conforming to ANSI C63.2-1987 [1]. Other instruments may be used for certain restricted and specialized measurements when data so measured is correlated to a meter conforming to ANSI C63.2-1987. Automatic scan receivers may be used, but the maximum scan speed shall be limited by the response time of the measuring system and the repetition rate of the radio noise to be measured so as to ensure that the level of each emission is measured correctly, i.e., in accordance with a measurement with a nonscanning receiver. Bandwidth and scan rates shall be chosen that are appropriate for the frequencies being scanned.

##### NOTES:

- 1 — For quasi-peak detectors, the requirements in C63.2-1987 are the same as those in CISPR Publication 16-1987 [6] for “quasi-peak instruments” in Bands A, B, C, and D.
- 2 — If the output of the quasi-peak or average detector is indicated in decibels (dB) or other logarithmic units, the logarithms shall be taken after the signal is detected and the detector function is fully realized. Otherwise, instruments that use logarithmic detectors or predetection logarithmic circuits or both shall include corrective circuits so that the output indication is the logarithm of the true average or quasi-peak value of the signal and/or noise.

#### 4.1.1.2 Spectrum Analyzer

When a spectrum analyzer is used, it shall be provided with appropriate accessories to provide sufficient sensitivity and overload protection to ensure accurate, repeatable measurements of all emissions over the specified frequency range. The autoscan limitations of 4.1.1.1 also apply to spectrum analyzers.

##### NOTES:

- 1 — The accessories needed will depend upon the specific measurement task and may include preamplifiers for improving sensitivity, filters and attenuators for overload protection, and additional quasi-peak detection circuits.
- 2 — Overload includes harmonic distortion, intermodulation distortion, and gain compression of spectrum analyzer input signals.
- 3 — If a post-detector filter is used, its bandwidth shall be wide enough so as to not affect peak detector readings.

#### 4.1.2 Line Impedance Stabilization Network (LISN)

An LISN, sometimes also called an artificial mains network, having an impedance characteristic within the limits shown in Fig 1, is required for conducted radio-noise measurements. When the “measuring instrument” ports are terminated in 50  $\Omega$ , the characteristic impedance in Fig 1 shall be present at the EUT ports of the LISN. Figures 2 and 3 show two circuits that will provide the specified impedance over the frequency ranges of 0.15 to 30 MHz and 0.01 to 0.15 (30) MHz, respectively.

Where specific equipment requirements specify another LISN, for example IEEE Std 213-1987 [14], that LISN shall be used.

NOTE — The extension of the impedance characteristic shown in Fig 1 down to 9 kHz is under consideration.

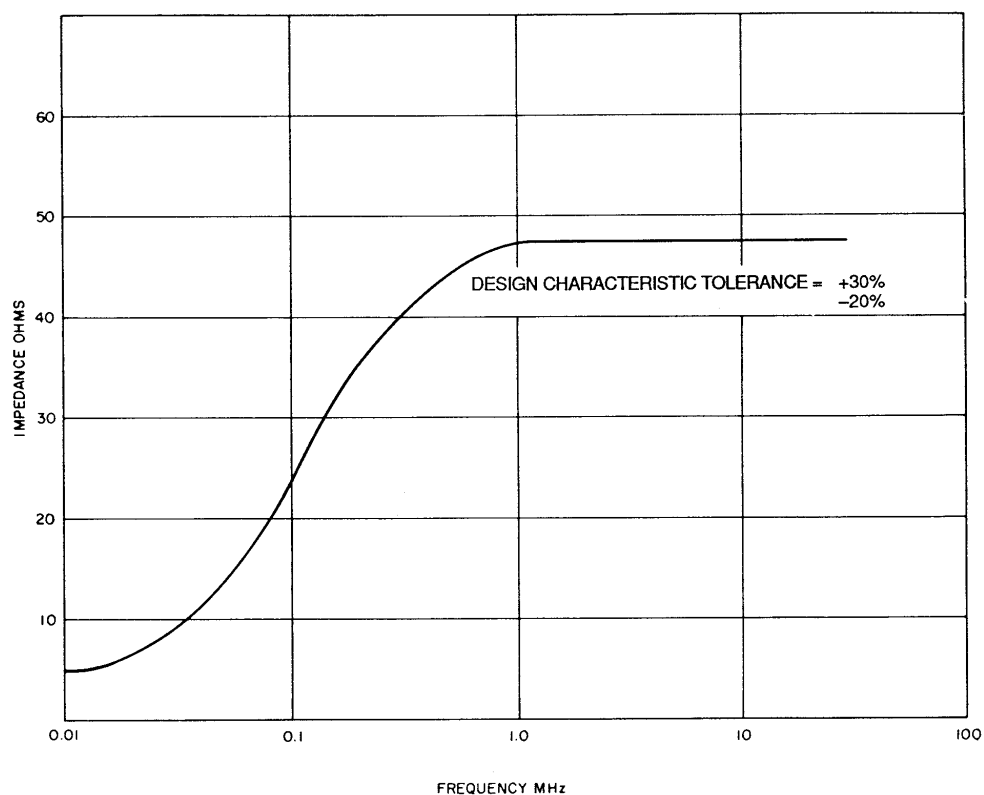
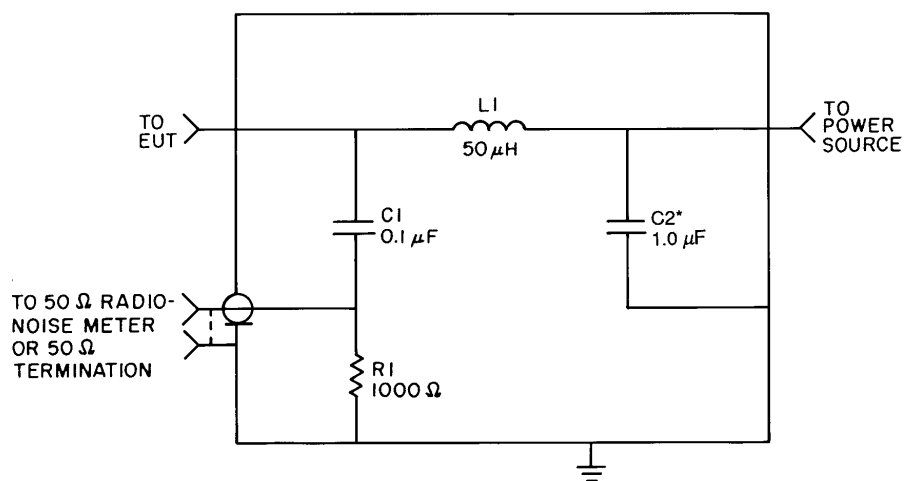
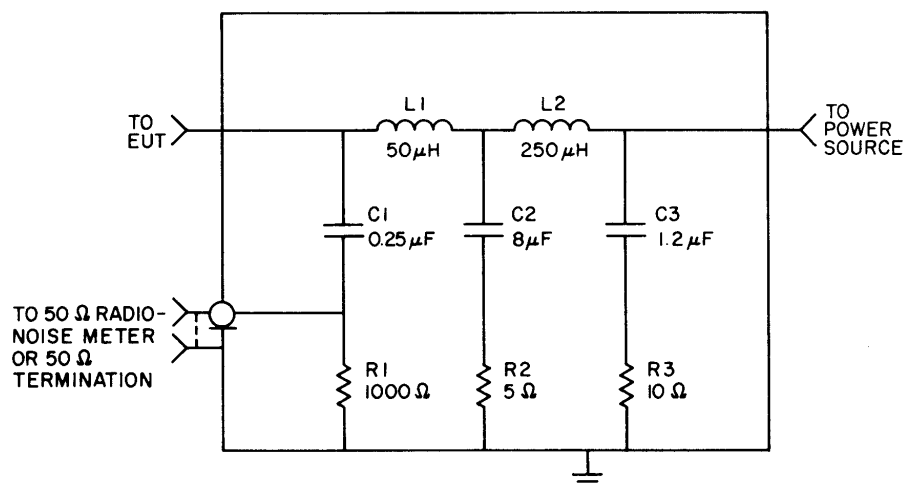


**Fig 1— Impedance Characteristic of LISN at EUT Port  
10 kHz to 30 MHz**



\*IN SOME LISNs, A SERIES RESISTANCE IS INCLUDED IN SERIES WITH CAPACITOR C2, E.G., CISPR PUBLICATION 16 (1987) [6].

**Fig 2— Circuit Diagram of LISN to Provide Impedance of Fig 1 for the 0.15 MHz to 30 MHz Frequency Range**



\* IF CAREFULLY CONSTRUCTED, THIS NETWORK CAN BE USED ABOVE 150 kHz TO AS HIGH AS 30 MHz.

**Fig 3— Circuit Diagram of LISN to Provide Impedance of Fig 1 for the 10 kHz to 150 kHz (30 MHz) Frequency Range**

#### 4.1.3 Voltage Probes

A voltage probe may be used for radio-noise voltage measurements when measurements are made at a user's installation (see 5.6) or when the ac current level exceeds the current-carrying capability of commercially available LISNs. For such measurements, the method shown in Fig 4 may be used. Special precautions shall be taken to establish a reference ground for the measurements. An LISN shall not be used in conjunction with a voltage probe for measurements at a user installation. The measurements are dependent on the impedance presented by the supply mains and may vary with time and location due to variations in the supply mains. (It may be necessary to perform repeated measurements over a suitable period of time to determine the variation in measured values. The time period shall be sufficient to cover all significant variations due to operating conditions at the installation.) Such measurement results shall be regarded as unique to that EUT and installation environment. The measurements shall be made between each current-carrying conductor in the supply mains and the ground conductor with a blocking capacitor (C) and a resistor (R), shown in Fig 4, such that the total resistance between line and ground is 1500  $\Omega$ . Since the voltage probe attenuates the radio-noise voltage, appropriate calibration factors shall be added to the measured values. Measurements made with LISNs shall take precedence over measurements made with voltage probes.

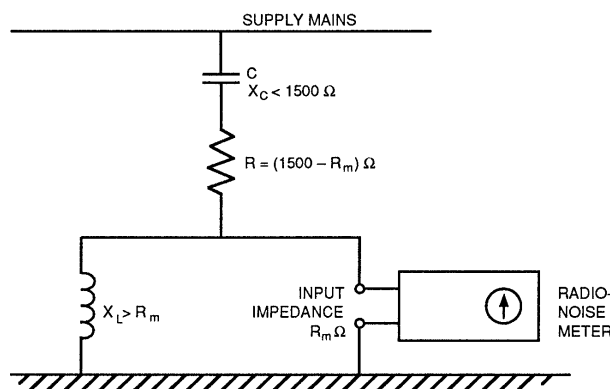


**Fig 4— Voltage Probe for Tests at User's Installation**

#### 4.1.4 Current Probes

A current probe that fits around each current-carrying conductor under test may be used, when permitted, to measure radio-noise currents (in lieu of radio-noise voltages) generated by the EUT. The probe shall be immune to external fields, calibrated, and used with the proper terminating impedance. An LISN in accordance with 4.1.2 shall be inserted between the EUT conductors and the mains outlet. The probe is placed between the EUT and the LISN as near the LISN as possible. An appropriate adapter may be fitted between the EUT and the LISN to allow the current probe to be clamped on individual current-carrying conductors. If an appropriate LISN satisfying the current requirements of the EUT is not commercially available, the LISN may be eliminated and the current probe placed between the EUT and the mains outlet.

#### 4.1.5 Antennas

The use of specific antennas depends on the frequency range and field (electric or magnetic) being measured in performing radiated emissions measurements as indicated in 4.1.5.1–4.1.5.4.

##### 4.1.5.1 Magnetic Field Measurements (9 kHz to 30 MHz)

Calibrated loop antennas as specified in ANSI C63.2-1987 [1] shall be used to measure magnetic fields in the frequency range of 9 kHz to 30 MHz.

##### 4.1.5.2 Electric Field Measurements (9 kHz to 30 MHz)

Calibrated monopole (rod) antennas as specified in ANSI C63.2-1987 [1] and IEEE Std 291-1991 [15] shall be used to measure electric fields in the frequency range of 9 kHz to 30 MHz. Generally, a 1.04 m (approximately 41 in) vertical monopole antenna is used with or without a counterpoise as specified by the manufacturer.

##### 4.1.5.3 Electric Field Measurements (30 MHz to 1000 MHz)

Calibrated, linearly polarized antennas as specified in ANSI C63.2-1987 [1] shall be used to measure electric fields in the frequency range of 30 MHz to 1000 MHz. Tunable dipoles should be used. Alternatively, a linearly polarized broadband antenna or a dipole tuned only above 80 MHz, and set to the 80 MHz tuned length when used between 30 and 80 MHz, may be used in lieu of a tuned dipole provided that the measurement can be correlated with that made with a tuned dipole with an acceptable degree of accuracy. In case of dispute, data taken with a reference antenna or a tuned dipole calibrated in accordance with ANSI C63.5-1988 [2] shall take precedence.

##### 4.1.5.4 Electric Field Measurements (1 to 40 GHz)

Calibrated, linearly polarized antennas as specified in ANSI C63.2-1987 [1] should be used. These include double-ridged guide horns, rectangular waveguide horns, pyramidal horns, optimum gain horns, and standard gain horns. The “beam” or major lobe of the pattern of any antenna used shall be large enough to encompass the EUT when located at the measuring distance, or provisions shall be made for “scanning” the EUT to locate the direction or source of its radiated emissions. The aperture dimensions of these horn antennas shall be small enough that the measurement distance in meters is equal to or greater than the Rayleigh Distance, i.e.,  $R_m = D^2 / (2\lambda)$ , where  $D$  is the largest dimension of the aperture in meters of the antenna, and  $\lambda$  is the free-space wavelength in meters at the frequency of measurement. In case of dispute, measurements made with the standard gain horn antenna shall take precedence.

NOTE — Any calibrated, linearly polarized antenna, e.g., a log-periodic dipole array may be used to make these measurements. The gain of many antennas, other than horn antennas, in this frequency range may be inadequate if the antennas are used with spectrum analyzers or older radio-noise meters. The tester shall assure that the overall measurement sensitivity is at least 6 dB below the applicable limit at the measurement distance in use, and that any means used to improve sensitivity, e.g., a preamplifier, does not cause distortion, spurious signals, or other overload problems. Since a log-periodic dipole array has a much wider beam width than a horn antenna, reflections from the ground plane may cause significant error in measurements that are made with a log-periodic dipole array. The tester shall assure that these reflections do not adversely affect the measured value.

#### 4.1.6 Absorbing Clamp

Measurements of radio-noise power, if required, are made with an absorbing clamp (see Section 9).

### 4.2 Detector Function/Selection of Bandwidth

Unless otherwise specified, radio-noise meters or spectrum analyzers shall have as the reference detector function the quasi-peak detector specified in ANSI C63.2-1987 [1] for frequencies up to and including 1 GHz. For measurements above 1 GHz, if peak or average detectors are specified, use the C63.2-1987 requirements. Detector functions other than those specified by the procuring or regulatory agency may be used for making such measurements, provided (1) data so taken are correlatable to data taken with the appropriate detector and the associated instrument bandwidth, or (2) peak detector measured data may be substituted for the appropriate detector data to show compliance if the peak level obtained does not exceed the limit. The bandwidth used shall be equal to or greater than that specified in ANSI C63.2-1987. The bandwidth used shall be equal to or greater than 100 Hz from 9 kHz to 150 kHz, 9 kHz from 150 kHz to 30 MHz, 100 kHz from 30 MHz to 1000 MHz, and 1 MHz from 1 GHz to 40 GHz.

The measuring instrument shall satisfy the following conditions:

- 1) The measuring instrumentation with either the quasi-peak, peak, or average detector shall have a linear response.
- 2) When measuring an emission with a low duty cycle, the dynamic range of the measuring instrument shall not be exceeded.

NOTE — Use of bandwidths greater than those specified may produce higher readings for certain types of emissions.

### 4.3 Receiver Monitoring

All radio-noise measurements shall be monitored using either a head-set, a loudspeaker, a spectrum display, or any combination thereof as an aid to detecting ambient signals and selecting the emissions that have the highest amplitude relative to the limit. Precautions shall be taken to ascertain that the use of a headset or speaker does not affect the measuring instrument indication during measurements.

### 4.4 Calibration of Measuring Equipment

The calibration of the instrumentation shall be checked frequently to assure its accuracy in accordance with requirements of ANSI C63.2-1987 [1]. Adjustments shall be made and correction factors applied in accordance with instructions contained in the instruction manual of the equipment. Normally a direct reading measurement method is preferred. However, signal substitution methods may be used provided it can be established that the results are equivalent to a properly calibrated direct reading method.

In addition to the measuring instrumentation, cables, antennas, LISNs, voltage and current probes, etc., and the test facility are to be checked and calibrated as necessary on a regular basis to ensure the accuracy of the test results, but no less frequently than annually.

As a minimum, all instrumentation shall be calibrated using secondary standards traceable to the National Institute of Standards and Technology (NIST) or an equivalent standards reference organization. An example of a satisfactory calibration system is given by MIL-STD-45662 [17].

#### 4.4.1 Antenna Calibration

All antennas shall be individually calibrated to show traceability to NIST or an equivalent standards reference organization. Antennas calibrated by the methods given in ANSI C63.5-1988 [2] meet the traceability requirements.

Antenna factors shall be rechecked at least once a year, by recalibration techniques or by checking against reference antennas or known signal sources. Spot-checking during the period between calibrations is recommended.

Reference antennas that are used only for calibration or comparison purposes and not used on a daily basis should be recalibrated at least every three years.

Antennas for use below 30 MHz shall be calibrated using an acceptable method, such as one of the methods in IEEE Std 291-1991 [15].

Antennas for use from 30 to 1000 MHz shall be calibrated using one of the methods specified in ANSI C63.5-1988 [2]. Reference antennas shall be constructed as specified therein. It is strongly recommended that the reference antenna be spot-checked against other known antennas. If adjustable (tunable) dipole antennas are used below 80 MHz while set at their 80 MHz resonant length, they shall also be calibrated at that length for the range of frequencies of use according to ANSI C63.5-1988.

Antennas for use at or above 1 GHz shall be calibrated using an acceptable method, such as one of the methods in IEEE Std 291-1991 [15] or IEEE 149-1979 [12]. The antenna used shall be calibrated at the measuring distance at which it will be used.

#### NOTES:

- 1 — If the antenna is calibrated at a distance  $\geq 2.D^2/\lambda$ , it may be used to make measurements at any distance greater than  $2.D^2/\lambda$  with an error of less than 1 dB.
- 2 — Gain standard horn antennas (sometimes called standard gain horn antennas) need not be calibrated beyond that which is provided by the manufacturer unless (a) they are damaged or deterioration is suspected, or (b) they are used at a distance closer than  $2.D^2/\lambda$ . Gain standard horn antennas have gains that are fixed by their dimensions and dimensional tolerances.

### 4.4.2 LISN Calibration

The impedance and insertion loss of each LISN used in testing for conducted emissions is to be measured over the frequency range of use in accordance with the procedure described in Appendix F. LISN impedance shall be calibrated at least once a year, and frequent spot-checking is recommended. Where the LISN is permanently installed on a test site, calibration should be performed as required in 5.2.3.

### 4.4.3 Absorbing Cable Clamp Calibration

The absorbing cable clamp may be calibrated using the procedure in clause 11.3 of CISPR Publication 16 (1967) [6], much of which is summarized in Appendix G.

### 4.4.4 Cable Calibration

Cables used for connection of antennas or transducers to measuring instruments (radio-noise meters, spectrum analyzers, etc.) shall be calibrated for loss using an acceptable standard, such as IEEE Std 474-1973 [16], and checked frequently for deterioration caused by use and exposure to sunlight, physical wear, and other conditions.

## 5. Test Facilities

Radiated and ac powerline conducted measurements shall be made in an environment that assures valid, repeatable measurement results as described in 5.2 (ac powerline conducted emissions test sites) or 5.3, 5.4, and 5.5 (radiated emissions test sites). Where appropriate, tests may be made at the manufacturer's location or the user's installation (5.6). In any case, the requirements of 5.1 shall be observed.

## 5.1 General Requirements

### 5.1.1 Power Source

Sufficient power shall be available to operate the EUT at its rated voltage, current, power, and frequency.

### 5.1.2 Ambient Radio Noise and Signals

AC powerline conducted and radiated ambient radio noise and signal levels, measured at the test site with the EUT de-energized, should be at least 6 dB below the allowable limit of the applicable specification or standard. In the event that the measured levels of ambient plus EUT radio noise are not above the applicable limit, the EUT shall be considered to be in accordance with the limit.

If the ambient field or the powerline ambient level exceeds the applicable limit(s), the following alternatives may be used:

- 1) In the case of radiated measurements, perform measurements at the closest distance permitted by 5.4.1 and extrapolate results to the specified limit distance. The method of extrapolation shall be justified and described in the test report.
- 2) Perform measurements of critical frequency bands during hours when broadcast stations are off the air and at times when ambients from industrial equipment are reduced to less than the 6 dB level.
- 3) Perform measurements in an absorber-lined room (see 5.4.2 for conditions of use).
- 4) Make ac powerline conducted measurements in a shielded enclosure. However, this method is recommended only at frequencies below the resonant frequencies of the enclosure, usually under 30 MHz.
- 5) For ac powerline conducted measurements, insert suitable powerline filters between the power source and the LISN.
- 6) Orient the test site so as to discriminate against such ambient signals insofar as possible.
- 7) If the signal being measured is narrowband and the ambient field is broadband, reduce the bandwidth of the receiver.
- 8) Rotate the EUT on a turntable while observing possible correlation between emission amplitude and EUT azimuth.
- 9) Monitor the radio-noise meter audio with a loudspeaker or headphones and its video with a time-based oscilloscope display to discriminate between ambient noise and signals and EUT emissions.

## 5.2 AC Powerline Conducted Emissions Test Site Requirements

AC powerline conducted measurements may be made at a site that meets the requirements of this section. This may include a shielded (screened) room or a radiated emissions test site.

### 5.2.1 Conducting Ground Plane

The conducting ground plane for measuring ac powerline conducted emissions is to consist of a floor earth-grounded conducting surface, which may be the metal floor of a shielded test chamber. The conducting surface is to be at least 2 m by 2 m in size, and shall extend at least 0.5 m beyond the vertical projection (footprint) of the EUT. Where the EUT normally does not make physical contact with a ground plane, the ground plane shall be covered by insulating materials between 3 mm and 12 mm thick.

### 5.2.2 Vertical Conducting Surface

For measurements of ac powerline conducted emissions on a tabletop device, a vertical conducting plane or screen of at least 2 m by 2 m in size shall be located 40 cm to the rear of the EUT. The conducting plane or screen shall be electrically connected to the conducting ground plane at intervals not greater than one meter along its entire length

through low-impedance connection, e.g., 3 cm-wide metal straps. The metal wall of a screen room will normally satisfy this requirement.

For a tabletop device tested on an open area test site for ac powerline conducted emissions, a vertical conducting surface is optional. However, in case of a dispute, ac powerline conducted measurements made on a tabletop device with a vertical conducting surface in place shall take precedence.

A vertical conducting surface is not required for ac powerline conducted emissions measurements on a floor-standing device.

### 5.2.3 LISN Installation

Where use of an LISN is required (see Section 7), it shall be placed on the top surface of, or immediately beneath, the conducting ground plane and grounded to the plane.

The impedance at the EUT socket end of the LISN or the socket end of any cable connected to the EUT end of the LISN, with the measuring instrument port of the LISN terminated in  $50\ \Omega$ , shall be within +30% and –20% of the nominal LISN impedance shown in Fig 1 over the frequency range of the network to be used. If the attenuation (insertion loss) between the EUT plug and the measuring instrument port on the LISN is more than 0.5 dB, it shall be taken into account when calculating the EUT emission levels. The site ground plane is the ground reference for the LISN.

Ambient noise may be present on the ac power mains at some locations at some frequencies within the range of measuring interest. If the levels are sufficient to cause interference with readings made using an LISN, filtering of the ac mains may be required. The filter should be inserted between the ac mains supply and the ac input connection to the LISN, preferably as close as possible to the LISN to reduce interference pickup by the leads between the filter and the LISN. The LISN impedance shall be rechecked if an ac mains filter is used.

Where an isolation transformer is used between the ac mains supply and the LISN, care must be taken to ensure that this transformer's rating is large enough to not affect the peak current drawn by the EUT (this may require ten times the kVA rating of the EUT). If other than air core inductors are used in the LISN, they shall be in a linear permeability range at the peak currents drawn by the EUT.

### 5.2.4 Voltage Probe

Where use of an LISN is impossible due to high current requirements of the EUT, or where a conducting ground plane is not available, conducted emissions tests shall be performed using the voltage probe as discussed in 4.1.3. See also 5.6.

## 5.3 Radiated Emissions Test Site Requirements for Measurements Below 30 MHz

For magnetic field strength measurements (see 8.2.1), a site similar to that of Fig 5 should be used except that a conducting ground plane is not required. If a conducting ground plane is present, the measured level of emissions may be higher. Magnetic field strength measurements made at a site with no conducting ground plane shall take precedence. If permitted by the procuring or regulatory agency, measurements may be made in a shielded enclosure at frequencies below its resonant frequency.

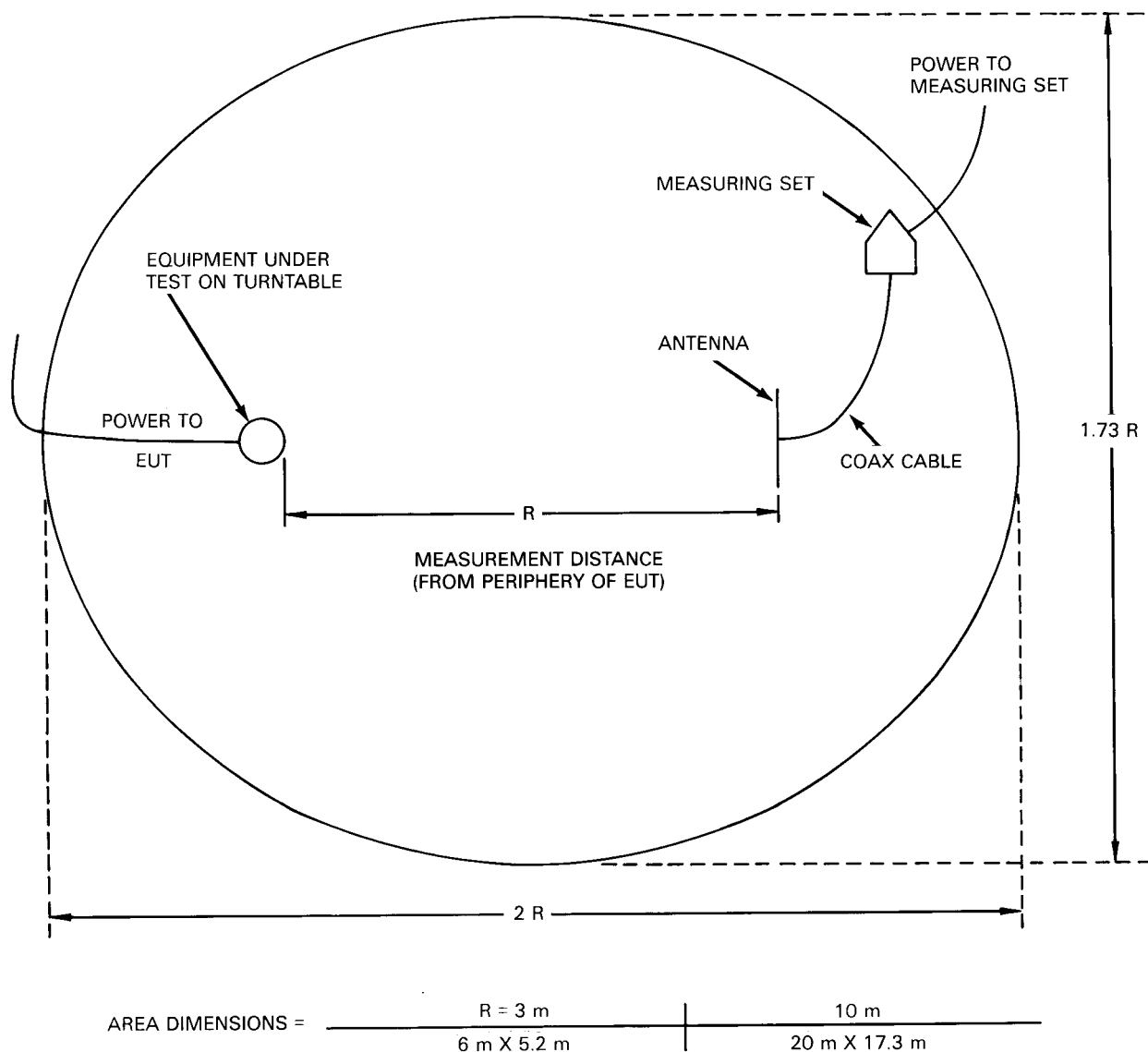


**Fig 5— Radiated Emissions Measurement Obstruction-Free Area for Site with a Turntable**

## 5.4 Radiated Emissions Test Site Requirements for Measurements 30 MHz to 1 GHz

Test sites used for making final radiated emissions tests shall be capable of meeting the applicable requirements given in 5.4.6.

### 5.4.1 Reference Test Site

The reference site for radiated tests is an open, flat area (open area test site) characteristic of cleared, level terrain. Such a site shall be void of buildings, electric lines, fences, trees, underground cables, pipelines, etc., except as required to perform the test. A suggested layout of an open area test site is shown in Fig 5, where the recommended distance for  $R$  (measured from the nearest perimeter of the EUT) is 3, 10, or 30 m. All reflecting objects including test personnel shall lie outside the perimeter of the ellipse. ANSI C63.7-1988 [4] further describes the characteristics and construction of open area test sites. A conducting ground plane is required (see 5.4.3).

### 5.4.2 Alternate Test Sites

Measurements can be made at a location other than an open area test site, such as a weather-protected site, an absorber-lined room, a dedicated laboratory, or a factory site provided the alternate site meets the site attenuation requirements of 5.4.6 over the volume occupied by the EUT (see 5.4.6.5) and the conducting ground plane requirements of 5.4.3. For the time being, weather-protected sites are exempt from the requirements to meet 5.4.6.5, as this matter is under study (see Appendix C). Measurements can also be made where the requirements of 5.4.6 are not met but it can be demonstrated to the relevant authority that the results achieved are equivalent to those obtained at an open area test site over the frequency range at which measurements are made. In cases of disagreement, final radiated emissions tests performed at an open area site meeting the requirements of 5.4.1 and 5.4.6 take precedence.

#### 5.4.2.1 Shielded Enclosures

A shielded enclosure not containing absorber lining may be used only for preliminary testing (see 8.3.1.1).

### 5.4.3 Conducting Ground Plane

A conducting ground plane is required at a radiated emissions test site. The conducting ground plane shall extend at least 1 m beyond the periphery of the EUT and the largest measuring antenna, and cover the entire area between the EUT and the antenna. It shall be of metal with no holes or gaps having longitudinal dimensions larger than one-tenth of a wavelength at the highest frequency of measurement up to 1 GHz (ANSI C63.7-1988 [4]). A larger size conducting ground plane may be required if the test site has any of the following characteristics

- 1) The terrain of the site is discontinuous.
- 2) The terrain of the site is subject to extreme seasonal variations in ground conductivity.
- 3) There are unburied power or control cables on the site.
- 4) The site is located on pavement.
- 5) The site is raised or located on a rooftop or otherwise elevated above the surrounding in situ ground.
- 6) Test site does not meet site attenuation requirements.

NOTE — Ongoing studies may indicate the need for specifying a minimum conducting ground plane size.

### 5.4.4 Turntable

A continuously rotatable turntable shall be used for measuring radiated emissions from all sides of the EUT. It is strongly recommended that this turntable be remotely controlled to prevent test personnel from coming into close proximity to the EUT and thus affecting test results (See NOTE 1 below). For floor-standing EUTs, the turntable shall be metal-covered and flush with the conducting ground plane (NOTE 2). Table-mounted EUTs shall be tested by using a nonmetallic table of correct height mounted on top of the flush-mounted conductive turntable. A combination of a raised nonmetallic turntable and nonmetallic table located on top of the conducting ground plane may also be acceptable. Site attenuation measurements according to 5.4.6 shall be made to show if such combinations meet requirements. The site attenuation measurement should also show whether the gap between a conducting flush turntable circumference and the surrounding conducting ground plane should be electrically bridged with suitable rubbing or rolling flexible conductive material. The presence of such electrical connection can be temporarily simulated by bridging the circumferential gap with conductive tape and conductive adhesive at least every 30°. If there is no change in site attenuation, especially below 100 MHz for vertical polarization measurements, the gap need not be filled. If noticeable changes are observed, i.e., a change of approximately 1 dB or more, a suitable bridging mechanism as mentioned above should be installed. See ANSI C63.7-1988 [4] for further guidance.

For some applications, such as operation of the EUT via a remotely located simulator and I/O cabling, the turntable should have a center opening that will allow cabling to be routed directly down to the conducting ground plane for raised turntables or below the conducting ground plane for flush turntables (NOTE 3).

**NOTES:**

- 1 — If a remotely controlled turntable is not used for final radiated emissions measurements, the measurement report shall include information to demonstrate how the influence of the tester's body was eliminated from radiated emissions test results.
- 2 — Because of their present rather extensive use, raised turntables not exceeding 34 cm in height may be used until January 17, 1994, for measuring floor-standing equipment. If a raised turntable is used, the conducting ground plane shall be continuous beneath the turntable. Material used for such turntables should be selected so that there is no adverse effect when performing the site attenuation measurement. Because it is generally agreed that measured levels are dependent on equipment height, in case of dispute, measurements made with a flush-mounted turntable shall take precedence.
- 3 — If the center area does not rotate with the turntable, power and cooling access and receptacles can also be accommodated and supplied from below the top of the turntable.

**5.4.5 Antenna Positioner**

The antenna positioner used to position the measurement antenna for the radiated emissions measurements shall be capable of positioning the center of the antenna at any height in the range of 1 to 4 m above the ground plane. The positioner shall be capable of maintaining the antenna in both the horizontal and vertical polarizations. The positioner shall be in place and used for the support of the receiving antenna during site attenuation measurements.

To meet site attenuation requirements usually requires that the positioner and all antenna-mounting adapters be constructed of substantially nonreflecting materials such as wood, plastic, nylon, or fiberglass. Any antenna positioner components containing substantial amounts of metal, such as the motor, base assembly or wheels, should be mounted as close to the ground plane as practical.

**5.4.6 Validation Requirements**

Radiated emissions test sites shall be validated by making both horizontal and vertical normalized site attenuation (NSA) measurements. Antenna spacings used for making site attenuation measurements shall be the same as the spacing used for the EUT compliance tests at frequencies from 30 to 1000 MHz. The measured NSA data shall be compared to that calculated for an ideal site.

NOTE — During site attenuation measurements, the receiving antenna positioner normally used and raised turntable, if used, shall be in place.

**5.4.6.1 Site Attenuation**

A measurement site shall be considered acceptable for radiated electromagnetic field measurements if the horizontal and vertical NSA derived from measurements, i.e., the “measured NSA,” are within  $\pm 4$  dB of the theoretical NSA (5.4.6.3) for an ideal site.

**5.4.6.2 NSA Tolerance**

The  $\pm 4$  dB tolerance in 5.4.6.1 includes instrumentation calibration errors, measurement technique errors, and errors due to site anomalies. These errors are analyzed in ANSI C63.6-1988 [3], wherein it is shown that the performance of a well-built site contributes only 1 dB of the total allowable tolerance. Appendix C of this document suggests actions to be taken if a site fails to meet the requirements.

**5.4.6.3 Theoretical NSA**

The theoretical NSAs for the most used measurement separations and antennas are shown in Tables 1 through 3, for an ideal site.

The theoretical NSA is developed and calculated in [B15]. Tables 1 through 3 are from [B9], [B11], [B14], and [B15]. The mutual impedance correction factors for tuned dipole antennas were developed in [B15] and have subsequently been revised in [B9] and [B14] and are shown in Table 4. The symbols for these tables are defined as follows:

- $R$  = Horizontal separation between the projection of the transmit and receive antennas on the conducting ground plane (meters)  
 $h_1$  = Height of the center of the transmitting antenna above the conducting ground plane (meters)  
 $h_2$  = Height of the center of the receiving antenna above the conducting ground plane (meters)

NOTE — In the measurement procedure,  $h_2$  is varied and the maximum received signal in the height scan range is used in the NSA measurements.  $f_M$  = frequency in MHz,  $A_N$  = NSA (see Eq 1).

Table 1 is used for broadband antennas such as biconical and log periodic arrays. Table 2 is for tunable dipoles (and broadband antennas for alternate test site qualification) aligned horizontally with respect to the conducting ground plane. Finally, Table 3 is for tunable dipoles, vertically aligned with respect to the conducting ground plane. Note that in Table 3, there are restrictions in the scan height  $h_2$ . This takes into account the fact that the lowest tip of the receive dipole is kept 25 cm or more from the conducting ground plane.

NSA for frequencies other than those shown in the tables may be found using straight-line interpolation between the tabulated values.

NOTE — The spacing  $R$  between log-periodic array antennas is measured from the projection onto the conducting ground plane of the midpoint of the longitudinal axis of each antenna.

#### 5.4.6.4 NSA Measurement: Basic Procedures

Two antennas are set up on the test site in an appropriate geometry as shown in Figs 6 and 7. The NSA procedure requires two different measurements of the voltage received,  $V_R$ . The first reading of  $V_R$  is with the two coaxial cables disconnected from the two antennas and connected to each other via an adapter. The second reading of  $V_R$  is taken with the coaxial cables reconnected to their respective antennas and the maximum signal measured with the receive antenna scanned in height [B12]. For both of these measurements, the signal source,  $V_b$ , is kept constant. The first reading of  $V_R$  is called  $V_{\text{Direct}}$  and the second is  $V_{\text{Site}}$ . These are used in the following Eq 1 for the measured NSA,  $A_N$ ; all terms are in dB.

$$A_N = V_{\text{Direct}} - V_{\text{Site}} - AF_T - AF_R - \Delta AF_{TOT} \quad (\text{Eq1})$$

where

- $AF_T$  = Antenna factor of transmitting antenna  
 $AF_R$  = Antenna factor of receiving antenna  
 $AF_{TOT}$  = Mutual impedance correction factor

NOTE — The first two terms represent the actual measurement of site attenuations; i.e.,  $V_{\text{Direct}} - V_{\text{Site}}$  is equal to the classical site attenuation and

$$V_{\text{Direct}} = V_I - C_T - C_R \quad (\text{Eq2})$$

where  $C_T$  and  $C_R$  are the cable losses that do not need to be measured separately.

$AF_T$  and  $AF_R$  are determined as specified in ANSI C63.5-1988 [2]. The mutual impedance correction factor in Table 4 applies only to the recommended site geometry of 3 m separation, both horizontal and vertical polarization, with the use of resonant tuned dipoles.  $\Delta AF_{TOT} = 0$  for all other geometries and for broadband antennas.

**Table 1— Theoretical Normalized Site Attenuation for Ideal Site (Recommended Geometries for Broadband Antennas)\***

| Polarization | Horizontal | Horizontal | Horizontal | Vertical | Vertical | Vertical | Vertical | Vertical | Vertical |
|--------------|------------|------------|------------|----------|----------|----------|----------|----------|----------|
| $R$ meters   | 3          | 10         | 30         | 3        | 3        | 10       | 10       | 30       | 30       |
| $h_1$ meters | 1          | 1          | 1          | 1        | 1.5      | 1        | 1.5      | 1        | 1.5      |
| $h_2$ meters | 1–4        | 1–4        | 1–4        | 1–4      | 1–4      | 1–4      | 1–4      | 1–4      | 1–4      |
| $f_M$ (MHz)  | $A_N$ (dB) |            |            |          |          |          |          |          |          |
| 30           | 15.8       | 29.8       | 47.7       | 8.2      | 9.3      | 16.7     | 16.8     | 26.0     | 26.0     |
| 35           | 13.4       | 27.1       | 45.0       | 6.9      | 8.0      | 15.4     | 15.5     | 24.7     | 24.7     |
| 40           | 11.3       | 24.9       | 42.7       | 5.8      | 7.0      | 14.2     | 14.4     | 23.5     | 23.5     |
| 45           | 9.4        | 22.9       | 40.7       | 4.9      | 6.1      | 13.2     | 13.4     | 22.5     | 22.5     |
| 50           | 7.8        | 21.1       | 38.8       | 4.0      | 5.4      | 12.3     | 12.5     | 21.6     | 21.6     |
| 60           | 5.0        | 18.0       | 35.7       | 2.6      | 4.1      | 10.7     | 10.9     | 20.0     | 20.0     |
| 70           | 2.8        | 15.5       | 33.0       | 1.5      | 3.2      | 9.4      | 9.6      | 18.7     | 18.7     |
| 80           | 0.9        | 13.3       | 30.7       | 0.6      | 2.6      | 8.3      | 8.5      | 17.5     | 17.5     |
| 90           | –.7        | 11.4       | 28.7       | –0.1     | 2.1      | 7.3      | 7.6      | 16.5     | 16.5     |
| 100          | –2.0       | 9.7        | 26.9       | –0.7     | 1.9      | 6.4      | 6.8      | 15.6     | 15.6     |
| 120          | –4.2       | 7.0        | 23.8       | –1.5     | 1.3      | 4.9      | 5.4      | 14.0     | 14.0     |
| 125          | –4.7       | 6.4        | 23.1       | –1.6     | 0.5      | 4.6      | 5.1      | 13.6     | 13.7     |
| 140          | –6.0       | 4.8        | 21.1       | –1.8     | –1.5     | 3.7      | 4.3      | 12.7     | 12.7     |
| 150          | –6.7       | 3.9        | 20.0       | –1.8     | –2.6     | 3.1      | 3.8      | 12.1     | 12.1     |
| 160          | –7.4       | 3.1        | 18.9       | –1.7     | –3.7     | 2.6      | 3.4      | 11.5     | 11.6     |
| 175          | –8.3       | 2.0        | 17.4       | –1.4     | –4.9     | 2.0      | 3.1      | 10.8     | 10.8     |
| 180          | –8.6       | 1.7        | 16.9       | –1.3     | –5.3     | 1.8      | 2.7      | 10.5     | 10.6     |
| 200          | –9.6       | 0.6        | 15.2       | –3.6     | –6.7     | 1.0      | 2.1      | 9.6      | 9.7      |
| 250          | –11.7      | –1.6       | 11.6       | –7.7     | –9.1     | –0.5     | 0.3      | 7.7      | 7.9      |
| 300          | –12.8      | –3.3       | 8.7        | –10.5    | –10.9    | –1.5     | –1.9     | 6.2      | 6.4      |
| 400          | –14.8      | –5.9       | 4.5        | –14.0    | –12.6    | –4.1     | –5.0     | 3.9      | 4.3      |
| 500          | –17.3      | –7.9       | 1.8        | –16.4    | –15.1    | –6.7     | –7.2     | 2.1      | 2.8      |
| 600          | –19.1      | –9.5       | 0.0        | –16.3    | –16.9    | –8.7     | –8.9     | 0.8      | 1.8      |
| 700          | –20.       | –10.8      | –1.3       | –18.4    | –18.4    | –10.2    | –10.3    | –0.3     | –0.8     |
| 800          | –21.3      | –12.0      | –2.5       | –20.0    | –19.3    | –11.5    | –11.6    | –1.1     | –2.2     |
| 900          | –22.5      | –12.8      | –3.5       | –21.3    | –20.4    | –12.6    | –12.6    | –1.7     | –3.3     |
| 1000         | –23.5      | –13.8      | –4.5       | –22.4    | –21.4    | –13.6    | –13.6    | –3.6     | –4.3     |

none These data apply to antennas that have at least 25 cm of ground plane clearance when the center of the antenna is 1 m above the ground plane in vertical polarization.

**Table 2— Theoretical Normalized Site Attenuation for Ideal Site  
(Recommended Geometries for Tunable Dipoles and for Broadband Antennas  
on Alternate Test Sites, Horizontal Polarization)**

| Polarization                 | Horizontal                 | Horizontal                 | Horizontal                 |
|------------------------------|----------------------------|----------------------------|----------------------------|
| <i>R</i> meters              | 3*                         | 10                         | 30                         |
| <i>h</i> <sub>1</sub> meters | 2                          | 2                          | 2                          |
| <i>h</i> <sub>2</sub> meters | 1–4                        | 1–4                        | 1–4                        |
| <i>f</i> <sub>M</sub>        | <i>A</i> <sub>N</sub> (dB) | <i>A</i> <sub>N</sub> (dB) | <i>A</i> <sub>N</sub> (dB) |
| 30                           | 11.0                       | 24.1                       | 41.7                       |
| 35                           | 8.8                        | 21.6                       | 39.1                       |
| 40                           | 7.0                        | 19.4                       | 36.8                       |
| 45                           | 5.5                        | 17.5                       | 34.7                       |
| 50                           | 4.2                        | 15.9                       | 32.9                       |
| 60                           | 2.2                        | 13.1                       | 29.8                       |
| 70                           | 0.6                        | 10.9                       | 27.2                       |
| 80                           | −4.7                       | 9.2                        | 24.9                       |
| 90                           | −1.8                       | 7.8                        | 23.0                       |
| 100                          | −2.8                       | 6.7                        | 21.2                       |
| 120                          | −4.4                       | 5.0                        | 18.2                       |
| 125                          | −4.7                       | 4.6                        | 17.6                       |
| 140                          | −5.8                       | 3.5                        | 15.8                       |
| 150                          | −6.3                       | 2.9                        | 14.7                       |
| 160                          | −6.7                       | 2.3                        | 13.8                       |
| 175                          | −6.9                       | 1.5                        | 12.4                       |
| 180                          | −7.2                       | 1.2                        | 12.0                       |
| 200                          | −8.4                       | 0.3                        | 10.6                       |
| 250                          | −10.6                      | −1.7                       | 7.8                        |
| 300                          | −12.3                      | −3.3                       | 6.1                        |
| 400                          | −14.9                      | −5.8                       | 3.5                        |
| 500                          | −16.7                      | −7.6                       | 1.6                        |
| 600                          | −18.3                      | −9.3                       | 0.0                        |
| 700                          | −19.7                      | −10.6                      | −1.4                       |
| 800                          | −20.8                      | −11.8                      | −2.5                       |
| 900                          | −21.8                      | −12.9                      | −3.5                       |
| 1000                         | −22.7                      | −13.8                      | −4.5                       |

\*The mutual impedance correction factors in Table 4 for horizontally polarized tunable dipoles spaced 3 m apart should be inserted in Eq 1 of 5.4.6.4 in determining the measured NSA data for comparison with the theoretical normalized site attenuation values for an ideal site given in this table.

**Table 3— Theoretical Normalized Size Attenuation for Ideal Site  
(Recommended Geometries for Tunable Dipoles, Vertical Polarization)**

| $f_M$<br>MHz | $R = 3\text{m}^*$<br>$h_1 = 2.75\text{ m}$ |                   | $R = 10\text{m}$<br>$h_1 = 2.75\text{ m}$ |                   | $R = 30\text{m}$<br>$h_1 = 2.75\text{ m}$ |                   |
|--------------|--------------------------------------------|-------------------|-------------------------------------------|-------------------|-------------------------------------------|-------------------|
|              | $h_2\text{ (m)}$                           | $A_N\text{ (dB)}$ | $h_2\text{ (m)}$                          | $A_N\text{ (dB)}$ | $h_2\text{ (m)}$                          | $A_N\text{ (dB)}$ |
| 30           | 2.75–4                                     | 12.4              | 2.75–4                                    | 18.8              | 2.75–4                                    | 26.3              |
| 35           | 2.39–4                                     | 11.3              | 2.39–4                                    | 17.4              | 2.39–4                                    | 24.9              |
| 40           | 2.13–4                                     | 10.4              | 2.13–4                                    | 16.2              | 2.13–4                                    | 23.8              |
| 45           | 1.92–4                                     | 9.5               | 1.92–4                                    | 15.1              | 1.92–4                                    | 22.7              |
| 50           | 1.75–4                                     | 8.4               | 1.75–4                                    | 14.2              | 1.75–4                                    | 21.8              |
| 60           | 1.50–4                                     | 6.3               | 1.50–4                                    | 12.6              | 1.50–4                                    | 20.2              |
| 70           | 1.32–4                                     | 4.4               | 1.32–4                                    | 11.3              | 1.32–4                                    | 18.9              |
| 80           | 1.19–4                                     | 2.8               | 1.19–4                                    | 10.2              | 1.19–4                                    | 17.7              |
| 90           | 1.08–4                                     | 1.5               | 1.08–4                                    | 9.2               | 1.08–4                                    | 16.7              |
| 100          | 1–4                                        | 0.6               | 1–4                                       | 8.4               | 1–4                                       | 15.8              |
| 120          | 1–4                                        | –0.7              | 1–4                                       | 7.5               | 1–4                                       | 14.3              |
| 125          | 1–4                                        | –0.9              | 1–4                                       | 7.3               | 1–4                                       | 14.0              |
| 140          | 1–4                                        | –1.5              | 1–4                                       | 5.5               | 1–4                                       | 13.0              |
| 150          | 1–4                                        | –2.0              | 1–4                                       | 4.7               | 1–4                                       | 12.5              |
| 160          | 1–4                                        | –3.1              | 1–4                                       | 3.9               | 1–4                                       | 12.0              |
| 175          | 1–4                                        | –4.1              | 1–4                                       | 3.0               | 1–4                                       | 11.3              |
| 180          | 1–4                                        | –4.5              | 1–4                                       | 2.7               | 1–4                                       | 11.1              |
| 200          | 1–4                                        | –5.4              | 1–4                                       | 1.6               | 1–4                                       | 10.3              |
| 250          | 1–4                                        | –7.0              | 1–4                                       | –0.6              | 1–4                                       | 8.7               |
| 300          | 1–4                                        | –8.9              | 1–4                                       | –2.3              | 1–4                                       | 7.6               |
| 400          | 1–4                                        | –11.4             | 1–4                                       | –4.9              | 1–4                                       | 3.9               |
| 500          | 1–4                                        | –13.4             | 1–4                                       | –6.9              | 1–4                                       | 1.8               |
| 600          | 1–4                                        | –14.9             | 1–4                                       | –8.4              | 1–4                                       | 0.2               |
| 700          | 1–4                                        | –16.3             | 1–4                                       | –9.7              | 1–4                                       | –1.2              |
| 800          | 1–4                                        | –17.4             | 1–4                                       | –10.9             | 1–4                                       | –2.4              |
| 900          | 1–4                                        | –18.5             | 1–4                                       | –12.0             | 1–4                                       | –3.4              |
| 1000         | 1–4                                        | –19.4             | 1–4                                       | –13.0             | 1–4                                       | –4.3              |

\*The mutual impedance correction factors in Table 4 for vertically polarized tunable dipoles spaced 3 m apart should be inserted in Eq 1 of 5.4.6.4 in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

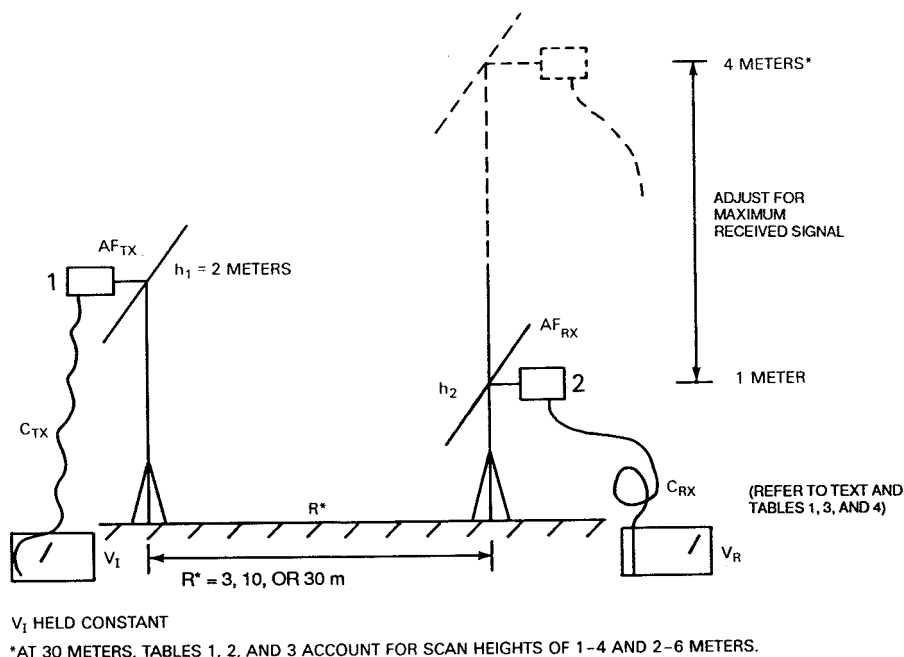


**Fig 6— Site Attenuation Measurement Horizontal Polarization, Broadband and Tuned Dipoles**

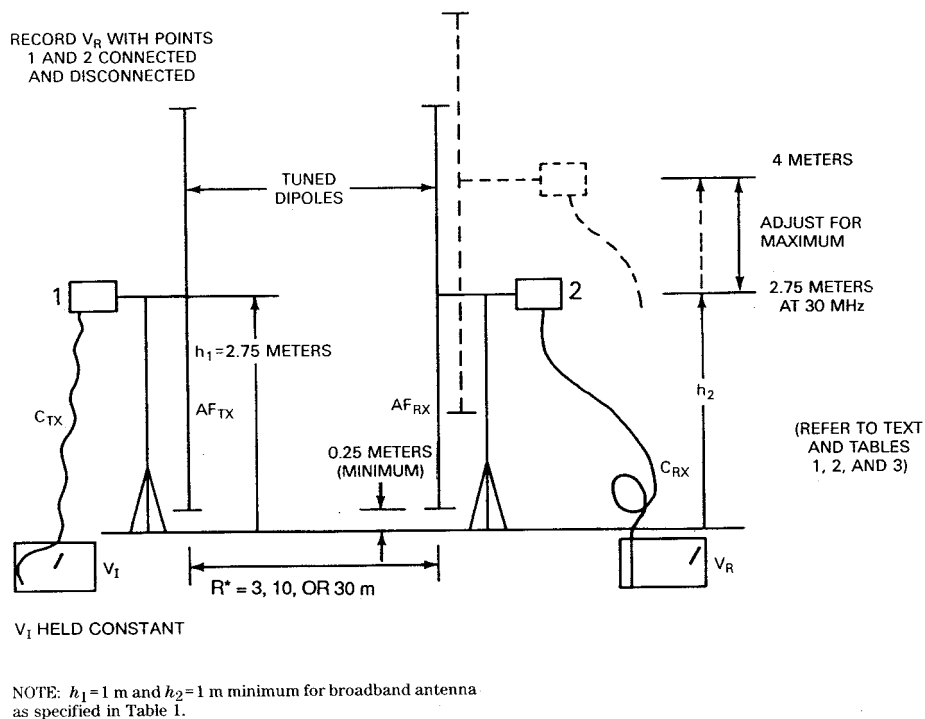


**Fig 7— Site Attenuation Measurement Vertical Polarization Using Tuned Dipole Antennas**

**Table 4— Mutual Impedance Correction Factors ( $\Delta AF_{TOT}$ ) for Geometry Using Two Resonant Tunable Dipoles Spaced 3 m Apart**

| $f_M$ MHz | Horizontal Pol<br>$R = 3m$<br>$h_1 = 2m$<br>$h_2 = 1 \text{ to } 4 \text{ m Scan}$ | Vertical Pol<br>$R = 3 \text{ m}$<br>$h_1 = 2.75 \text{ m}$<br>$h_2 = (\text{see Table 3})$ |
|-----------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
|           | $\Delta AF_{TOT}$                                                                  |                                                                                             |
| 30        | 3.1                                                                                | 2.9                                                                                         |
| 35        | 4.0                                                                                | 2.6                                                                                         |
| 40        | 4.1                                                                                | 2.1                                                                                         |
| 45        | 3.3                                                                                | 1.6                                                                                         |
| 50        | 2.8                                                                                | 1.5                                                                                         |
| 60        | 1.0                                                                                | 2.0                                                                                         |
| 70        | -0.4                                                                               | 1.5                                                                                         |
| 80        | -1.0                                                                               | 0.9                                                                                         |
| 90        | -1.0                                                                               | 0.7                                                                                         |
| 100       | -1.2                                                                               | 0.1                                                                                         |
| 120       | -0.4                                                                               | -0.2                                                                                        |
| 125       | -0.2                                                                               | -0.2                                                                                        |
| 140       | -0.1                                                                               | 0.2                                                                                         |
| 150       | -0.9                                                                               | 0.4                                                                                         |
| 160       | -1.5                                                                               | 0.5                                                                                         |
| 175       | -1.8                                                                               | -0.2                                                                                        |
| 180       | -1.0                                                                               | -0.4                                                                                        |

NOTE — Calculated for resonant dipoles with reference antenna baluns using Method of Moments (NFPA 70-1990, National Electrical Code).

Theoretical free-space antenna factors are for ideal resonant dipoles with an assumed 0.5 dB balun loss (each antenna). If the actual balun loss is known, it should be used to provide an appropriate modification to each antenna factor used in arriving at the correction factors in this table. See Reference Antenna in ANSI C63.5-1988 [2]. These correction factors do not completely describe antenna factors measured above a ground plane, e.g., at heights of 3 or 4 m, since these antenna factors differ from free-space antenna factors at the lower frequencies.

However, within the error, and for baluns with substantially different loss than 0.5 dB, hounds described in ANSI C63.6-1988 [3], the values are adequate to indicate site anomalies.

User is cautioned when using half-wavelength dipoles or antennas with other than reference antenna baluns. These may exhibit characteristics different than the reference antenna.

Mutual coupling correction factors for 10 and 30 m are under consideration. As an interim procedure, site adequacy can be assessed by considering these correction factors to be equal to zero for such geometries and for all measurements using broadband antenna.

Accurate antenna factors are necessary in determining the measured NSA. In general, antenna factors provided with the antenna are inadequate unless they were specifically or individually measured and the calibration is traceable to a national standard. Linearly polarized antennas are required. ANSI C63.5-1988 [2] contains a design of a reference antenna and methods for calibrating antennas. The reference dipole antenna (4.1.5.3) should be spot-checked against a known calibrated antenna. Antenna factors usually account for losses due to the balun. If a separate balun or any integrally associated cables are used, their effects shall be accounted for.

Two procedures may be employed to determine the measured NSA: a discrete frequency method and a swept frequency method. The swept method may be used only with broadband antennas. Figure 6 shows the horizontal polarization geometry. In Fig 7, the recommended vertical polarization geometries for using tunable resonant half-wave dipoles are shown. This assumes that the dipoles are tuned down to 30 MHz. The limiting factor of maintaining at least a 25 cm clearance between the lower tip of the receive and transmit antennas is covered by (1) fixing the transmit height at 2.75 m, and (2) restricting the downward travel of the receive antenna. These restrictions are stated explicitly in Table 3. For vertical NSA measurements with broadband antennas, no such scan height restrictions are required due to the much smaller fixed dimensions of a broadband antenna compared to a tuned dipole, especially between 30 and 80 MHz. Using linearly polarized broadband antennas also allows a transmit antenna height of 1 m.

#### NOTES:

- 1 — For both methods, an impedance mismatch at the output of the signal source or at the input of the radio-noise meter or spectrum analyzer may result in cable reflections that could cause errors exceeding the NSA tolerance. This can be avoided by use of padding attenuators of 10 dB; one at the output end of each transmitting and receiving cable. These attenuators shall remain in the cables for both  $V_{\text{Direct}}$  and  $V_{\text{Site}}$  measurements.
- 2 — Attenuator values of 6 dB are often adequate and values as low as 3 dB can sometimes be used.

For the discrete frequency method, specific frequencies given in Tables 1, 2, and 3 are measured in turn. At each frequency the receive antenna is moved over the height range given in the appropriate table to maximize the received signal. These measured parameter values are inserted in Eq 1 to obtain the measured NSA. Appendix A contains a suggested procedure involving a worksheet approach to record the data, calculate the measured NSA, and then compare it with the theoretical NSA.

For the swept frequency method, measurements using broadband antennas may be made using automatic measuring equipment having a peak hold (maximum hold) storage capability and a tracking generator. In this method both antenna height and frequency are scanned or swept over the required ranges. The frequency sweep speed shall be much greater than the antenna height scan rate. Otherwise the procedure is the same as in the previous paragraph. A detailed procedure is given in Appendix B.

#### 5.4.6.5 NSA for Alternate Test Sites

For an alternate test site (see 5.4.2) a single-point NSA measurement is insufficient to pick up possible reflections from the construction and/or RF-absorbing material comprising the walls and ceiling of the facility. For these sites, a “test volume” is defined as that volume traced out by the largest equipment or system to be tested as it is rotated about its center location through 360°, such as by a turntable. In evaluating the site, the transmit antenna shall be placed at various points within the test volume with both horizontal and vertical polarization, such as illustrated in Figs 8(a) and 8(b) [B10]. This may require a maximum of 20 separate site attenuation measurements, i.e., five positions in the horizontal plane (center, left, right, front, and rear, measured with respect to the center and a line drawn from the center to the position of the measuring antenna), for two polarizations (horizontal and vertical), and for two heights (1 and 2 m, horizontal) (1 and 1.5 m, vertical).

These measurements are carried out with a broadband antenna and distances are measured with respect to the center of the antenna. The transmit and receive antennas shall be aligned with the antenna elements parallel to each other and orthogonal to the measurement axis.