

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

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Secretariat

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Abstract: ANSI C63.4-1991, *American National Standard Methods of Measurement of Radio-Noise Emissions From Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz*, sets forth uniform methods of measurement of radio noise emitted from low-voltage electrical and electronic equipment, including digital and other information technology equipment (ITE), in the frequency range of 9 kHz to 40 GHz. Methods for the measurement of radiated and power-line-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 (ITE), intentional radiators, line-impedance stabilization network (LISN), low-voltage electrical equipment, low-voltage electronic equipment, magnetic field measurement, normalized site attenuation, periodic intentional radiators, power-line-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 ANSI C63.4-1991, 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 problems 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–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 power lines, 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 which 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. This resulted in publication of 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.

The standard C63.4-1963 was reaffirmed in 1969, and a revision was published in 1981, which embraced a broader frequency range and incorporated newer measurement techniques that had been developed within the USA and by the International Special Committee on Radio Interference (CISPR).

Although many improvements had been made in Std 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 One 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 (a) control of site ground plane conductivity, flatness, site enclosures, effects of surrounding objects, and certain other site construction features, (b) accounting for antenna factors, associated cabling, and balun and device under test characteristics and (c) 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 the 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 utilized. The present edition is the result of a major effort on the part of the members of the Committee and various other participating individuals. To expedite the work, the following members of the C63 Committee served as task group leaders to address various issues:

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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 noise emitted from low-voltage electrical and electronic equipment, including digital and other information technology equipment (ITE), in the frequency range of 9 kHz to 40 GHz. Methods for the measurement of radiated and power-line-conducted radio noise are covered and may be applied to any such equipment unless otherwise specified by individual equipment requirements.

These methods are not currently intended for measurement of deliberately radiated energy, such as that from intentional emitters, nor is this standard intended for certification/approval of avionic equipment, except where specifically referenced. Methods of measurement of various types of intentional emitters are under consideration.

These methods apply to the measurement of individual units or systems comprised of 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 30–1000 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 lap-top computers, 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 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 μ H line-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 15)
- (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.

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 revision shall apply.

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

[2] ANSI C63.5-1988, American National Standard for Calibration of Antennas Used for Radiated Emission Measurements in Electromagnetic Interference (EMI) Control.

[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.

[5] CISPR Publication 14 (1985), Limits and Methods of Measurement of Radio Interference Characteristics of Household Electrical Appli-

ances, Portable Tools and Similar Electrical Apparatus.²

[6] CISPR Publication 16 (1987), CISPR Specification 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]).³

[8] FCC 47 CFR Part 2, Frequency Allocation and Radio Treaty Matters; General Rules and Regulations (1990).⁴

[9] FCC 47 CFR Part 15, Radio Frequency Devices (1990).

[10] FCC/OET Bulletin 62, Understanding FCC Rules for Digital Devices (1988).

[11] IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronics Terms — 4th ed. (ANSI).⁵

[12] IEEE Std 139-1988, IEEE Recommended Practice for Measurement of Radio Frequency Emission from Industrial, Scientific, and Medical (ISM) Equipment Installed on User's Premises (ANSI).

[13] IEEE Std 149-1979 (Reaff 1990), IEEE Standard Test Procedures for Antennas (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.

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

³Bracketed numbers preceded by B correspond to those of the Bibliography in Section 16.

⁴For information on how to purchase FCC publications, contact the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

⁵IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

¹ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

[15] IEEE Std 291-1969 (Reaff 1981), IEEE Standards Report on Measuring Field Strength in Radio Wave Propagation.

[16] IEEE Std 302-1969 (Reaff 1981), Standard Methods for Measuring Electromagnetic Field Strength for Frequencies Below 1000 MHz in Radio Wave Propagation.⁶

[17] IEEE Std 376-1975 (Reaff 1981), IEEE Standard for the Measurement of Impulse Strength and Impulse Bandwidth (ANSI).

[18] IEEE Std 474-1973 (Reaff 1982), IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz (ANSI).

[19] MIL-STD-45662 (rev. A, 8/1/88), Military Standard Calibration Systems Requirements.⁷

3. Definitions

The definitions in IEEE Std 100-1988 [11]⁸, unless otherwise noted below, apply throughout this document. Definitions in particular product standards or in applicable regulations take precedence.

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/meter.

NOTES: (1) This factor includes the effects of antenna effective length and mismatch and may include transmission line losses.

⁶IEEE Std 302-1969 has been withdrawn; however, copies can be obtained from the Standards Department, IEEE Service Center.

⁷MIL publications are available from the Director, U.S. Navy Publications and Printing Service, Eastern Division, 700 Robbins Avenue, Philadelphia, PA 19111.

⁸The 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 16.

(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.

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 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 flat 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) that 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, 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.

incidental radiator. A device that produces radio-frequency energy during the course of its operation, although the device is not intentionally designed to generate or emit radio-frequency 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 are 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 radio-frequency energy by radiation or induction.

line-impedance stabilization network (LISN). A network inserted in the supply mains lead of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages, and which 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 device connected to 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 that enables individuals to perform a variety of computing or word processing functions or both, and that 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.

power-line-conducted radio noise. Radio noise produced by equipment operation that exists on the power line 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 radio frequency 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 radio-frequency range. For the purposes of this standard, an electromagnetic disturbance of a sinusoidal character is also considered radio noise.

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.

table-top device. A device designed for and normally placed on the raised surface of a table; e.g., most personal computers are considered to be table-top devices.

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

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 power-line-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 power-line-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 non-scanning 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" port is terminated in 50 Ω , 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 0.15–30 MHz and 0.01–0.15 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 to 9 kHz is under consideration.

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's 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.)

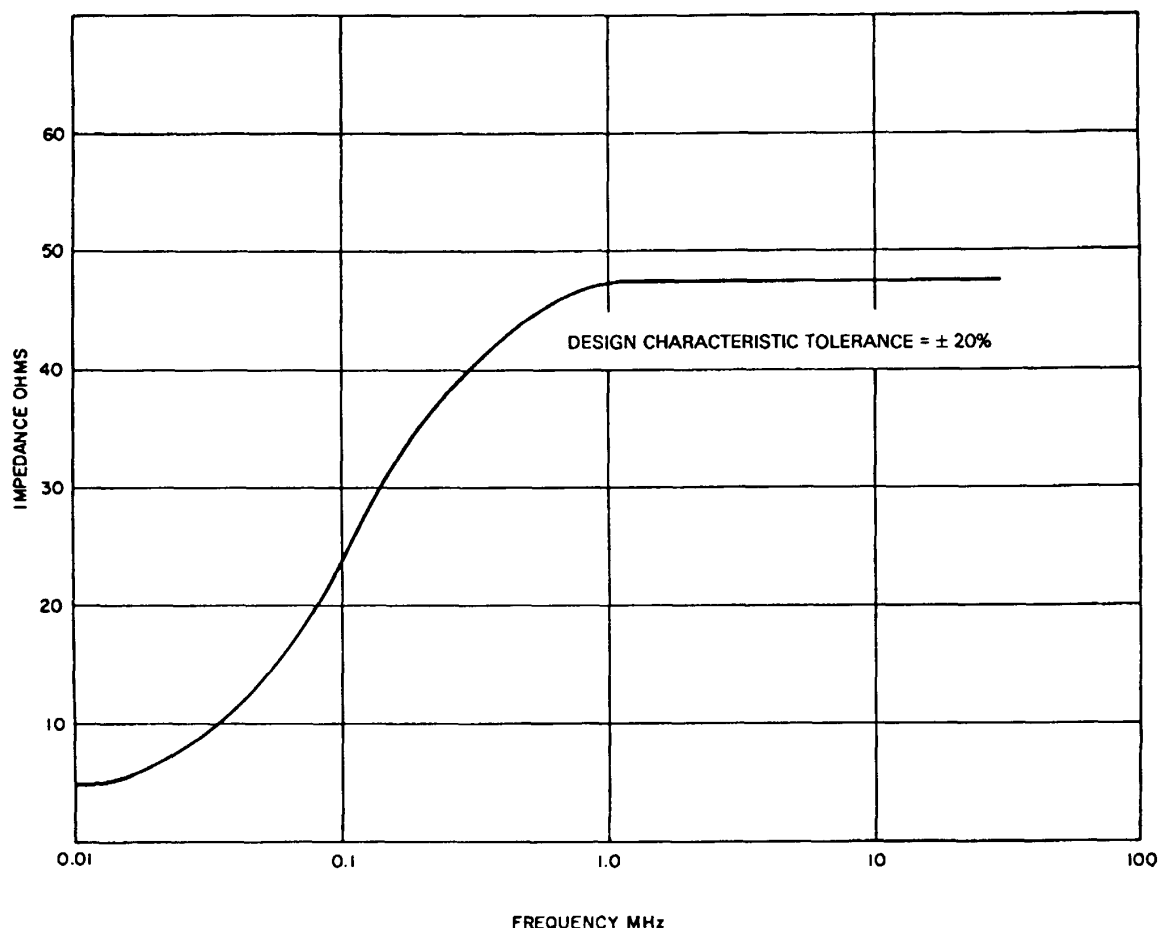
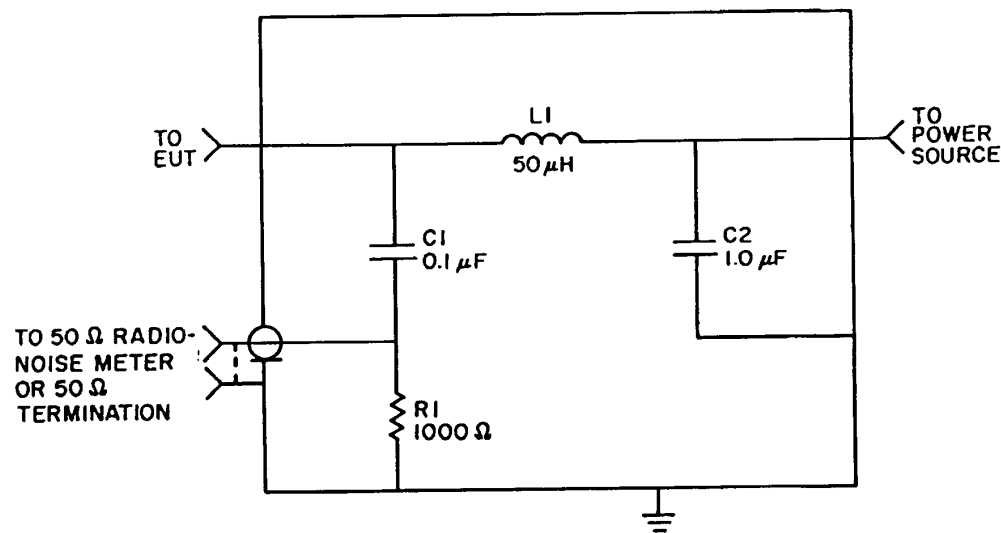


Fig 1
Impedance Characteristic of LISN:
10 kHz – 30 MHz

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 Ω . Since the voltage probe attenuates the radio-noise voltage, appropriate

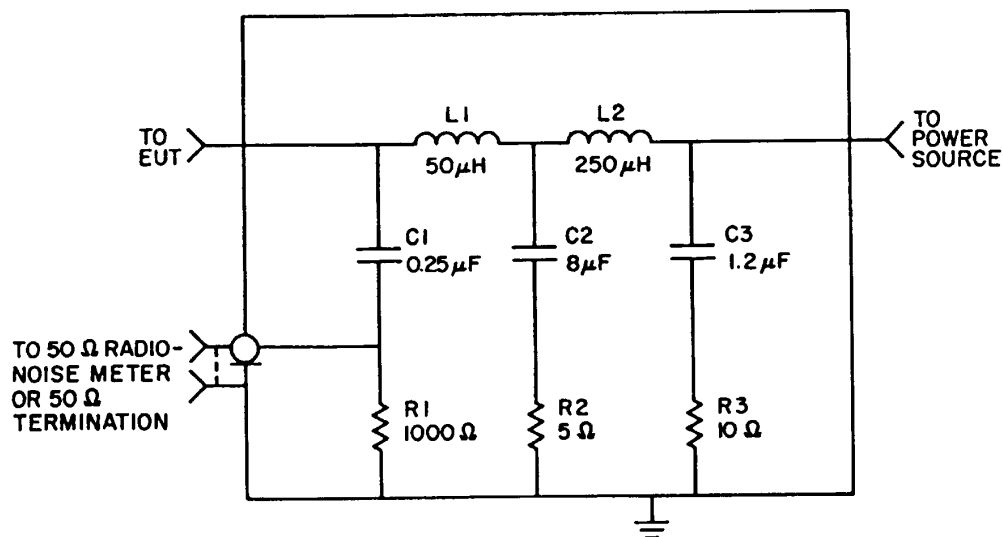
calibration factors shall be added to the measured values. Measurements made with LISNs shall take precedence over measurements made with voltage probes.

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 as per 4.1.2 shall be



* IN SOME LISNs, A SERIES RESISTANCE IS INCLUDED,
E.G., CISPR PUB 16.

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 (30 MHz) Frequency Range

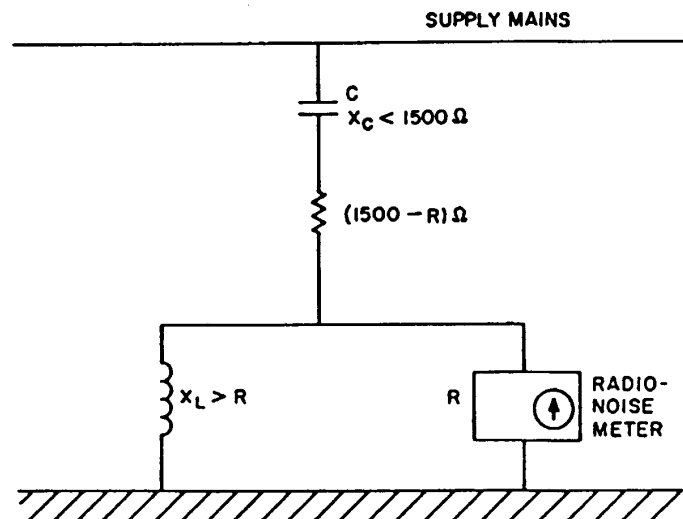


Fig 4
Line Probe for Tests at User's Installation

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 being measured in performing radiated emission measurements as indicated in 4.1.5.1–4.1.5.4.

4.1.5.1 Magnetic Field Measurements (9 kHz–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–30 MHz.

4.1.5.2 Electric Field Measurements (9 kHz–30 MHz). Calibrated monopole (rod) antennas as specified in ANSI C63.2-1987 [1] and C63.5-1988 [2] shall be used to measure electric fields in the frequency range of 9 kHz–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–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 30 MHz–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 (1–40 GHz). Calibrated, linearly polarized horn antennas as specified in ANSI C63.2-1987 [1] shall 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 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 aper-

ture of the antenna, and λ is the free-space wavelength in meters at the frequency of measurement.

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 a quasi-peak detector for frequencies up to and including 1 GHz. For measurements above 1 GHz, peak and average detectors may be specified. Detector functions other than specified in ANSI C63.2-1987 [1] may be used for making such measurements, provided (1) data so taken is 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 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 frequencies for which the amplitudes are highest with respect 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 man-

ual 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, line impedance stabilization networks, 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.

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 [19].

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.

Antennas for use below 30 MHz shall be calibrated using an acceptable method, such as one of the methods in IEEE Std 291-1969 [15] or IEEE Std 302-1969 [16].

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 per 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 291-1969 [15] or IEEE 149-1979 [13]. 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 $\geq 2 \cdot D^2/\lambda$, it may be used to make measurements at any distance greater than $2 \cdot D^2/\lambda$ 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 $2 \cdot D^2/\lambda$. Gain standard horn antennas have gains that are fixed by their dimensions and dimensional tolerances, and are most often used for calibration of other antennas.

4.4.2 LISN Calibration. The impedance and attenuation of each LISN used in testing for conducted emissions is to be measured 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 16 (1987) [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 [18], and checked frequently for deterioration caused by use and exposure to sunlight, physical wear, and other conditions.

5. Test Facilities

Radiated and ac power-line-conducted measurements shall be made in an environment that assures valid, repeatable measurement results as described in 5.2 (conducted tests) or 5.3, 5.4, and 5.5 (radiated tests). 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 and current.

5.1.2 Ambient Radio Noise and Signals. 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 power-line 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 chamber (see 5.4.2 for conditions of use).
- (4) Make 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 power-line-conducted measurements, insert suitable line 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 narrow-band and the ambient field is broad-band, reduce the bandwidth of the receiver.
- (8) Rotate the EUT on a turntable while observing possible correlation between emission amplitude and EUT azimuth.

5.2 Conducted Emission Test Site Requirements. 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 emission test site.

5.2.1 Conducting Ground Plane. The conducting ground plane for 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 horizontal

projection (footprint) of the EUT. Where a floor-mounted EUT normally does not make physical contact with a grounded surface, the ground plane shall be covered by insulating materials between 3 mm and 12 mm thick.

5.2.2 Vertical Conducting Surface. When conducted emissions are measured for devices that are tested on a table top, a conducting vertical plate or screen of at least 2 m by 2 m in size shall be located 40 cm to the rear of the device. The conducting vertical plate or screen shall be electrically connected to the conducting ground plane along its entire length. This conducting vertical plate is required even if the test is performed at an open area test site. The metal wall of a screen room may satisfy this requirement. These requirements do not apply to conducted emission tests performed on floor-standing devices.

5.2.3 Line Impedance Stabilization Network Installation. Where use of an LISN is required (see Section 7), it shall be placed on top 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 Ω , 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 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 and 7.2.2.

5.3 Radiated Emission Test Site Requirements for Measurements Below 30 MHz. Measurements of electric field strength (see 8.3) should be made on an open area test site as shown in Fig 5. If permitted by the procuring or regulatory agency, measurements may be made in a shielded enclosure at frequencies below its resonant frequency. 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 emission may be higher. Magnetic field strength measurements made at a site with no conducting ground plane shall take precedence.

5.4 Radiated Emission Test Site Requirements for Measurements 30 MHz to 1 GHz. Test sites used for making final radiated emission tests shall be capable of meeting the applicable requirements given in 5.4.5.

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,