

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

Amendment 1: Test Site Validation

C63[®]

Accredited Standards Committee C63[®] — Electromagnetic Compatibility

Accredited by the
American National Standards Institute

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ANSI C63.4a-2017
(Amendment to ANSI C63.4-2014)

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

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Accredited Standards Committee C63®—Electromagnetic Compatibility

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American National Standards Institute

Secretariat
Institute of Electrical and Electronics Engineers, Inc.

Approved 15 September 2017
American National Standards Institute

C63®

Abstract: U.S. consensus standard methods are specified in Annex D of this amendment for validating standard test sites and alternative test sites used for measurement of radiated radio-frequency (RF) signals and noise emitted from electrical and electronic devices in the frequency range of 30 MHz to 1 GHz. In addition, various updates are made to equations in 4.5, Annex F, Annex G, and Annex N.

Keywords: Annex D, ANSI C63.4, normalized site attenuation, NSA, site attenuation, site validation

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Introduction

This introduction is not part of ANSI C63.4a-2017, 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—Amendment 1: Test Site Validation.

Following several recent interpretation requests, in late 2015 the ASC C63® Main Committee directed ASC C63® Subcommittee 1 to prepare a fast-track amendment primarily concerned with Annex D on test site validations of the 2014 edition of ANSI C63.4 (ANSI C63.4-2014). The scope of this fast-track amendment project was limited mainly to topics raised by the interpretation requests. At the time that this amendment was developed, a separate routine maintenance project for ANSI C63.4-2014 overall was also in progress in ASC C63® Subcommittee 1; other issues and topics outside the scope of this amendment project may be considered in that ANSI C63.4 overall review and revision project. This amendment forms a permanent addition to ANSI C63.4, and as such it is subject to the ASC C63® normal maintenance procedures for any future updates. The contents of this amendment are not expected to be changed by the other ANSI C63.4 revision project that is ongoing at the time of preparation of this document.

This amendment mainly updates the test site validation procedures in Annex D in ANSI C63.4-2014 and corrects equations in several annexes. At the May 2017 meeting of ASC C63®, another addition to the amendment was approved. This addition corrected the value of the separation distance between the receiving antenna and the equipment under test. The latter correction brought it back to what was in previous editions of ANSI C63.4. Hence, this amendment combines changes in the Annex D test site evaluation, corrections to equations in annexes, and a correction to a separation distance value in the main body of the standard.

The more significant updates to Annex D consist of the following:

- Corrected the equation for calculating the measured NSA value [i.e., Equation (D.1) of ANSI C63.4-2014]
- Added text to clarify the single-position NSA geometry for validation of standard test sites, which previously was indicated mainly by the measurement setup figures and NSA tables
- Added requirements for maximum frequency step size for both the discrete frequency method and the swept frequency method; also quantified the existing requirement for the receive antenna height scan rate for the swept frequency method
- For the swept frequency method, added the requirement to report in tabular format those measured NSA values that are within 1 dB of the site acceptability criterion
- Removed the provision from D.3 for moving the antenna inward from the periphery for the left and right positions in horizontal polarization
- Added equations to be used for calculating theoretical NSA for an ideal site, which can be used for frequencies and/or geometries other than those listed in the tables
- Expanded the tables of theoretical NSA for an ideal site by adding values for a 5 m measurement distance (for example, CISPR 32:2015 [B53] allows a 5 m measurement distance),^a for greater transmit antenna heights (for validating test volumes taller than 2 m), and for the frequency increments specified in the measurement procedures subclauses (i.e., D.4 and D.5)
- Updated the figures and added a top-view figure for vertical polarization [i.e., Figure D.3 b)], depicting the re-orientations of the transmit antenna and the receive antenna for the left and right positions of the transmit antenna

^a Numbers in brackets correspond to those of the bibliography in Annex O of ANSI C63.4-2014.

In addition to the Annex D changes, updates to various equations in Annex F, Annex G, and Annex N and the antenna to equipment under test separation distance value in 4.5 of ANSI C63.4-2014 are provided in this amendment.

Based on a recently issued interpretation,^b the measurement distance criterion for electric field strength measurements (1 GHz to 40 GHz) with horn antennas in 4.5.5 (and in table footnotes in 4.5.1) of ANSI C63.4-2014 is modified to as it was in the 1992 edition of ANSI C63.4, and consistent with CISPR 16-1-4^c and CISPR 16-2-3 [B14].

^b Clause 4.5 Horn antenna aperture, June 2017 (http://c63.org/documents/misc/posting/new_interpretations.htm).

^c Information on references can be found in Clause 2 of ANSI C63.4-2014.

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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

Amendment 1: Test Site Validation

NOTE 1—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard to form the comprehensive standard.

The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strike through~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE 1 will not be carried over into future editions because the changes will be incorporated into the base standard.

NOTE 2—In this document, a table note (a note to a table) is informative, and a table footnote is normative. A table note is set immediately following the table to which it belongs, enclosed within the boxed table, above the bottom border of the table. General notes apply to the entire table and are introduced by “NOTE—” set in all, uppercase letters. A table footnote always contains normative information. A table footnote is set outside of the boxed table to which it belongs, immediately below the bottom border. Table footnotes are marked with lowercase letters starting with “a” for each table.

NOTE—This amendment mainly updates the test validation procedures in Annex D in C63.4-2014 and corrects equations in several annexes. At the May 2017 meeting of ASC C63®, another addition to the amendment was approved. This addition corrected the value of the separation distance between the receiving antenna and the equipment under test. The latter correction brought it back to what was in previous editions of ANSI C63.4. Hence, this amendment combines changes in the Annex D test site evaluation, corrections to equations in annexes, and a correction to the antenna to equipment under test separation distance value in 4.5 of the main body of the standard.

4.5 Antennas

4.5.1 General considerations

Table 1—Radiated emissions antennas for exploratory and/or relative-comparison evaluation purposes (and their frequency ranges of operation)

Replace footnote g in Table 1 as follows:

- ^g The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) 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 antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

Table 2—Antennas (and their frequency ranges of operation) for use in making final compliance measurements on devices

Replace footnote f in Table 2 as follows:

- ^f The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) 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 antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

Table 3—Antennas (and their frequency ranges of operation) for use in performing test site validation measurements

Replace footnote g in Table 3 as follows:

- ^g The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) 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 antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

4.5.5 Electric field measurements (1 GHz to 40 GHz)

Replace the second paragraph of 4.5.5 as follows:

The aperture dimensions of these horn antennas shall be small enough so 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 antenna aperture (in meters) and λ is the free-space wavelength (in meters) at the frequency of measurement. In case of dispute, measurements made with a standard-gain horn antenna shall take precedence.

Changes to Annex D include the following:

- *New Table D.1 is added in D.1, and new Table D.2 is added in D.2.4.*
- *Subclauses D.2.1 to D.2.4 are added in D.2.*
- *In D.2.1 (formerly D.2), Equation (D.1) is updated and replaced by Equation (D.1) and Equation (D.2). The existing Equation (D.2) is renumbered as Equation (D.3).*
- *New subclauses D.3.1 to D.3.4 are added in D.3.*
- *The NOTE at the end of the existing D.3 of ANSI C63.4-2014 is moved to the end of D.3.3.*
- *The last paragraph (before the NOTE) of the existing D.3 of ANSI C63.4-2014 is updated and moved to the new D.2.5.*
- *Insert new D.7, and renumber the existing D.7 of ANSI C63.4-2014 as D.8.*
- *The existing Table D.1 of ANSI C63.4-2014 is split into four tables as Table D.3 through Table D.6 (see associated editing instructions in D.8).*
- *The existing Table D.2 through Table D.7 of ANSI C63.4-2014 are renumbered (also with updates) as Table D.7 through Table D.12 (see associated editing instructions in D.8).*
- *Footnotes are inserted, and any following this annex should be renumbered accordingly.*

Replace Annex D as follows:

Annex D

(normative)

Validation of radiated emission test sites (30 MHz to 1 GHz)

NOTE—In this annex, for contiguous readability of body text, all tables (except Table D.1 and Table D.2) and figures are placed in their own subclause following the text subclauses, i.e., entitled **D.8 Tables and figures for Annex D**.

D.1 Theoretical NSA

Subclause 5.4.4.1 (General requirements) of ANSI C63.4-2014 describes what normalized site attenuation (NSA) for site validation is and how it is evaluated.²⁷ The theoretical NSA values for an ideal site for the most frequently used measurement distances and antenna types are shown in Table D.3 through Table D.8 (see D.8).²⁸ The theoretical NSA was developed and calculated in Smith et al. [B28], and the equations used for calculating the theoretical NSA for an ideal site are provided in D.7. Mutual impedance correction factors for NSA data obtained with tuned dipole antennas, shown in Table D.9 (see D.8), were developed in Smith et al. [B28], and were subsequently revised in Berry et al. [B8] and Pate [B26]. Table D.1 gives a summary of the contents of the tables of theoretical NSA values in D.8.

²⁷ The site validation process using measured *GSCF* values obtained per Annex I of ANSI C63.5-2017 is mathematically equivalent to comparing the measured site attenuation results directly to the results from the antenna calibration site (Chen [B54]). The site validation process using *GSCF* values for biconical dipole antennas per Annex G of ANSI C63.5-2017, or ΔAF_{TOT} for tuned dipole antennas from Table D.8 (see D.8), is functionally equivalent to comparing the measured site attenuation results to numerically-derived site attenuation values for an ideal site. Notwithstanding the preceding sentences, the only acceptable methods for demonstrating compliance with the NSA requirements of ANSI C63.4 are those detailed in D.1 through D.7.

²⁸ Some regulatory and/or purchasing agencies may not accept the use of a 5 m separation distance for measurements of radiated emissions.

Table D.1—Summary of tables of NSA theoretical values given in D.8

Table number	Antenna type	Antenna polarization	Measurement method	h_1 , m
Table D.3	broadband	horizontal	discrete frequency	1.0, 2.0, 2.5, 3.0
Table D.4	broadband	vertical	discrete frequency	1.0, 1.5, 2.0, 2.5
Table D.5	broadband	horizontal	swept frequency	1.0, 2.0, 2.5, 3.0
Table D.6	broadband	vertical	swept frequency	1.0, 1.5, 2.0, 2.5
Table D.7	tuned dipoles	horizontal	discrete frequency	2.0
Table D.8	tuned dipoles	vertical	discrete frequency	2.75
NOTE 1—Discrete frequency measurement method—see D.4. NOTE 2—Swept frequency measurement method—see D.5. NOTE 3—Measurement distance R , m: 3, 5, 10, 30.				

The symbols used in the tables of NSA values in D.8 are defined as follows:

- R is the horizontal separation distance between the projection of the reference points of the transmit antenna and the receive antenna on the reference ground plane (m)
- h_1 is the height of the center of the transmit antenna above the reference ground plane (m)
- h_2 is the height of the center of the receive antenna above the reference ground plane (m); in the measurement procedure, h_2 is varied, and the maximum received signal in the h_2 height scan range is used in the NSA calculations
- f_M frequency (in megahertz)
- A_N is theoretical NSA; see Equation (D.4) in D.7

Table D.3 through Table D.6 are used for broadband antennas (such as biconical and LPDA antennas), aligned horizontally and vertically, respectively, relative to the reference ground plane, at a standard test site or an alternative test site. Table D.7 and Table D.8 are for tuned dipoles, aligned horizontally and vertically, respectively, relative to the reference ground plane, at a standard test site. Note that the transmit antenna and receive antenna heights in Table D.8 are specified to keep the lowest tip of the dipole element spaced 25 cm or more from the reference ground plane.

NSA values for frequencies other than those shown in the tables shall be calculated using linear interpolation between the tabulated values; alternatively, the equations for theoretical NSA for an ideal site provided in D.7 may be used.

D.2 NSA measurements

D.2.1 General

Two antennas are set up on the test site in a specific geometry as illustrated in Figure D.1 and Figure D.2 (see D.8); Figure D.2 is an illustration for dipoles only—the actual geometry requirements are in D.2.3. 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, including any added impedance matching attenuators whose insertion losses are not included with the antenna factors (if used), 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, including any added impedance matching attenuators (if used), reconnected to their respective antennas and the maximum signal measured with the receive antenna scanned in height (Heirman [B20]). For both of these measurements, the signal generator voltage level V_I is kept constant. The first reading of V_R is called V_{Direct} and the second reading is called V_{Site} . These voltages are used in Equation (D.1) or Equation (D.2) to calculate the measured NSA (A_N):

$$A_N = V_{\text{Direct}} - V_{\text{Site}} - AF_T - AF_R - \Delta AF_{\text{TOT}}, \quad \text{for tuned dipoles} \quad (\text{D.1})$$

$$A_N = V_{\text{Direct}} - V_{\text{Site}} - AF_T - AF_R - GSCF, \quad \text{for all other antennas} \quad (\text{D.2})$$

where

AF_T is the antenna factor of transmit antenna (dB/m)

AF_R is the antenna factor of receive antenna (dB/m)

ΔAF_{TOT} is the mutual impedance correction factor (dB)

$GSCF$ is the geometry-specific correction factor (dB)

The latter antenna parameters are described in D.2.2. The difference of the first two terms in Equation (D.1) and Equation (D.2), i.e., $V_{\text{Direct}} - V_{\text{Site}}$, represents the conventional (classical) site attenuation (CSA).²⁹ V_{Direct} (in dBμV) is given by Equation (D.3):

$$V_{\text{Direct}} = V_I - C_T - C_R \quad (\text{D.3})$$

where C_T and C_R (in dB) are the cable losses that do not need to be measured separately, and V_I (in dBμV) is the signal generator output voltage.

D.2.2 Antennas

The parameters AF_T and AF_R in Equation (D.1) and Equation (D.2) are determined using the applicable antenna calibration process as specified in ANSI C63.5. For Equation (D.1), the mutual impedance correction factor ΔAF_{TOT} (see Table D.9 in D.8) applies only to the site geometry of 3 m separation, for both horizontal and vertical polarizations, when using tuned dipoles. The mutual impedance correction factor $\Delta AF_{\text{TOT}} = 0$ for all other geometries using tuned dipoles. For Equation (D.2), the appropriate $GSCF$ values, as determined per ANSI C63.5, shall be used; see also the considerations in NOTE 2 about use of Annex G and Annex I of ANSI C63.5-2017.

NOTE 1—Users are cautioned that the determination of the appropriate $GSCF$ values using the methods described in ANSI C63.5 is a complex undertaking, and that these factors are dependent on the exact type of antenna used.

NOTE 2—The theoretical values for $GSCF$ in Annex G of ANSI C63.5-2017 apply only for biconical antennas that comply with the dimensional and other conditions stated within that annex. If such biconical antennas are used for performing NSA measurements at heights that are not covered in that Annex G (e.g., 2.5 m for vertical, and 3 m for horizontal), appropriate $GSCF$ values are determined using the procedure in Annex I of ANSI C63.5-2017. For biconical antennas that differ from the dimensional and other conditions stated in Annex G of ANSI C63.5-2017, and for LPDA antennas and/or hybrid antennas, $GSCF$ values are determined using the procedure in Annex I of ANSI C63.5-2017.

Linearly-polarized antennas, with calibrated antenna factors, are required for NSA measurements. Antenna factors shall be calibrated using the Standard Site Method (SSM) specified in ANSI C63.5, and the measurements involved shall be traceable to a national standard. Antennas shall be calibrated as a pair (i.e., transmit antenna and receive antenna shall be calibrated together), in accordance with 4.4.2 of ANSI C63.5-2017.

Antenna factors usually account for losses in the balun. If a separate balun or any integrally associated attenuators, or both, are used, their effects shall be included in the antenna calibration results.

The receive antenna and the transmit antenna shall be identical (i.e., same manufacturer and model number; or the antenna factors of the individually calibrated antennas shall differ from each other within 1 dB at each calibration frequency), and shall be of the types specified in Table 3 (see 4.5.1 of ANSI C63.4-2014) for use in performing test site validation measurements. The design of a tuned dipole reference antenna is described in ANSI C63.5 (see also the NOTE in 4.5.4 of ANSI C63.4-2014).

²⁹ The terms “classical site attenuation” and “conventional site attenuation” have been used in the literature (see, e.g., Heirman [B19]) to refer to propagation loss measurements using a pair of tuned dipole antennas at a ground-plane site, but without normalizing by antenna factors as is done for NSA results. Another term used is “site insertion loss” (SIL).

D.2.3 Measurement methods

NSA shall be measured using one or both of the following procedures:

- The discrete frequency measurement method — see D.4 (for use with tuned dipole antennas or broadband antennas)
- The swept frequency measurement method — see D.5

The swept frequency method may be used only with broadband antennas, but tuned dipoles may be used at specific (fixed) frequencies in case spot checks or troubleshooting of such NSA values becomes necessary (i.e., for standard test sites only; tuned dipoles shall not be used for NSA validation of alternative test sites – see D.3.2).

For tuned dipoles, Figure D.1 illustrates the horizontal polarization NSA measurement geometry and Figure D.2 illustrates the vertical polarization NSA measurement geometry (assuming that the dipoles are tuned for all frequencies down to 30 MHz; see figures in D.8). The limiting factor of maintaining at least a 25 cm clearance between the reference ground plane and the lower tip of the receive antenna and the transmit antenna is addressed by fixing the transmit antenna height at 2.75 m and restricting the downward travel of the receive antenna. These restrictions are stated explicitly by the lower scan-height limit in Table D.8 (see D.8).

For NSA measurements with broadband antennas, the horizontal polarization geometry is also illustrated by Figure D.1. For vertical polarization NSA measurements with broadband antennas, scan height restrictions usually are not required because of the much smaller fixed dimensions of a broadband antenna compared with a tuned dipole, especially between 30 MHz and 80 MHz. Using linearly-polarized broadband antennas allows minimum transmit antenna and receive antenna heights of 1 m (see also N.2 in Annex N of ANSI C63.4-2014 for dimensional restrictions on hybrid antennas). The requirement for a minimum clearance of 25 cm between the reference ground plane and the lower tips of the receive antenna and the transmit antenna also applies for broadband antennas.

NOTE 1—For both the discrete frequency and the swept frequency methods, an impedance mismatch at the output of the signal source or at the input of the EMI receiver 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, i.e., one at the antenna end of the transmit antenna cable and one at the receiver end of the receive antenna cable, for both V_{Direct} and V_{Site} measurements. Attenuator values of 6 dB are often adequate, and values as low as 3 dB can sometimes be used.

NOTE 2—For vertically polarized antennas, it is especially important to maintain cables leaving the antennas in the same horizontal plane as the center of the antenna directly behind the antenna for a minimum distance of 1 m. Use of ferrite beads on both the transmit antenna and the receive antenna cables close to the antennas can help to eliminate common-mode signals that can contribute to measurement errors.

D.2.4 Single-position NSA measurements for standard test sites

A standard test site³⁰ shall be validated by measuring NSA with the transmit antenna and the receive antenna separated by the measurement distance, for both horizontal and vertical antenna polarizations, for a single location of the antenna pair above the reference ground plane. Basic setups are shown in Figure D.1 and Figure D.2 (see D.8), for horizontal polarization and vertical polarization of the antenna pair, respectively. The test site shall be evaluated in the exact measurement geometry (i.e., locations of transmit antenna and receive antenna on the site) that is used for subsequent product testing. The transmit antenna shall be placed at the EUT location used during subsequent radiated emission measurements (e.g., at the center of the turntable), while the receive antenna shall be positioned at a location that is separated from the transmit antenna location by the measurement distance; see also the site descriptions in 5.4.1, and the site layout in Figure 5 of 5.7 (both in ANSI C63.4-2014). The transmit antenna and the receive antenna shall be placed in the same polarization, and oriented towards each other. Antenna heights above the ground plane per polarization and antenna type for single-position NSA standard test site validation are as shown in Table D.2.

³⁰ Per 5.4.1 of ANSI C63.4-2014, a standard test site is “an open, flat, level area that is clear of overhead wires and reflecting structures and is sufficiently large to permit measuring antenna placement at the specified distance. This is commonly called an OATS when the ground is covered with conductive material.” Per Clause 3 of ANSI C63.7-2015 [B55], a standard test site is an “open-area test site (OATS) that does not incorporate weather-protection (or other) structures above the surface of its ground plane.”