

American National Standard Guide for Construction of Test Sites for Performing Radiated Emission Measurements

C63[®]

Accredited Standards Committee C63[®]—Electromagnetic Compatibility

Accredited by the
American National Standards Institute



IEEE
3 Park Avenue
New York, NY 10016-5997
USA

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American National Standard Guide for Construction of Test Sites for Performing Radiated Emission Measurements

Accredited Standards Committee C63®—Electromagnetic Compatibility

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American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

Approved 29 January 2015

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Abstract: Information that is useful in constructing test sites used to perform radiated emission measurements in the frequency range of 30 MHz to 18 GHz is provided. Final validity of a test site can only be determined by performing normalized site attenuation and/or site voltage standing-wave ratio measurements as described in ANSI C63.4.

Keywords: ANSI C63.7, emission measurement, fully anechoic room, open-area test site, radiated emission measurement, semi-anechoic chamber

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Harry H. Hodes
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Introduction

This introduction is not part of ANSI C63.7-2015, American National Guide Guide for Construction of Test Sites for Performing Radiated Emission Measurements.

ANSI C63.4, 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, has undergone several revisions since the original document covering methods of measurement was produced in 1940. While many improvements were made in that standard up to the version published in early 2004, the reproducibility of measurements of radiated emissions from one open-area test site (OATS) to another had not been completely satisfactory.

In 1982, a concerted effort was organized in Subcommittee One of Accredited Standards Committee C63[®], to determine how the OATS technique could be improved. Evidence showed that the variability at the time was due, in part, to inadequate: a) control of the site ground plane conductivity, its flatness, site enclosure effects, and certain other characteristics; b) accounting for antenna factors, associated cabling, and balun and equipment under test (EUT) characteristics; and c) consideration of mutual coupling effects between the EUT and the receiving antennas and their images in the conducting ground plane. Accordingly, after over five years of deliberations and investigations, ANSI C63.4 was revised. In the same year, ANSI C63.5 (American National Standard for Electromagnetic Compatibility—Radiated Emission Measurements in Electromagnetic Interference (EMI) Control—Calibration of Antennas (9 kHz to 40 GHz)), ANSI C63.6 (American National Standard for Electromagnetic Compatibility—Open-Area Test Site Measurements—Guide for Computation of Errors), and ANSI C63.7 (American National Standard Guide for Construction of Open-Areas Test Sites for Performing Radiated Emission Measurements) were first published. All of this occurred in 1988.

In 1992, the next edition of ANSI C63.7 was published. That update included improvements to the text resulting from experience testing at an OATS, which continues to serve as the reference test site for performing radiated emission measurements. These measurements continue to be used to determine product compliance to radiated emission limits, although there are other test facilities that are used, such as semi-anechoic chambers, which replicate an OATS because both have conductive ground planes and both are validated using the normalized site attenuation technique contained in ANSI C63.4.

The 2005 edition of ANSI C63.7 further improved on the 1992 edition by clarifying and elaborating how:

- a) cables from the receiving antenna should be routed;
- b) the metal conducting ground plane should be treated when exposed to the weather;
- c) choices can be made for the ground plane material; and
- d) the slope of the ground plane affects the test site.

This edition of ANSI C63.7 extends the application of the document to use above 1 GHz extending up to 18 GHz and is thus applicable for the use with ANSI C63.4. While there is no site validation method available above 18 GHz, the changes are considered appropriate guidance for use up to 40 GHz. As construction guidance is different in some cases for sites below 1 GHz and for sites above 1 GHz, the material is broken into clauses that apply to these two frequency ranges and the most used test facilities. Where the same guidance holds and is frequency independent, that guidance will also be in an introductory clause to the provisions for both frequency ranges.

There are major changes and additions in this document over that in the 2005 edition. This document:

- a) Addresses open-area test sites (OATSSs) which are covered for weather protection;
- b) Introduces provisions relating to other test sites, i.e., semi-anechoic chambers (SACs) and fully anechoic rooms (FARs);
- c) Describes grounding for both radio frequency (RF) low impedance and human safety;
- d) Expands the bibliography and references with more recent material;
- e) Introduces web URLs for further literature investigation;
- f) Adds Annex C that cites the occurrences of “test site” in ANSI C63.4 and ANSI C63.5.
- g) Extends coverage of the document above 1 GHz up to 40 GHz.

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American National Standard

Guide for Construction of ~~Open-Area~~ Test

Sites for Performing Radiated

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1. Overview

1.1 Scope

This guide provides information ~~that is useful in constructing an open-area test site (OATS) used to perform~~ on construction of radiated emission ~~measurements~~ test facilities in the frequency range of 30 MHz to ~~1000 MHz. Final validity of~~ 40 GHz. Standardized site validation methods above 18 GHz remain unavailable at present, however the changes in this edition are considered appropriate guidance for use up to 40 GHz. In general, the construction techniques described apply either below 1 GHz, or for 1 GHz and above.

This guide does not address construction code compliance issues. Parties responsible for the design and construction of test sites are advised to consult with the various authorities having jurisdiction (AHJ) to determine the building, HVAC, plumbing, electrical, etc., codes and regulations that are applicable for the test site~~can only be made by performing site attenuation measurements described 2003,¹ section 5.4.6.~~

In addition, beyond the similarity of basic principles, this guide also does not specifically address considerations on construction of test sites used for calibration of antennas used in EMC radiated emissions measurements; that topic is covered in ANSI C63.5.^{1, 2} In addition, site-dependent measurement instrumentation and signal cabling issues are not in the scope of this guide.

1.2 Purpose

To account for the frequency ranges and differing measurement needs as described in 1.1, this document provides construction guidance focused on two applications:

- a) At 1 GHz and below, the test site can be either an open-area test site (OATS) or a semi-anechoic chamber (SAC).
- b) At 1 GHz and above, the test site can be an OATS with absorber material on a portion of the ground plane, a SAC with absorber on a portion of the ground plane, or a SAC with absorbers on all conductive surfaces; the latter test site is called a fully anechoic room (FAR).³

¹ For information on references, see Clause 2.

² ANSI C63[®] publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>) or from the American National Standards Institute (<http://www.ansi.org/>).

³ Various other international and national standards and open literature have used the acronym FAR to refer to fully absorber-lined environments, i.e., shielded or unshielded chambers or rooms having absorber material covering all internal surfaces in their entirety. For the purposes of this document, FAR is used to refer to a performance-based fully anechoic condition with reflections reduced to below specified levels; see 5.4.

Common construction techniques are also described that apply for all the above test facilities.

NOTE—As a guide, this document does not contain requirements or specifications because the material is meant to be informative. However, some of the guidance should be strongly considered because not taking the guidance can lead to a test site that does not meet site validation requirements which are specified in such documents as ANSI C63.4. On the other hand, some of the guidance identifies what to consider among several options. As this guide is read, keep in mind that there are these levels of consideration. The sense of these levels of consideration as indicated by the verbs used is given in the following list. A search of the document will show where “should,” “recommended,” and “might” appear, the criteria below will give the emphasis needed. Also, different from the usual style for IEEE standards of marking annexes as normative or informative, because all annexes in this document are informative thus such marking is unneeded.

- “Strongly suggested” is identified by use of the verb “should.”
- Items “to be considered” are identified by the use of the verb “recommended” or “might.”
- “Is possible” is identified by use of the verb “can.”
- There is no use of the normative verbs such as “shall” and “must” in this guide.

2. Normative References

The following references are intended to assist the user of this guide and are listed here because they have direct application to this guide. The information in each of these references as applied in this document is to be considered as informative. For all ASC C63[®] documents referenced in this document, the latest version applies. For non-ASC C63[®] documents with no date, the latest version applies. Regional documents should be consulted for variations from the international standards referenced. Throughout this document, in-text reference to a specific clause, subclause, table, or figure of another document is dated even if the undated version of the document is listed in this clause. ~~The following standards should be consulted when validating an OATS.~~

ANSI C63.4-~~2003~~, 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.²⁴

ANSI C63.5, American National Standard for Electromagnetic Compatibility—Radiated Emission Measurements in Electromagnetic Interference (EMI) Control—Calibration of Antennas (9 kHz to 40 GHz).

ANSI C63.14~~1998~~, American National Standard Dictionary ~~for Technologies~~ of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3). ~~Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD) (Dictionary of EMC/EMP/ESD Terms and Definitions).~~

CISPR 16-1-4 Edition 3.1 with Amendment 1:2011, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-4: Radio Disturbance and Immunity Measuring Apparatus— Antennas and Test Sites for Radiated Disturbance Measurements.

Hemming, L. H., *Electromagnetic Anechoic Chambers: A Fundamental Design and Specification Guide*, Piscataway, NJ: IEEE Press, 2002.

~~ANSI C63.5-2006, American National Standard for Calibration of Antennas Used for Radiated Emission Measurements in Electromagnetic Interference (EMI) Control.~~

3. Definitions

For the purposes of this guide, refer also to the definitions provided in ~~see~~ ANSI C63.14-~~1998~~ and ANSI C63.4.

⁴ ANSI C63[®] publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>), or from the Sales Department, American National Standards Institute, 11 West 42nd Street, New York, NY 10036, USA (<http://www.ansi.org/>).

alternative test site: A location commonly identified as follows:

- Radio frequency (RF) absorber-lined metal test chambers with only the floor composed of a conductive material, generally referred to as a semi-anechoic chamber (SAC);
- office or factory buildings large enough for reflections to not disrupt the field at the point of measurements;
- weather-protected (covered) open-area test site (OATS), because of the potential effects of the cover material.

NOTE—Metal-shielded enclosures and other sites that do not comply with the volumetric normalized site attenuation(NSA) requirements should be used only for exploratory radiated emission measurements; see 5.4.2 in ANSI C63. 4-2014.

fully anechoic room (FAR): Shielded enclosure, the internal surfaces of which are lined with radio- frequency energy absorber material that absorbs electromagnetic energy in the frequency range of interest.

normalized site attenuation (NSA): Site attenuation divided by the antenna factors of the radiating and receiving antennas (all in linear units).⁵

site voltage standing wave ratio (SVSWR): Ratio of maximum received signal to minimum received signal, caused by interference between direct (intended) and reflected signals. (CISPR 16-1-4:2011, MOD)

⁵ See ANSI C63.5 for details about applicable antenna factors and other parameters.

where

$$S_{\text{VSWR}} = \frac{E_{\text{max}}}{E_{\text{min}}} = \frac{V_{\text{max}}}{V_{\text{min}}}$$

$E_{\text{max}}, E_{\text{min}}$ are the maximum and minimum received signals, and

$V_{\text{max}}, V_{\text{min}}$ are the corresponding measured voltages when a receiver or spectrum analyzer is used for reception.

standard test site: An open-area test site (OATS) that does not incorporate weather-protection (or other)structures above the surface of its ground plane.

NOTE— A standard test site is commonly referred to as a “non-weather-protected OATS.”

test site: A location meeting appropriate validation criteria, if identified, to perform electromagnetic compatibility (EMC) measurements on equipment under test (EUT). This may also include in situ locations or areas where the EUT is installed or operated.

4. General considerations

Below 1 GHz, test sites such as OATSs, have a conductive ground plane with no significant reflective surfaces above that plane. At 1 GHz and above, test sites simulate near free-space conditions which significantly reduce the reflection off the conductive ground plane used at 1 GHz and below. Reflective surfaces above the ground plane can affect emission measurements below, at, and above 1 GHz. Such surfaces should either be a significant distance away from the measurement area, or treated with RF absorber material such as those used in a SAC or FAR to reduce unwanted reflections from the metal walls and ceiling (and floor in the case of a FAR) if not treated with absorbers.

~~Clause 5 through Clause 8 describe key~~ Recommended construction characteristics of the test site, the ground plane, instrumentation ~~and~~, EUT services, and ~~all-weather-covers~~ related information, are provided in Clauses 5, 6, 7, and 8. These recommendations should be ~~used~~ followed so as to ~~ensure~~ achieve adequate test sites. ~~Adequacy is determined,~~ as established by performing site validation tests. These tests include the normalized site attenuation (NSA) measurement for 30 MHz to 1 GHz, as described in ANSI C63.4, ~~2003, section 5.4.6,~~ and the SVSWR (site voltage standing wave ratio) measurements for 1 GHz to 18 GHz, as described in CISPR 16-1-4 (also referenced in ANSI C63.4). This guide describes construction techniques that can assist in meeting the site validation requirements.

~~Section 5.1 through 5.4.5 of ANSI C63.4-2003 list general conditions for test sites and, in particular, OATSs. To summarize, radiated emission tests can be performed in an open, flat area of cleared, level terrain. Alternate sites might include a raised platform; rooftop site; an open area such as a large factory floor, relatively clear of obstructions that could adversely affect the measurements; or an effectively absorber-lined shielded room that is also free of undesired reflections from the walls and ceiling. The preferred test site is an OATS, which is internationally recognized as the standard for making radiated emission measurements (see [B4]).³~~

~~Such OATSs should be void of buildings, electric lines, fences, trees, etc., and free of underground cables, pipelines, etc., except when using a metallic ground plane that isolates the adverse effects of such underground metallic objects. Services to operate the equipment under test (EUT) and the cabling to the receive antenna should be trenched into the earth if no metallic ground plane is used. The depth of the trench should be such that the cabling will not significantly affect the normalized site attenuation measurement.~~

³ ~~The numbers in brackets correspond to those of the bibliography in Annex C.~~

5. Basic test site construction planning and guidance

5.1 General

This clause presents construction considerations for OATSs and covered OATSs, semi-anechoic chambers, and fully anechoic rooms. While emissions measurements can also be performed in transverse electromagnetic (TEM) cells and reverberation chambers, those will not be addressed as the construction considerations are specific to the manufacturer's design. In addition, it is assumed that any enclosed test facility such as a semi-anechoic chamber provides sufficient shielding in its design to not have the RF ambient outside the chamber affect emission measurements inside the chamber.

5.2 OATS and covered OATS (30 MHz to 1 GHz)

ANSI C63.4 provides general conditions for test sites and, in particular, OATSs. Such test sites can be used to measure radiated emissions particularly for frequencies from 30 MHz to 1 GHz. Generally these sites have these characteristics as stated in ANSI C63.4.

Historically the preferred test site is an OATS, which is internationally recognized, and was the test site standard for making radiated emission measurements (see CISPR 16 [B6]).⁶ The current view is that due to the exposure to ambient RF noise, an enclosed shielded facility such as a semi-anechoic chamber is preferred as long as it meets the site validation as would an OATS. Nonetheless, OATSs still exist and are used.

A typical OATS can be constructed as follows:

- a) a conductive ground plane in an open flat area, on level or near-level terrain, void of buildings, electric lines, fences, trees, etc.;

⁶ The numbers in brackets correspond to those of the bibliography in Annex D.