ANSI C63.7-1992
(Revision of ANSI C63.7-1988)

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

Accredited Standards Committee on Electromagnetic Compatibility, C63

accredited by the

American National Standards Institute

Secretariat

Institute of Electrical and Electronic Engineers, Inc.

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American National Standards Institute

Abstract: Information that is useful in constructing an open-area test site (OATS) used to perform radiated emission measurements in the frequency range of 30-1000 MHz is provided. Final validity of the test site can only be made by performing site attenuation measurements as described in ANSI C63.4-1992.
Keywords: emission measurement, open-area test sites, radiated emission measurement

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Introduction

(This introduction is not a part of ANSI C63.7-1992, American National Standard Guide for Construction of Open-Area Test Sites for Performing Radiated Emission Measurements.)

ANSI C63.4, Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 10 kHz to 1 GHz, has undergone several revisions since the original document covering methods of measurement was produced in 1940. While many improvements were made in the standard from time to time, 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 Accredited 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, ANSI C63.4 was revised; and ANSI C63.5, Standard Calibration of Antennas Used for Radiated Emission Measurements in Electromagnetic Interference (EMI) Control, and C63.6, Guide for the Computation of Errors in Open Area Test Site Measurement, were published respectively in 1989 and 1988 to provide additional information. The first version of C63.7 on test-site construction was also published in 1988. The present version contains improvements in the text resulting from experience gained in its application.

At the time this document was approved, members of Task Group on Open-Area Test Sites were as follows:

Donald N. Heirman, *Chair*

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Jon Curtis
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At the time that the Accredited Standards Committee on Electromagnetic Compatibility, C63, approved this standard, it had the following membership:

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Edwin L. Bronaugh, *Vice Chair*
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CLAUSE PAGE

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

1. Scope

This guide provides information that is useful in constructing an open-area test site (OATS) used to perform radiated emission measurements in the frequency range of 30–1000 MHz. Final validity of the test site can only be made by performing site attenuation measurements described in ANSI C63.4-1992 ,[1] 5.4.6.

2. Definitions

For definitions, see ANSI C63.14-1992

3. References

The following standards should be consulted when validating OATS:

ANSI C63.4-1992, 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.[2]

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

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[1] Information on references can be found in clause 3.. The numbers in brackets preceded by the letter B correspond to those of the bibliography in clause 9.

[2] ANSI 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 Street, New York, NY 10036, USA.

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

ANSI C63.14-1992, American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD) (Dictionary of EMC/EMP/ESD Terms and Definitions).

4. General considerations

Sections 5.1–5.4.5 of ANSI C63.4-1992 list general conditions for test sites and, in particular, open-area test sites. 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 [B3]).

Such open-area sites 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 following describes key recommended characteristics of the test site, the ground plane, instrumentation and EUT services, and all-weather covers. These recommendations should be used to ensure adequate test sites. Adequacy is determined by performing normalized site attenuation measurements described in ANSI C63.4-1992, 5.4.6.

5. Obstruction-free area

An obstruction-free area surrounding the EUT and field strength measuring antenna is required. The obstruction-free area should be free from significant scatterers of electromagnetic fields, and should be large enough so that scatterers outside the obstruction-free area will have little effect on the fields measured by the field-strength measuring antenna. The definitive test of the obstruction-free area is to perform normalized site attenuation measurements indicated in ANSI C63.4-1992.

Since the magnitude of the field scattered from an obstruction depends on many factors (size of the obstruction, distance from the EUT and receiving antenna, orientation with respect to the EUT and receiving antenna, conductivity and permittivity of the obstruction, frequency, etc.), it is impossible to specify an obstruction-free area that is necessary and sufficient for all applications. However, a reasonable guide is given in the following paragraphs.

The size and shape of the obstruction-free area are dependent upon the measurement distance and whether or not the EUT will be rotated. If the site is equipped with a turntable, the recommended obstruction-free area is an ellipse with the receiving antenna and EUT at the two foci, and having a major axis equal to twice the measurement distance and a minor axis equal to the product of the measurement distance and the square root of three (see figure 1). For this ellipse, the path of the undesired ray reflected from any object on the perimeter is twice the length of the direct ray path between the foci.

In the original development of the reflection-free area ellipse, the rationale for using twice the direct path length was that it implies that the scattered signal at the boundary will be at least 6 dB down from the direct signal between the EUT and receiving antenna, and hence have minimal impact on the direct path measurement. Calculations since have shown that a spurious reflected signal 6 dB down from the direct path signal can cause 2 to 3 dB errors in the measurements. However, the magnitude of a ground plane edge reflection is dependent upon the path distance and the degree to which the edge is electrically terminated or produces reflections.

For large EUTs, the obstruction-free area must be expanded so that the obstruction clearance distances exist from the perimeter of the EUT. Since the first Fresnel ellipse encloses the area on the ground plane from which the major part of the ground-reflected energy comes, it follows logically that there should be no obstructions in this area. For a 3 m site, the first Fresnel ellipse (see table 1) is larger than the obstruction-free area ellipse shown in figure 1. If the site fails to meet the normalized site attenuation criteria in ANSI C63.4-1992, the area that is outside of the construction-free ellipse but enclosed within the first Fresnel ellipse should be investigated for scatterers and obstructions. The effects of poor test-site construction including inadequate obstruction-free area, improper ground-plane construction and sizing, and other site defects are discussed in [B2] and [B9] . If the site is not equipped with a turntable, that is, if the EUT is stationary, the recommended obstruction-free area is a circular area such that the radial distance from the boundary of the EUT to the boundary of the area is equal to the measurement distance multiplied by one and one-half (see figure 2). In this case, the receiving antenna will be moved about the EUT and a clear area of the 1.5 times the measurement separation distance will provide the same prevention of undesired reflections as the boundary shown in figure 1.

The terrain within the obstruction-free area should be smooth, but does not have to be flat. Small slopes needed for adequate drainage may be acceptable. (See 6.2 for a discussion of smoothness requirements.)

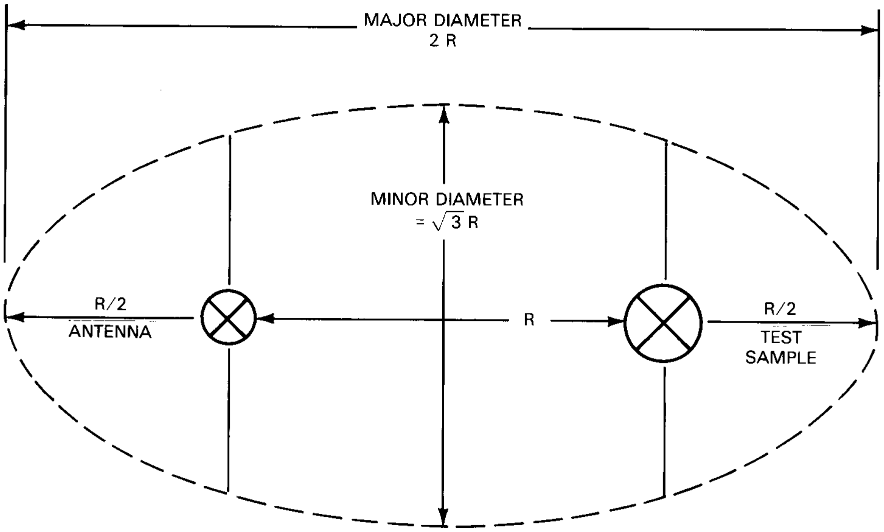

Figure 1— Obstruction-free area for OATS with a turntable

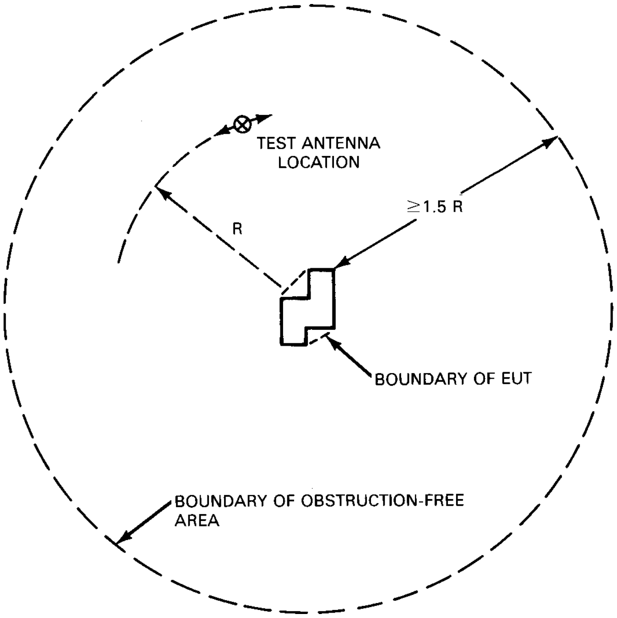

Figure 2— Obstruction-free area for OATS with stationary EUT

Table 1— Dimensions for several representative measurement conditions

Measurement Distance (m)	Frequency (MHz)	Antenna Heights (m)		Ellipse Axes (m) Major	Ellipse Axes (m) Minor	Ellipse Center (m) (Note 2)
R		h_1	h_2	$2X_1$	$2Y_1$	X_0
3 (Note 1)	30	1 2	4 4	9.9 11.3	9.5 11.0	1.4 1.5
	100	1 2	4 4	5.9 7.6	5.3 7.1	1.2 1.4
	1000	1 2	4 4	4.0 6.1	3.4 5.5	1.0 1.3
10	30	1 2	4 4	15.3 16.3	12.0 13.0	4.7 4.9
	100	1 2	4 4	10.8 12.4	6.6 8.1	4.3 4.7
	1000	1 2	4 4	7.7 10.6	3.6 5.7	3.4 4.5
30	30	1 2	4 4	34.5 35.2	18.3 18.9	14.6 14.8
	100	1 2	4 4	29.5 31.1	10.1 11.1	13.9 4.5
	1000	1 2	4 4	22.5 28.0	4.3 6.1	11.0 13.7

NOTES:

1 — The dimensions of the first Fresnel ellipse calculated for the 3 m measurement distance at 30 MHz are larger than the recommended obstruction-free area ellipse dimensions in figure A.1. See clause 5. and 6.1 for further discussion.

2 — X_0 is the distance from the position of the EUT to the center of the first Fresnel ellipse. (See figure A.1.)

6. Ground plane

6.1 Size and shape of ground plane

The size and shape of the reflecting surface, or ground plane, are dependent upon the measurement geometry and whether or not the EUT can be rotated. In general, the reflecting surface is contained wholly within the obstruction-free area. It is prudent, however, to construct the ground plane so that it may be extended in all directions if needed. For a site equipped with a turntable, the theoretically minimum ground plane size and shape is that of the first Fresnel ellipse. See annex A for a discussion of Fresnel ellipses, figure A.1 and footnote for a descriptive picture, and table 1 for dimensions of several representative ellipses. Practical experience indicates that rectangular ground planes having length and width dimensions substantially less than the Fresnel ellipse dimensions shown in table 1 may be satisfactory. For example, [B3] shows a 6 m × 9 m ground plane for making 3 m measurements. Table 1 indicates that at 30 MHz the ellipse is 9.9 m × 9.5 m, which for certain areas of the ellipse is larger than the rectangular 6 m × 9 m size (which is generally adequate for measurements). The 6 × 9 m ground-plane size may not be adequate for vertical polarization, particularly if the ground plane is raised. In this case, it should be expanded to the dimensions in table 1. The Fresnel ellipse dimensions should, therefore, be used only as a guide and the adequacy of an actual ground plane should be determined using the site characterization procedure and acceptability criterion given in ANSI C63.4-1992. Since the first Fresnel ellipse encloses the area on the ground plane from which the major part of the ground-reflected energy comes, it may be prudent to have the capability to extend the rectangular or trapezoidal dimensions of the ground plane up to or larger than the dimensions of the Fresnel ellipse. This is especially important for ground planes that are elevated above the surrounding surfaces.

If the site is not equipped with a turntable and the receiving antenna must be moved around the EUT, a circular ground plane is recommended. The radius of the ground plane derived by rotating the first Fresnel ellipse about the source focal point is given by

$$R = X_0 + X_1$$

where

X_0 is the distance from the closest point of the EUT to the center (midway between the two foci) of the first Fresnel ellipse

X_1 is the length of semimajor axis of Fresnel ellipse (see table 1)

For example, for a 3 m measuring distance, use of the calculated Fresnel ellipse major axis from table 1 in the above equation ($R = 1.4 + 9.9/2 = 6.35$ m) results in a ground plane that is larger than the obstruction-free area radius given in figure 2 at a frequency of 30 MHz, that is, 1.5 m × 3 m = 4.5 m.

6.2 Smoothness of ground plane

In some cases, the Rayleigh roughness criterion described in annex B provides a useful estimate of maximum allowable rms ground-plane roughness (see figure B.1).[3] Some examples for representative geometries are given in table 2. For most practical test sites, especially for 3 m separation applications, up to 4.5 cm (1.8 in) of “valleys” are not significant. Clearly, any site reasonably graded would meet this criterion. The obvious exceptions would be raised ground planes where the edge would probably exceed 4.5 cm. For those cases in particular, site attenuation measurements as described in ANSI C63.4-1992 would have to be made to determine the impact of exceeding the roughness criterion. As can be seen in table 2, the roughness for the 10 m and 30 m separations is not as restrictive as that for the 3 m site.

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[3] The rms roughness is a general view of undulations in the ground plane by representing these undulations as shown in figure B.1.

6.3 Ground-plane material

As stated in ANSI C63.4-1992, 5.4.1 and 5.4.3, a conducting ground plane is required. Metals such as copper, steel, and aluminum are recommended as the ground-plane material for measurement distances between 3 m and 30 m. Some examples include solid metal sheets, metal foil, perforated metal, expanded metal, wire cloth, wire screen, and metal grating. The ground plane should have no voids or gaps with linear dimensions that are greater than 1/10 of a wavelength at the highest frequency of measurement (about 3 cm at 1000 MHz). Material comprised of individual sheets, rolls, or pieces should be soldered or welded at the seams, preferably continuously, but in no case with gaps longer than the 1/10 wavelength criterion. After installation and especially if the above criterion is not adhered to, the adequacy of the ground-plane material and interconnecting mechanism and fastening techniques should be determined by using the site-characterization procedure and acceptability criterion in ANSI C63.4-1992. If the ground plane is exposed to the weather, adequate precautions should be taken to ensure that the material and interconnecting mechanism do not oxidize or corrode to the point that the conductive properties of the entire test area ground plane are degraded. Repeat site-attenuation measurements are clearly needed for all sites (a minimum of every six months is recommended) and, for sites exposed to the weather, more frequently. In fact, some test laboratories perform representative attenuation measurements at the start of each major test program.

Table 2— Typical values of maximum rms terrain roughness[*]

			Maximum rms Roughness, *b*		
Measurement Distance, *R* *(m)*	**Source Height, h_1 (m)**	**Maximum Receiving Antenna Height, h_2 (m)**	**In Wavelenghts**	**At 1000 MHz (cm)**	**(in)**
3	1	4	0.15λ	4.5	1.8
10	1	4	0.28λ	8.4	3.3
30	2	4	0.64λ	19.1	7.5

NOTES:

1 — The rms roughness *b* is determined from a profile section of the surface. For a random rough surface the rms value is equal to the standard deviation.

2 — The Rayleigh criterion for a smooth surface is

$$b \le \frac{\lambda}{8}\left[1 + \left(\frac{R}{h_1 + h_2}\right)^2\right]^{\frac{1}{2}}$$

where

h_1, h_2, and R are shown in figure B.2.

λ is the wavelength in meters.

[*] See annex B.

Use of ground plane materials other than metal may result in failure of the site to meet the ±4 dB acceptability criterion in 5.4.6.1 of ANSI C63.4-1992. Thick (several millimeters or more) dielectric coatings such as sand, asphalt, or wood on top of metal ground planes, not under the EUT (ANSI C63.4-1992; see Note in 7.1) may also result in unacceptable site-attenuation characteristics in certain frequency ranges, especially for vertical polarization measurements.

6.4 Ground-plane earthing

It is recommended that the ground plane be connected to the surrounding earth (for earth-mounted ground planes) by either a continuous method or periodically spaced ground rods. To avoid corrosion, use the same metal to “earth” as is used for the ground plane itself. Especially for elevated ground plane, all safety grounds should be connected to a single-point ground for the ground plane which is, in turn, connected to the building supply ground point.

7. Measurement facilities

7.1 Turntables

A remotely controlled turntable is recommended for convenience in measuring radiated emissions from all sides of the EUT. For testing floor-standing EUTs, the turntable should be metal covered and flush with the conducting ground plane. With respect to the possible use of a raised turntable for measuring floor-standing equipment, see Note 2 of 5.4.4 of ANSI C63.4-1992. The site attenuation measurement should show whether the gap between the conducting flush turntable surface and the surrounding conducting ground plane should be electrically bridged with suitable rubbing or rolling flexible conductive material. The presence of such an electrical connection can be temporarily simulated by bridging the circumferential gap with conductive tape (fastened with a conductive adhesive) at least every 30 degrees or so (see [B6]). If there is no change in site attenuation, especially below 100 MHz for vertical polarization measurements, the gap need not be filled. If changes are noted that are significant, that is, greater than 0.5 dB, a suitable bridging mechanism as mentioned above should be installed.

Tabletop EUTs may be tested on a flush turntable or on a nonmetallic turntable above the ground plane.

NOTE — Some standards require an insulating surface between the ground plane and floor-standing equipment under test.

In the case of a raised turntable, the ground plane should be continuous under the turntable. Material used for such raised turntables and nonmetallic tables of appropriate height should be selected so that there is no adverse effect when performing the site-attenuation measurement. For some applications, such as operation of the EUT via a remote simulator and *I/O* cabling, the turntable should have a center-area hole that will allow the cabling to drop directly down to the ground plane for raised turntables or below the ground plane for flush turntables. If this 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.

7.2 Services to EUT

Electrical service wiring to the EUT should be run under the ground plane to the maximum extent possible and preferably at right angles to the measurement axis. All wires, cables, and plumbing to the turntable or mounting of the EUT should also preferably be run under the ground plane. When not possible, service to the EUT should be placed in a shielded conduit on top of, and bonded, to the ground plane, with as low a profile as possible. These should be in place during site attenuation measurements. If radiation from these services on top of the ground plane may occur, they should be run through a shielded conduit so as not to affect the site attenuation.

7.3 Receiving antenna mast installation

The receiving antenna should be mounted on a nonconducting support or positioner that will allow the antenna to be raised between 1 m and 4 m. The cable shall be connected to the antenna balun such that the cable is orthogonal to the axis of the antenna elements at all antenna heights in order to maintain balance with respect to ground. The cabling from the receiving antenna balun should drop vertically to the ground plane approximately 1 m or more to the rear of the receiving antenna. An antenna boom approximately 1 m in length will suffice. From that point the cable shield should be bonded to the ground plane or, preferably, attached via an RF feed-through connector (attached to the ground plane) to below the ground plane. Cables that lie on the ground randomly or come closer than 1 m to any portion of the receive antenna elements should be avoided unless it is shown that the effects on site attenuation are negligible. Take-up reels and the like could be used, providing that the effects (both short term and long term) of cable flexing and rotating connectors are investigated and checked periodically via the site-attenuation measurement or other suitable RF impedance checks. Preferably, the take-up reel should be directly under the vertical drop of the cable. The cable between the antenna and radio-noise meter should be as short as practical to ensure acceptable received signal levels at high frequencies.

For both cases, the antenna factor calibration should not be affected by the presence of the antenna positioners and disposition of the coaxial cabling attached to the antenna. ANSI C63.5-1988 provides techniques for proper measurement of antenna factors.

To reduce adverse effects from RF currents induced by the EUT or calibrating source antenna on the exterior of the coaxial antenna cables, particularly with vertically polarized measurements, it is recommended that the portion of the cables above the ground plane be strung with lossy ferrite beads at intervals of approximately 6 in (150 mm), or that the outer jacket be heavily impregnated with lossy ferrite material (see [B4] and [B5]).

7.4 Location of personnel and radio-noise meter

The location of test instrumentation and personnel should be chosen to minimize scattering from these objects during measurements. If any doubt exists, a normalized site-attenuation measurement can be performed to verify the acceptability of instrumentation and personnel positioning. Some standards require test personnel to access the equipment under test during testing for such purposes as I/O cable movement. If this is done, the full effect of introducing the person as a scatterer should be investigated, since the mere presence of the person can enhance or suppress emissions compared to those found when the person is not present. In any case, the final measurement should be made with test personnel and measuring instrumentation clear of the test area, or test documentation should describe the method used to correct the test results for the effect of the tester's body.

An underground instrumentation room located beneath the metal ground plane will eliminate scattering from instrumentation and personnel and has other advantages in servicing the EUT. A location perpendicular to the test axis and outside the obstruction-free area indicated in clause 5. is also appropriate for test personnel and measurement instrumentation. If an underground (or under-the-ground plane) instrumentation room is used, a great deal of attention should be paid to bonding of the EUT, EUT cable shields (if used), antenna cable shield, and filtering of the power to the EUT at the ground plane. The reference and physical connection for these bonds should be to a single point connection to the ground plane. If the ground plane does not form the true ground reference for all the equipment involved in the test and is not an effective barrier isolating the test set up from the emissions possibly emanating from the room below, the test results may be affected adversely.

7.5 Services to the radio-noise meter

Electric service to the radio-noise meter (or properly instrumented spectrum analyzer) should preferably be derived from a different power distribution panel, or alternately, a filtered panel other than that used to supply the EUT, in order to provide as much RF isolation as possible. Electric service lines for the radio-noise meter should preferably be run underground and should be separated from the EUT and EUT service lines to the maximum extent possible. Where not possible, service should be kept flush with, and bonded to, the ground plane and installed so as not to move during testing. Proper isolation between the EUT and instrumentation power sources is obtained when an RF powerline filter is inserted in the path between the ac outlet for the EUT power and the ac outlet for the instrumentation.

8. Weather-protection enclosure

8.1 Construction recommendations

Weather protection is desirable if the test facility is to be used throughout the year, during extremes of weather, and to protect the metallic ground plane, EUT, and receiving antennas from corrosion and deterioration.

Three types of structures are in common use:

a) *Type 1.* A structure that encloses the measurement range, that is, both the EUT, the receiving antenna, and the space in between.
b) *Type 2.* A structure that encloses only the EUT (the receiving antenna and most of the intervening space between the EUT and antenna are outside).
c) *Type 3.* A structure that is outside the obstruction-free area (that is, encloses neither the EUT nor the receiving antenna). This type of structure is used, for example, to house instrumentation and test personnel only.

Weather-protection materials must be RF transparent so as not to cause undesirable reflections and attenuations of the EUT fields at the highest measurement frequency. The structure should preferably be shaped to allow easy or self-removal of snow, ice, or water. RF transparency of these materials should be measured. If there is a significant (>O.5 dB) increase in site attenuation with the material placed between the transmit and receive antenna, such material or construction practice should not be used. Such example measurements are cited in [B10] .

The most critical structure from an RF transparency viewpoint is Type 2, since the propagation path from the EUT to the receiving antenna passes through the structure and periodic cleaning of the structure may be advisable. The next most critical structure is Type 1, since reflections and scattering from materials can disturb the fields inside the structure. The least critical is Type 3, which is more amenable to use of conventional materials and construction techniques, such as wood and common nails. It is prudent to consider making site-attenuation measurements in accordance with 5.4.6 of ANSI C63.4-1992 if the weather-enclosure material is considered to be affecting emission measurements.

8.2 Materials and fasteners

Up to 1000 MHz, thin sections of fiberglass, most other plastics, specially sealed woods, and fabric material will not cause appreciable attenuation. Moisture absorption in some materials (for example, wood and nylon) can cause transmission losses that are particularly critical if EUT emissions are measured through such material as in a Type 2 structure. Care should be taken to ensure that air-deposited conductive particles, standing water, and ice do not build up on the structure or within the material forming the structure.

Use of metal above the ground plane should be kept to a minimum. Use of plastic or fabric fasteners is recommended for Type 1 and Type 2 structures. Any anchors, pilings, or similar foundations should be at or below ground-plane elevation or be far enough removed so as not to affect the measurement. Modern RF transparent building practices and materials such as those cited in [B7] and [B8] are available and do not contain any metal above the ground-plane elevation.

The RF attenuation and scattering properties of materials and fasteners should be measured or evaluated before commitment to the final design. In [B10] it is shown that scattering from 2 in x 4 in wood studs can cause nonnegligible attenuation through walls using this type of construction. Again, site-attenuation measurements described in ANSI C63.4-1992 provide the definitive mechanism for determining the suitability of such building practices. Measurements with a sample construction section are prudent and are strongly recommended.

8.3 Internal arrangements

All structural members should be nonreflective. Any blowers or ducts for heating, cooling, or air support should be outside the test area, outside the structure, or beyond the obstruction-free area, unless they are made of nonconductive material or run below the ground plane. Temperature and humidity control may be required for the operation of the equipment and for control of electrostatic discharge effects. Thermostats or humidistats and their control wires should be located in underground return plenums so as not to cause control wiring reflections. Insulation or windows should be free of metal backing or framing. Safety rails or stairs should also be nonconductive if located above the ground plane.

8.4 Size

The size of a weather-protection enclosure will depend on the size of the EUT and whether or not the antenna range is to be enclosed. If the antenna position is enclosed, the enclosure height should be high enough to accommodate the highest elevation of the receive antenna upper element during vertical polarization measurements.

8.5 Uniformity with time and weather

It is recommended that periodic site-attenuation measurements be made in accordance with 5.4.6.5 of ANSI C63.4-1992 in order to detect anomalies due to degradation of all-weather protection caused by weather conditions (for example, moisture absorption) or contamination of enclosure materials. A six-month interval is generally adequate unless physical signs indicate material degradation sooner, that is, the material changes color due to airborne contaminants.

8.6 Other considerations

The walls of a weather-protection enclosure should not be located at the ground-plane edges. For economy of design, a structure may be smaller than the ground plane, provided care is taken to avoid discontinuities as the ground plane passes under the building walls. Experience has shown that the axis of measurements should be nonparallel with the building axis. This will usually reduce the reflective effects of the building, if any.

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Annex A Fresnel ellipse

(Informative)

(These annexes are not a part of ANSI C63.7–1992, American National Standard Guide for Construction of Open-Area Test Sites for Performing Radiated Emission Measurements, but are included for information only.)

This annex contains a derivation of the Fresnel zones. The Fresnel zones give one an indication of the shape and location of the regions on a reflecting plane that contribute the most to the total field received at a given point. The derivation follows from [B1] .

Assume a smooth *xy* plane (figure A.1). A source at the point A ($0, 0, h_1$) induces surface currents on the *xy* plane that radiate a reflected field. The reflected field, as well as the direct field, is received at the point *B* ($R, 0, h_2$).

The ray through the geometrical point of reflection (illustrated with dashed lines) has a longer path length than the direct ray path. This increase of path length δ is given by the expression

$$\delta = R_1 + R_2 - d \qquad \text{(A1)}$$

For a given measurement geometry, δ and *d* are constant and equation A1 may be rewritten

$$R_1 + R_2 = \delta + d = \text{Constant} \qquad \text{(A2)}$$

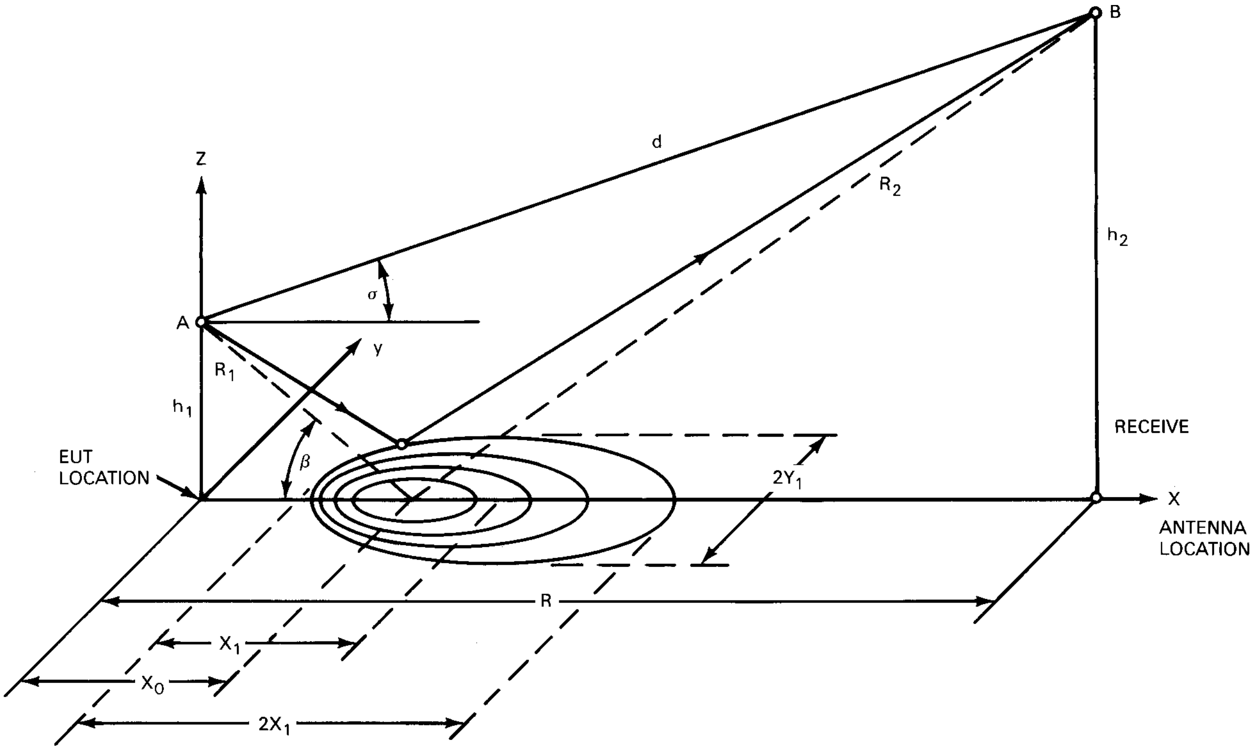
In three dimensions, equation A2 is the equation of an ellipsoid of revolution about the axis connecting foci A and B and touching the *xy* plane only at the geometrical reflection point. This ellipsoid defines the locus of all possible reflection points that would produce a reflected ray exactly δ longer than the direct ray *d*. If δ is increased by λ/2, a new ellipsoid is formed that describes the locus of all possible reflection points that would produce a reflected ray with a path length λ/2 longer than a ray through the geometrical point of reflection. A series of such ellipsoids may be formed by replacing δ in equation A1 by δ_n, where

$$\delta_n = \delta + \frac{n\lambda}{2},\ n = 0, 1, 2, 3,... \qquad \text{(A3)}$$

The intersection of these ellipsoids and the xy plane yields the family of ellipses shown in figure A.1. For the case where $n = 0$, the intersection of the ellipsoids is the geometrical point of reflection. The average phase of the radiation from each zone bounded by two neighboring ellipses will differ from the adjacent zone by π so that the elementary secondary waves radiated by successive zones will be in phase opposition.

For the purposes of this annex, the ellipses may be expressed in terms of R, h_1, h_2, and δ . The center of the ellipse (X_0, 0, 0) is given as

$$X_0 = \frac{R}{2}\left[1 - \frac{\tan^2\theta}{\left(\frac{\delta_n}{R} + \sec\theta\right)^2 - 1}\right] \qquad \text{(A4)}$$



NOTE—For simplicity, the EUT location is considered at the center of the turntable for this figure. For actual application, *R* and X_0 are measured from the closest point of the EUT to the receive antenna. Hence, the largest linear dimension projected onto the ground plane should be considered when applying the Fresnel ellipse equation.

Figure A1 —The Fresnel ellipses on a reflecting surface

where θ is the angle formed between line *d* and a line through point A parallel with the X axis. (See figure A.1.) The semiminor axis is

$$Y_1 = \frac{R}{2}\left\{\left[\left(\frac{\delta_n}{R}\right)^2 + \frac{2\delta_n}{R}\sec\theta\right]\left[1 - \frac{\tan^2\theta}{\left(\frac{\delta_n}{R} + \sec\theta\right)^2 - 1}\right]\right\}^{\frac{1}{2}} \qquad \text{(A5)}$$

The semimajor axis is

$$X_1 = Y_1\left\{1 + \frac{1}{\left(\frac{\delta_n}{R} + \sec\theta\right)^2 - 1}\right\}^{\frac{1}{2}} \qquad \text{(A6)}$$

Annex B The Rayleigh criterion

(Informative)

Rayleigh has suggested a way of formulating the criterion for a specularly smooth surface. Figure B.1 depicts the derivation. If two rays are incident on a surface with roughness of height *b* at a grazing angle of β, the path difference between the two rays is

$$\Delta d = 2b\sin\beta \tag{B1}$$

Hence the phase difference is

$$\Delta\phi = \frac{2\pi}{\lambda}\cdot\Delta d = \frac{4\pi b}{\lambda}\sin\beta \tag{B2}$$

If the phase difference is small, the two rays will be nearly in phase as they are when reflected from a perfectly smooth surface. As the phase difference increases, the two rays will interfere until they cancel when $\Delta\varnothing = \pi$. If this happens, no energy is transferred in this direction so it must be scattered in other directions. Then, the surface must be considered rough at $\Delta\varnothing = \pi$ and smooth at $\Delta\varnothing = 0$. Rayleigh chose the value half-way between the two, or $\Delta\varnothing = \pi/2$ as the distinguishing criterion. (Other values, for example π/4, have been called more realistic [B1]). Using the Rayleigh criterion, a surface is “smooth” if

$$b < \frac{\lambda}{8\sin\beta} \tag{B3}$$

For measurement distance *R* and source and receive antenna heights h_1 and h_2 (see figure B.2), we have

$$\sin\beta = \frac{h_1 + h_2}{[R^2 + (h_1 + h_2)^2]^{\frac{1}{2}}} \tag{B4}$$

and equation B3 can be rewritten as

$$b < \lambda\left[\frac{R^2 + (h_1 + h_2)^2}{8(h_1 + h_2)}\right]^{\frac{1}{2}} \tag{B5}$$

or

$$b < \frac{\lambda}{8}\left[1 + \left(\frac{R}{h_1 + h_2}\right)^2\right]^{\frac{1}{2}} \tag{B6}$$

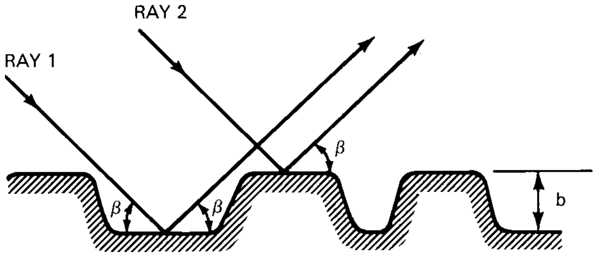


Figure B1 ——The Rayleigh criterion

The right-hand side of the inequality (equation B5 or B6) is a minimum (that is, most stringent condition) when the receiving antenna is at the maximum height $h_2^{\max}$ in the scan range $h_2^{\min} \leq h_2 \leq h_2^{\max}$

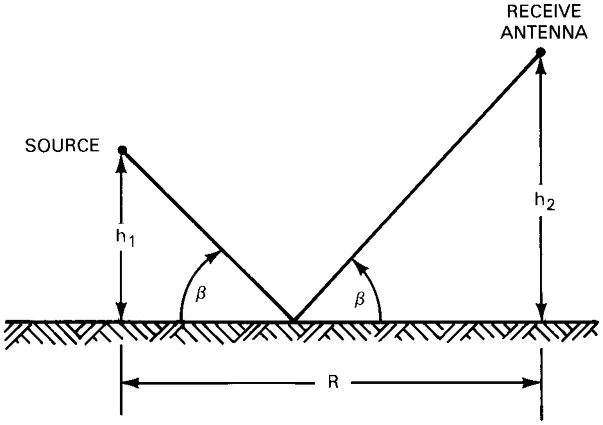


Figure B2 ——Reflection geometry