CISPR TR 16-4-5

Edition 1.0 2021-10

TECHNICAL REPORT

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

AMENDMENT 2

Specification for radio disturbance and immunity measuring apparatus and methods –
Part 4-5: Uncertainties, statistics and limit modelling – Conditions for the use of alternative test methods

CISPR TR 16-4-5:2006-10/AMD2:2021-10(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC online collection - oc.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

CISPR TR 16-4-5

Edition 1.0 2021-10

TECHNICAL REPORT

colour inside

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

AMENDMENT 2

Specification for radio disturbance and immunity measuring apparatus and methods –
Part 4-5: Uncertainties, statistics and limit modelling – Conditions for the use of alternative test methods

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.100.10; 33.100.20

ISBN 978-2-8322-9844-2

Warning! Make sure that you obtained this publication from an authorized distributor.

FOREWORD

This amendment has been prepared by subcommittee CISPR A: Radio-interference measurements and statistical methods, of IEC technical committee CISPR: International special committee on radio interference.

The text of this amendment is based on the following documents:

DTR	Report on voting
CIS/A/1321/DTR	CIS/A/1324/RVDTR

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

---

1 Scope

Add, in the second sentence, the following new text “and total radiated power” *to the parentheses to read:* “i.e. field strength and total radiated power”.

2 Normative references

Add the following new reference to the existing list:

CISPR 16-1-1:2019, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

Delete the existing reference to CISPR 16-4-1, modified by Amendment 1.

Replace the existing reference to CISPR 16-4-2:2003 with the following:

CISPR 16-4-2:2011, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Measurement instrumentation uncertainty*
CISPR 16-4-2:2011/AMD1:2014
CISPR 16-4-2:2011/AMD2:2018

3 Terms and definitions

3.8
intrinsic uncertainty of the measurand

Replace the existing source, modified by Amendment 1, with the following: "[CISPR 16-4-1:2009, 3.1.6, modified – Deletion of notes]"

Add, after the existing definition 3.10, added by Amendment 1, the following new term and definition as follows:

3.11
EUT volume
cylinder defined by EUT boundary diameter and height that fully encompasses all portions of the actual EUT, including cable racks and 1,6 m of cable length (for 30 MHz to 1 GHz), or 0,3 m of cable length (for 1 GHz and above)

NOTE 1 The test volume is one of several criteria limiting the EUT volume.

NOTE 2 The EUT volume has a diameter *D* (boundary diameter) and a height *h*.

4 Symbols and abbreviated terms

Add, to the existing introductory statement, the following new sentence as follows:

The following abbreviations are used in this technical report. Note that the symbol *k* is used for four different quantities.

Add the following new lines to the existing list modified by Amendment 1:

FAR fully anechoic room

RC reverberation chamber

SCU standards compliance uncertainty

Replace the two existing lines K and k with the following:

k $= 2\pi/\lambda$, wave number (in this document, *k* is used in the electrical size *ka*, where *a* is the EUT radius)

k(*f*) linear conversion factor

K(*f*) logarithmic conversion factor

k coverage factor

k Boltzmann's constant

5 Introduction

Replace the existing text with the following new text:

Over the years, several test methods and test set-ups for radiated disturbance measurement have been described in basic standards. One particular combination of test method and test set-up also having defined disturbance limits is the open area test site (OATS) method, which has proven to be successful for the protection of radio services. Since the first edition of this document, limits have been defined for other – alternative – test methods, e.g., fully anechoic rooms and TEM waveguides, but not for reverberation chambers.

Each alternative method can be used to get measurement results related to disturbance from an EUT. Although each method gives a disturbance level from an EUT, the different methods might capture the EUT disturbance differently. For example, considering radiated disturbance measurements, different methods may capture different EUT radiation pattern lobes, a different number of lobes, or the test facility might alter the EUT radiation pattern producing a different apparent disturbance level. Therefore the limits defined for the established test method cannot be applied directly to the alternative test methods. Consequently, procedures are needed to derive limits to be used for the results of alternative test methods.

The specification of such procedures considers the general goal of disturbance measurements, which is to verify whether an EUT satisfies or violates certain compliance criteria. Past experience has shown that using the present system of established test methods and associated limits yields a situation without many cases of interference due to conducted disturbance or radiated disturbance. Applying an established test method with its associated limits will fulfill the protection requirement with a high probability. To preserve this situation, the most important requirement for the use of alternative test methods is the following:

– Use of an alternative test method in a normative standard shall provide the same protection of radio services as the established test method.

This requirement can be met by developing procedures to derive disturbance limits for alternative test methods from the existing limits of the established test methods. Such procedures shall relate the results from an alternative test method to those from an established test method. Using the relations derived in this document, the limits of the relevant established test method can be converted into limits for the alternative test method. The measured values of the alternative test method can then easily be evaluated against the converted limits. Such procedures will provide a similar amount of protection, even though an alternative test method is used.

The limit conversion procedures consider the preceding goal of disturbance measurements. The results of standard disturbance measurements can be considered as an approximation of the interference potential of an EUT. Depending on the characteristics of an EUT (e.g., radiation pattern characteristics for radiated disturbance test methods), and the test set-up, the measured value deviates from the actual interference potential of the EUT. This deviation can be divided into two parts: 1) a systematic deviation, which can be interpreted as a bias of the test method; and 2) a random deviation depending on the characteristics of different EUTs, which can be interpreted as an uncertainty of the test method. Each disturbance test method contains both quantities, and consequently the established test method does too. In the following clauses, a procedure based on these two quantities for comparing an alternative test method with the established test method is described. To determine these quantities, the abstract term “interference potential” shall be expressed in terms of a physical quantity. For the purposes of this document, this physical quantity is called the “reference quantity” X. Other details about comparison of test methods using a reference quantity can be found in [1][1].

[1] Figures in square brackets refer to the Bibliography.

The significance of a reference quantity is under discussion (see Magdowski [16]). It is not used in the derivation of limits for an alternative test method based on measurements (see Clause 7 of CISPR TR 16-4-5:2006/AMD1:2014), and in the derivation of limits for disturbance measurements using a reverberation chamber (i.e. in this document).

Figure 1 – Overview of quantities to estimate for use in conversion procedure

Replace the existing figure with the following:

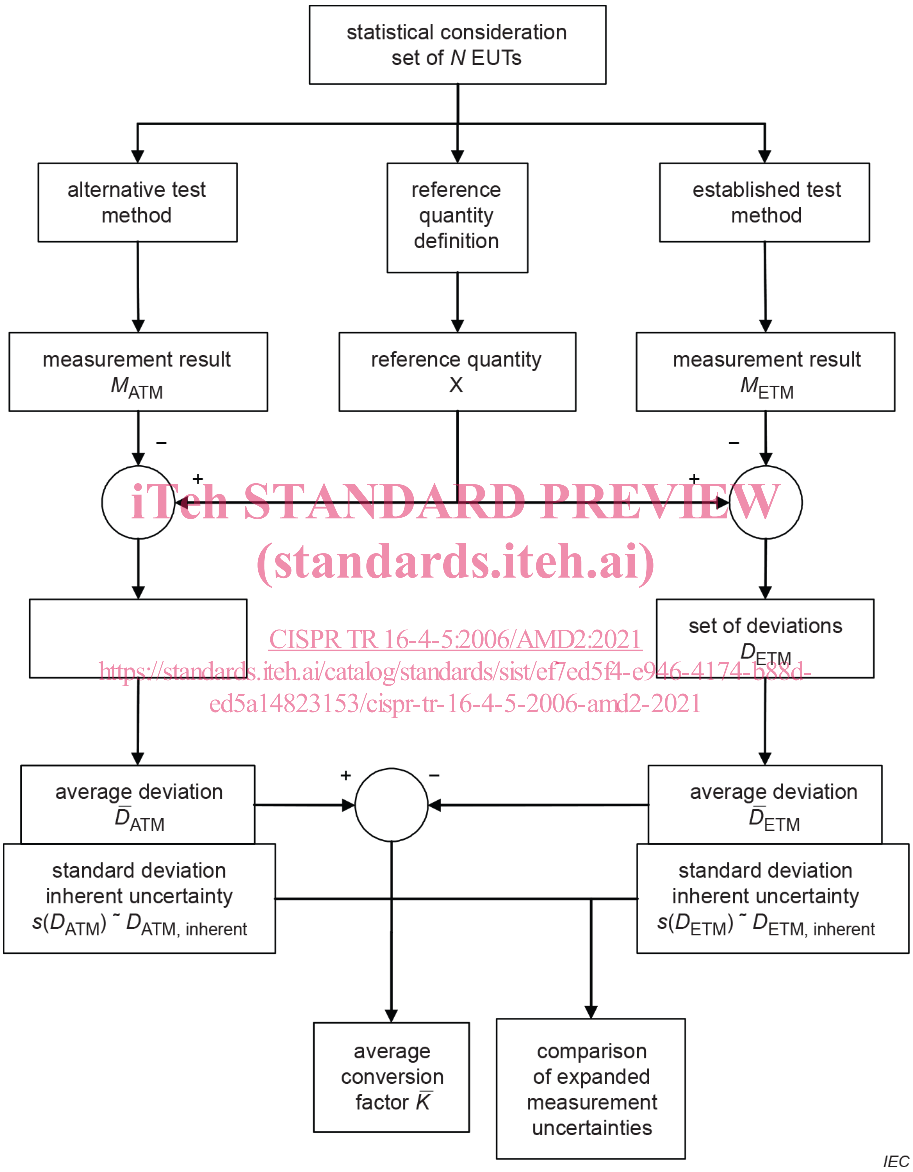


Figure 2 – Overview of limit conversion procedure using estimated quantities

Replace the existing figure with the following:

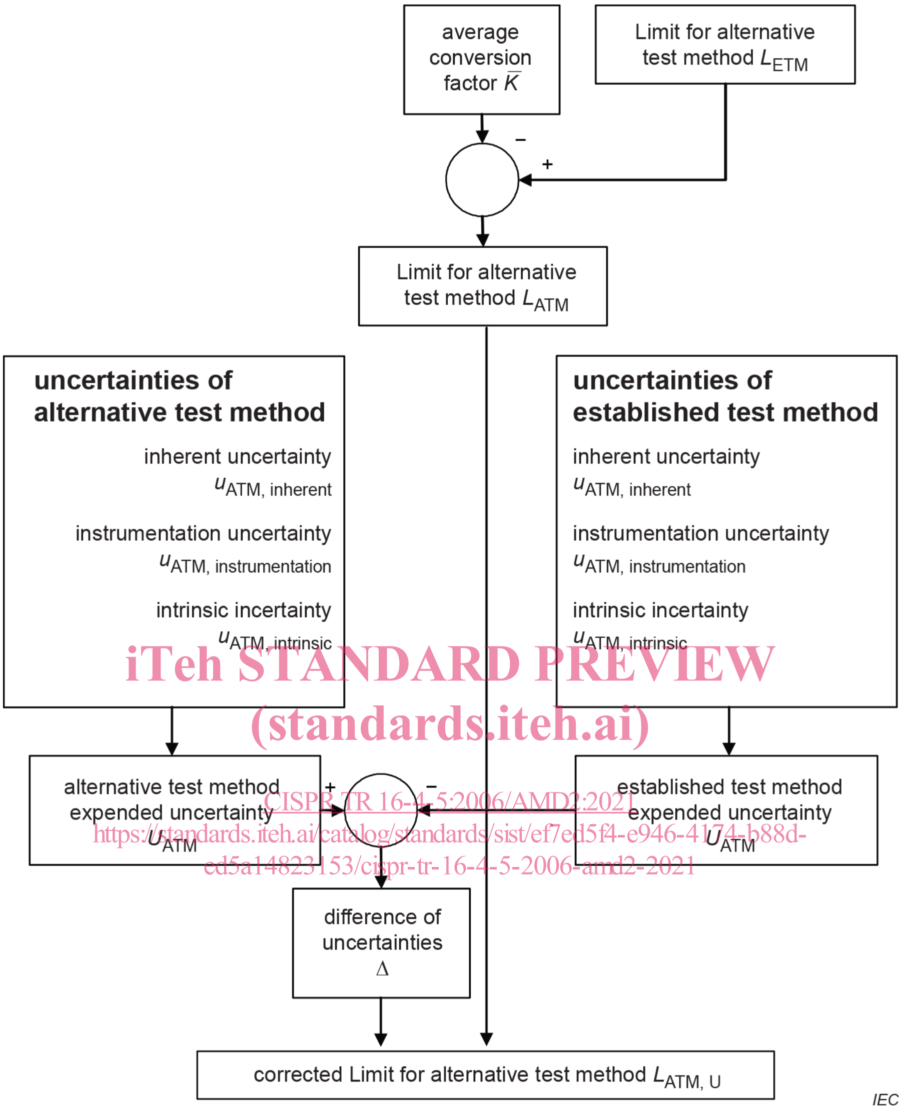


Table 2 – Overview of quantities and defining equations for conversion process

Add, at the bottom of the existing table, modified by Amendment 1, the following new rows:

E_{max}	Maximum field strength of an EUT in µV/m measured using the ETM, i.e. at d = 10 m at an OATS/SAC from 80 MHz to 1 000 MHz, and at d = 3 m at a FSOATS/FAR from 1 GHz to 18 GHz	(35)
P_T	Power transmitted from an EUT in pW measured using the reverberation chamber test method (ATM), and virtual power[a] producing the field-strength maximum E_{max} measured using the ETM	(35)
[a] The virtual power is the power generating E_{max} assuming the EUT directivity is estimated in this document.		

Add, after the existing Clause 7, modified by Amendment 1, the following new Clause 8:

8 Derivation of limits for the use of reverberation chambers as ATM for radiated disturbance measurements based on a statistical analysis of all essential factors

8.1 Conversion factor

Measurement of radiated power from an EUT using the RC method is described in IEC 61000-4-21 [22]. This clause attempts to provide rules to derive disturbance limits for the radiated power measured using the RC test method based on existing limits for radiated field strength measured using the ETM. Radiated field strength and radiated power of an EUT are related via the EUT directivity, and EUT directivity depends on frequency and EUT volume. Because the type of an EUT and its directivity are typically unknown for generic and product standards, this clause uses a statistical estimate based on assumptions described by Krauthäuser [19]. For comparison and easier understanding, the conversion factors using a short dipole as a model are described in D.2.

With reference to Annex D, conversion factors

– from OATS/SAC to RC for 80 MHz to 1 000 MHz, and
– from FSOATS/FAR to RC for 1 GHz to 40 GHz.

are introduced.

NOTE The start frequency of 80 MHz is selected because IEC 61000-4-21:2011, Table B.2 [22] on field uniformity requirements starts at 80 MHz. Because there are RCs with lower or higher lowest useable frequencies (LUFs), 80 MHz can be replaced by "LUF." The highest frequency of 40 GHz is selected because that is under consideration to be the highest frequency for all CISPR documents pending agreement by NCs.

The linear conversion factor $k(f)$ is defined as in Equation (35)

$$k(f) = E_{\max}^2 / P_{\mathrm{T}} \tag{35}$$

where

$E_{\max}$ is the maximum field strength of an EUT in μV/m measured using the ETM;

P_{T} is the power transmitted from an EUT in pW measured using the RC test method.

The unit of $k(f)$ is $\mathrm{V^2/m^2W}$ or Ω/m^2. To convert into logarithmic quantities, Equation (35) can be written as Equation (36):

$$\begin{aligned} \lg P_{\mathrm{T}} &= \lg E_{\max}^2 - \lg k(f), \text{ or} \\ 10 \lg P_{\mathrm{T}} &= 20 \lg E_{\max} - 10 \lg k(f) \end{aligned} \tag{36}$$

The logarithmic conversion factor $K(f)$ is defined as in Equation (37):

$$K(f) = 10 \lg k(f) \tag{37}$$

The logarithmic conversion factor can be used to convert radiated disturbance limits L_{ETM} in dB(μV/m) into limits of the disturbance power L_{ATM} in dB(pW) measured in an RC as shown in Equation (38) (see also Equation (15) in 6.10).

$$L_{\mathrm{ATM}}/\mathrm{dB(pW)} = L_{\mathrm{ETM}}/\mathrm{dB(\mu V/m)} - K(f) \tag{38}$$

The logarithmic conversion factor $K(f)$ has the unit dB(Ω/m^2).

8.2 Measurement uncertainty

Equation (7) and Equation (9) of 6.7 provide the combined standard uncertainties of ATM and ETM results with contributions designated in subscripts as: “m” for the instrumentation uncertainty, “intrinsic” for the intrinsic uncertainty of the measurand, and “inherent” for the inherent uncertainty of the method.

$$u_{\mathrm{XTM}} = \sqrt{u_{\mathrm{XTM,m}}^2 + u_{\mathrm{XTM,intrinsic}}^2 + u_{\mathrm{XTM,inherent}}^2}$$

where X in the subscript terms denotes either E or A (i.e. ETM or ATM).

For the effect of the measurement uncertainties of ETM and ATM on the disturbance limit, the expanded uncertainties are compared (see Equation (16) in 6.10). The expanded uncertainty of the conversion factor in Annex D (2σ in Table D.2, Table D.3,Table D.4,Table D.6, Table D.7 and Table D.8) takes into account the inherent uncertainties of the ETM ($U_{\mathrm{inherent,ETM}}$) and ATM ($U_{\mathrm{inherent,ATM}}$). The inherent uncertainty is an indicator of the ability of a measurement procedure to account for differences in EUT characteristics. A three-dimensional (3D) spatial scan would provide the lowest uncertainty for capturing the maximum field strength radiated by an EUT, but none of the ETMs are ideal in that respect. However, the RC ATM does capture the radiated power of an EUT across all directions. Consequently, the inherent uncertainty of the RC ATM is zero whereas the inherent uncertainties of the ETMs are non-zero.

In addition to the uncertainty of the conversion factor, the actual EUT size can deviate from the EUT size assumed for the conversion factor calculation in Annex D, which justifies a contribution U_{EUT}.

As can be seen from Table H.1 of CISPR TR 16-4-1:2009, the SCU $U_{\mathrm{ETM,SC}}$ of the ETM (OATS/SAC with d = 10 m) is on the order of 10 dB, whereas $U_{\mathrm{XTM,m}}$ is around 5 dB according to CISPR 16-4-2. Thus,

$$U_{\mathrm{ETM,SC}} = \sqrt{U_{\mathrm{ETM,intrinsic}}^2 + U_{\mathrm{ETM,m}}^2}$$

and consequently

$$U_{\mathrm{ETM,intrinsic}} = \sqrt{U_{\mathrm{ETM,SC}}^2 - U_{\mathrm{ETM,m}}^2} = 8{,}7\ \mathrm{dB}$$

This means that the intrinsic uncertainty of the ETM is much larger than the uncertainty of the conversion factor K, so Equation (28) of 7.2.3 does not apply for Annex D. The intrinsic uncertainty is largely dependent on cable layout and cable termination, which is an important topic for the reproducibility of measurement set-ups. By future standardization of cable layout and cable termination, intrinsic uncertainty and standards compliance uncertainty can be minimized.

At present values of SCU (and intrinsic uncertainty) are not available for the ETM above 1 GHz, as well as for the RC ATM below and above 1 GHz. This does not mean that the RC method should be precluded for radiated disturbance measurements usage; there is no reason to assume that the SCU of the RC method results will be larger than the SCU of the ETM results. Product committees should provide appropriate investigations and measurements for establishing the SCU.

In addition to any deviation from the EUT size for the conversion factor, the EUT type can be different from that assumed for the conversion; e.g. with different cable arrangement and cable termination. This means that Equation (32), Equation (33), and Equation (34) of 7.2.3 also apply for the use of an RC disturbance measurement method as an ATM.

Details on instrumentation contributions to uncertainty for RC disturbance measurement results is given in D.4.

B.1.1.5 Estimate the standard uncertainties of the test methods (see 6.6)

Replace the existing first paragraph with the following new paragraph:

Instrumentation uncertainty: At the time of drafting of this Annex, for the alternative test method (3 m FAR), the instrumentation uncertainty had not yet been given in CISPR standards. For the antenna and site contributions, numeric values from the final technical report of the EU FAR project have been used [4]. The other numeric values were taken from CISPR 16-4-2:2003 [24], because these were expected to be the same for OATS and FAR. These instrumentation measurement uncertainties are given in Table B.1. For the established test method, the measurement instrumentation uncertainty is as shown in the basic standard CISPR 16-4-2:2011.

B.2.1.5 Estimate the standard uncertainties of the test methods (see 6.6)

Replace, in the first paragraph, "CISPR 16-4-2:2003" with " CISPR 16-4-2:2011".

B.2.1.8 Verify the calculated values (see 6.9)

Replace, in the last paragraph, "CISPR 16-4-2:2002" with " CISPR 16-4-2:2011".

Add, at the end of the existing Annex C, added by Amendment 1, the following new Annex D:

Annex D
(informative)

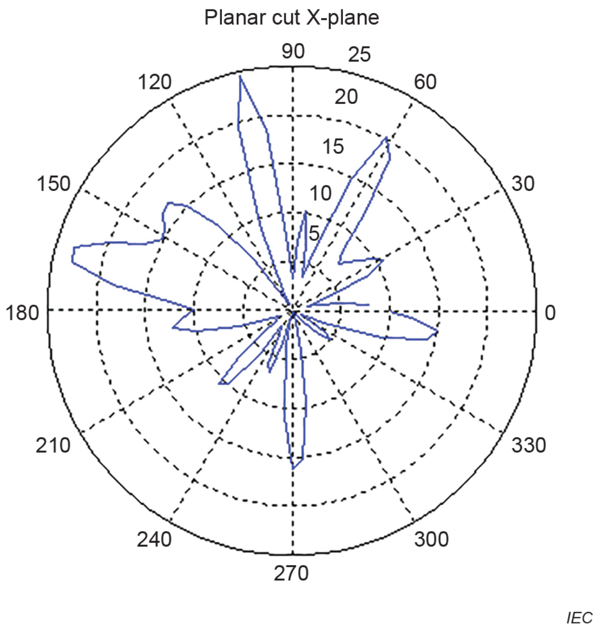
Statistical method for conversion of disturbance limits from radiated disturbance established test methods to the RC test method

D.1 General

Radiated disturbance established test methods (ETMs) measure field strength at a specified distance from an EUT, whereas the RC test method (alternative test method, ATM) measures the radiated power from an EUT. Because the EUT directivity varies from type to type, statistical techniques are used to derive conversion factors from ETM results to ATM results. With increasing electrical size of an EUT, the complexity of an EUT's radiation pattern increases (see Wilson [17]).

Wilson [17] explains how the electrical size of an EUT is established by the quantity *ka*, where $k = 2\pi/\lambda$ is the wave number, and *a* is the radius of the minimum sphere that encloses the EUT. The preceding concept applies for this entire annex. An EUT is considered electrically large, if $ka > 1$, and it is electrically small, if $ka \leq 1$. Figure D.1 shows an example radiation pattern for a simulated electrically-large emitter. Table D.1 provides the EUT dimensions for the transition from electrically small to electrically large as a function of frequency.

Wilson [17] also provides a statistical estimate of 3 dB for the probability of finding the maximum radiation between a planar-cut scan (e.g. an EUT rotation without an antenna height scan) and a full-sphere scan valid for very large EUTs. Thus, the planar-cut scan is regarded as a reduced sampling procedure for finding the maximum field strength of an EUT. This also means that the radiation limit for a full-sphere scan of a large EUT can be reduced by a conservative amount of 3 dB if the full-sphere scan is replaced by a planar-cut scan.



NOTE The Y-plane and Z-plane patterns have similar characteristics, but normally only a single lobe in one plane reaches the maximum (i.e. amplitude of 25 in this example).

Figure D.1 – Simulated radiation pattern of an electrically large emitter (50 cm radius, *ka* = 10,5 at 1 GHz) in a single plane (X-plane) (Wilson [17])