TECHNICAL REPORT

CISPR 16-4-5

First edition
2006-10

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

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

Reference number
CISPR 16-4-5/TR:2006(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site (www.iec.ch)**
- **Catalogue of IEC publications**

  The on-line catalogue on the IEC web site (www.iec.ch/searchpub) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.
- **IEC Just Published**

  This summary of recently issued publications (www.iec.ch/online_news/ justpub) is also available by email. Please contact the Customer Service Centre (see below) for further information.
- **Customer Service Centre**

  If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

  Email: custserv@iec.ch
  Tel: +41 22 919 02 11
  Fax: +41 22 919 03 00

TECHNICAL REPORT

CISPR 16-4-5

First edition
2006-10

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

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, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE X

For price, see current catalogue

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

CISPR 16-4-5, which is a technical report, has been prepared by CISPR subcommittee A: Radio-interference measurements and statistical methods.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
CISPR/A/665/DTR	CISPR/A/685/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the CISPR 16-4 series, published under the general title *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4: Uncertainties, statistics and limit modelling*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site 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.

A bilingual version of this publication may be issued at a later date.

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

1 Scope

This part of CISPR 16-4 specifies a method to enable product committees to develop limits for alternative test methods, using conversions from established limits. This method is generally applicable for all kinds of disturbance measurements, but focuses on radiated disturbance measurements (i.e. field strength), for which several alternative methods are presently specified. These limits development methods are intended for use by product committees and other groups responsible for defining emissions limits in situations where it is decided to use alternative test methods and the associated limits in product standards.

2 Normative references

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

CISPR 16-4-1:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-1: Uncertainties, statistics and limit modelling – Uncertainty in standardized EMC tests*

CISPR 16-4-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-2: Uncertainties, statistics and limit modelling – Uncertainty in EMC measurements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161 and the following apply.

3.1
established test method
test method described in a basic standard with established emissions limits defined in corresponding product or generic standards. An established test method consists of a specific test procedure, a specific test set-up, a specific test facility or site, and an established emissions limit

NOTE The following test methods have been considered to be established test methods in CISPR:

– conducted disturbance measurements: test method defined in CISPR 16-2-1:2003, Clause 7;
– radiated disturbance measurements up to 1 GHz: the test method defined in CISPR 16-2-3, 7.2.1;
– radiated disturbance measurements up to 18 GHz: the test method defined in CISPR 16-2-3, 7.3.

3.2
alternative test method
test method described in a basic standard without established emissions limits. The alternative test method is designed for the same purpose as the established test method. An alternative test method consists of a specific test procedure, a specific test set-up, a specific test facility or site, and a derived emissions limit that was determined by the application of the proposed method stated in this document

3.3
established limit
limit having “many years” of good protection of radio services.

NOTE An example is radiated field strength measured on OATS, developed to protect radio services as described in CISPR 16-3.

3.4
derived limit
limit applicable for the alternative test method, derived by appropriate conversion from the established limit and expressed in terms of the misbrands

3.5
conversion factor *K*
for a given EUT or type of EUT, the relation of the measured value of the established test method to the measured value of the alternative test method

NOTE The terms measured and calculated are used interchangeably at various places in this document to describe actual laboratory tests and computer simulations.

3.6
reference quantity *X*
the basic parameter which determines the interference potential to radio reception. It may be independent of the parameters presently used in established standards

NOTE The goal for both the established and alternative test methods is to determine the reference quantity (X) for all frequencies of interest. For both established and alternative test methods, the test results may deviate from the reference quantity values. The specification of the reference quantity when applying methods of this document should include applicable procedures and conditions to calculate (or measure) this quantity

3.7
inherent uncertainty
u_{inherent}
uncertainty caused solely by the difference in EUT characteristics and the ability of the measurement procedure to cope with them. It is specific to each test method and remains, even if the measurement is performed perfectly, i.e., the standards compliance uncertainty is zero and the measurement instrumentations uncertainty is zero

3.8
intrinsic uncertainty of the measurand
$u_{\text{intrinsic}}$
minimum uncertainty that can be assigned in the description of a measured quantity. In theory, the intrinsic uncertainty of the measurand would be obtained if the measurand was measured using a measurement system having negligible measurement instrumentation uncertainty.

[CISPR 16-4-1, definition 3.6]

3.9
EUT type
grouping of products with sufficient similarity in electromagnetic characteristics to allow testing with the same test installation and the same test protocol.

4 Symbols and abbreviated terms

The following abbreviations are used in this technical report:

ATM alternative test method (e.g. subscript in D_{ATM})

D deviation

ETM established test method (e.g. subscript in D_{ETM})

i index of one individual (e.g., of a number of EUTs)

K	conversion factor
k	coverage factor
L	limit
M	measurement (or calculation) result
N	number of EUTs
s	standard deviation
U	expanded uncertainty
u	standard uncertainty
v	volume
X	reference quantity
Δ	difference of two values or quantities
$\overline{x}$	mean value of a set of values x (e.g., $\overline{D}$)

5 Introduction

Over the years, several test procedures and test set-ups for radiated emissions testing have been described in basic standards. One particular combination of test method and test set-up also having defined emissions limits is the open area test site (OATS) method, which has proven to be successful for the protection of radio services. In general limits have not been defined for the other, alternative test methods, e.g., fully anechoic room, TEM waveguide, reverberation chamber.

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

The specification for such a procedure should consider the general goal of disturbance measurements. The aim of the disturbance measurement is to verify whether the EUT satisfies or violates certain compliance criteria. Past experience has shown that using the present system of the established test method and the associated limits yields a situation without many cases of interference due to conducted or radiated emissions. Applying the established test method with the 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 as follows.

– 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 a procedure for deriving emission limits for the alternative test method from the existing limits of the established test method. Such a procedure shall relate the results of the alternative test method to those of the established test method. Using this relation the limits of the 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 a procedure will provide a similar amount of protection, even though an alternative test method is used.

The limits conversion procedure should consider the goal of emissions measurements as described above. The results of standard emissions tests can be considered as an approximation of the interference potential of an EUT. Depending on the characteristics of the EUT (e.g., radiation pattern characteristics for radiated disturbance test methods), and on the measurement set-up, the measured value differs from the actual interference potential of the EUT. This deviation can be divided into two parts: a systematic deviation, which can be interpreted as a bias of the test method, and a random deviation depending on the characteristics of different EUTs, which can be interpreted as an uncertainty of the test method. Each emissions 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” needs to be expressed in terms of a physical quantity. For the purposes of this report, this quantity is called the “reference quantity,” *X*. More details about correlation of test methods using a reference quantity can be found in [1][1].

6 Procedure to derive limits for an alternative test method

6.1 Overview

A procedure to derive limits for an alternative test method based on the limits of an established test method is described in the following paragraphs. Figure 1 shows a summary of the estimated quantities needed for the correlation process. Figure 2 shows a flowchart for the correlation process using these quantities. The nine-step conversion process below can be accomplished using numerical simulations, measurements, or a combination of simulations and measurements. Calculable or reference EUTs are invaluable for this conversion procedure. In the following subclauses, as part of the conversion process the quantities shown in Figure 1 and Figure 2 are combined into several equations. A summary of the equations is given in Table 2. A summary of the steps in the conversion procedure is shown in Table 1.

Table 1 – Summary of steps in conversion procedure

1	Select the reference quantity
2	Describe the test methods and measurands
3	Determine the deviations of the measured quantities from the reference quantity
4	Determine the average values of the deviations
5	Determine the standard uncertainties of the test methods
6	Verify the calculated values
7	Apply the conversion

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

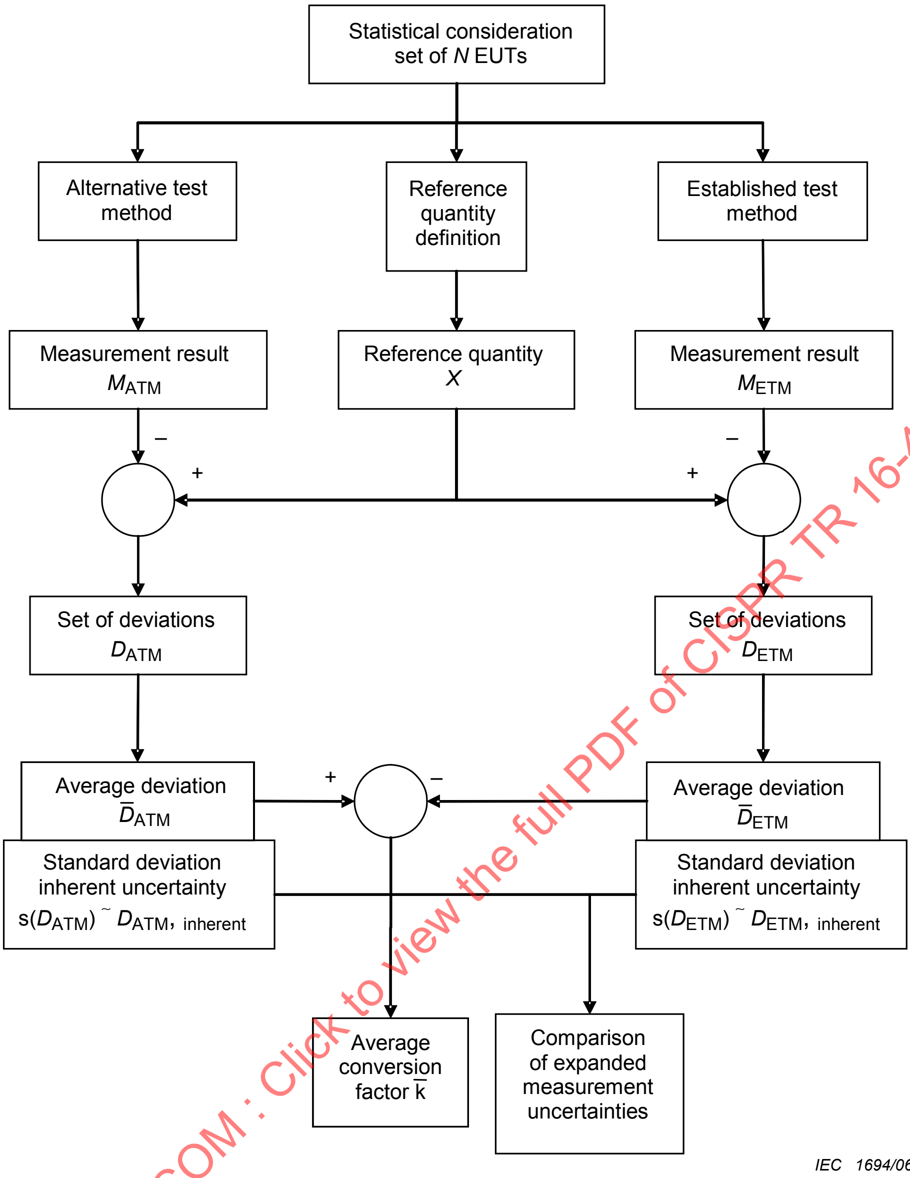


Figure 1 – Overview of quantities to estimate for use in conversion procedure

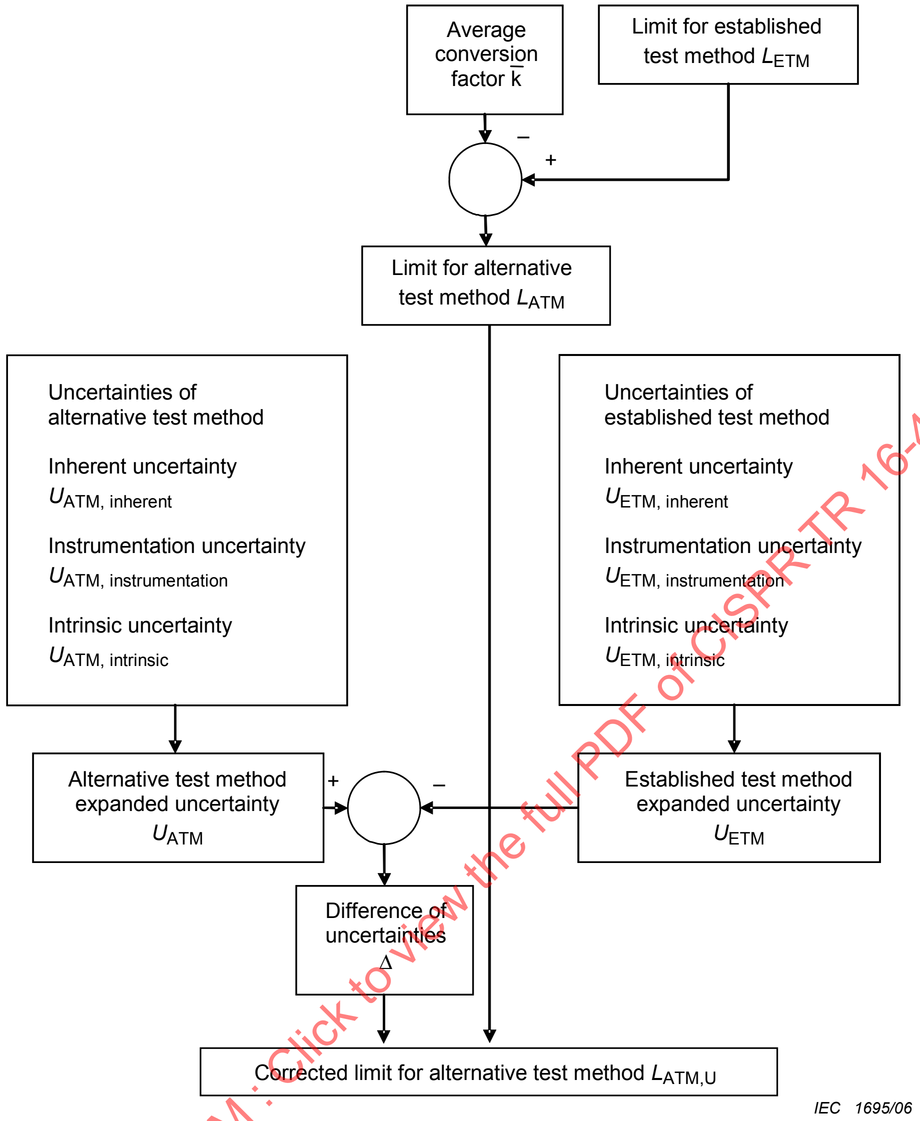


Figure 2 – Overview of limit conversion procedure using estimated quantities

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

Quantity	Meaning	Equation no.
$D_{\mathrm{ATM}i}(f)$	the deviation from the reference quantity of the measurement result of EUT *i* as produced by the alternative test method	(1)
$D_{\mathrm{ETM}i}(f)$	the deviation from the reference quantity of the measurement result of EUT *i* as produced by the established test method	(2)
$\overline{D}_{\mathrm{ATM}}$	the average deviation of the alternative test method	(3)
$\overline{D}_{\mathrm{ETM}}$	the average deviation of the established test method	(4)
$u_{\mathrm{ATM,inherent}}$	the inherent uncertainty of the alternative test method	(5)
$u_{\mathrm{ETM,inherent}}$	the inherent uncertainty of the established test method	(6)
u_{ATM}	combined standard uncertainty of the alternative test method	(7)
U_{ATM}	the expanded uncertainty of the alternative test method	(8)
u_{ETM}	combined standard uncertainty of the established test method	(9)
U_{ETM}	the expanded uncertainty of the established test method	(10)
$K_i(f)$	frequency dependent conversion factor for EUT *i*	(11)
$\overline{K}(f)$	the average of the conversion factors	(12), (13), (14)
$L_{\mathrm{ATM}}(f)$	the limit line of the alternative test method equivalent to the limit of the established test method, without consideration of the uncertainties	(15)
Δ	difference of expanded uncertainties	(16)
$L_{\mathrm{ATM},U}$	the limit to be used for alternative measurements	(17)

6.2 Select the reference quantity *X*

The first step is to select the reference quantity *X*. It should be selected on the basis of a quantity that can possibly cause interference to a radio service, and selection of a reference quantity also depends on the type of EUT.

For the types of EUTs investigated in Annex B, as an example the maximum electric field strength determined on a sphere of a certain radius around the EUT has been selected as the reference quantity for radiated emission measurements in the frequency range of 30 MHz to 1 GHz. In the frequency range below 30 MHz, depending on the frequency subrange and the coupling model, the reference quantity may be the vertical component of the electric field strength, the magnetic field strength, or the asymmetric voltage. In general, the reference quantity and the actual measurands will not necessarily have the same units.

6.3 Describe the test methods and measurands

The measurand shall be described for both the alternative and the established test methods. In addition, the test set-up geometry, the methods of measurement for EUT emissions, and any analysis methods producing the final measurement results shall be described. This description is necessary for an understanding about how the test method works and to give a basis for comparison of the two test methods. In most cases this description is explicit or implicit in the standards that specify the test methods.

6.4 Determine the deviations of the measured quantities from the reference quantity

Each test method provides results, each of which deviate from the reference quantity *X*. The deviation depends on the characteristics of the test set-up as well as on the characteristics of the EUT. Considering a certain EUT *i*, a frequency dependent deviation can be determined for both alternative and established test method.

For a given EUT *i* the deviation of the alternative test method, in a logarithmic scale, is given as

$$D_{\mathrm{ATM}i}(f) = X_i(f) - M_{\mathrm{ATM}i}(f) \tag{1}$$

where

- i is the index of the EUT;
- f is the frequency;
- $D_{\mathrm{ATM}i}(f)$ is the deviation from the reference quantity of the measurement result of EUT *i* as produced by the alternative test method;
- $X_i(f)$ is the reference quantity defined in 6.2 for the EUT *i*, and
- $M_{\mathrm{ATM}i}(f)$ is the measurement result given by the alternative test method for the EUT *i*.

The results of the established test method will deviate from the reference quantity as well. The deviation of the established test method is analogously given by the equation

$$D_{\mathrm{ETM}i}(f) = X_i(f) - M_{\mathrm{ETM}i}(f) \tag{2}$$

where

- $X_i(f)$, *f*, *i* are the same as in Equation (1);
- $D_{\mathrm{ETM}i}(f)$ is the deviation from the reference quantity of the measurement result of EUT *i* as produced by the established test method;
- $M_{\mathrm{ETM}i}(f)$ is the measurement result given by the established test method for the EUT *i*.

6.5 Determine the average values of the deviations

The deviations given by Equations (1) and (2) will differ for different EUTs. In order to obtain more universal results, varying characteristics of EUTs shall be considered, for example as shown in Annex A. Considering a range of *N* EUTs leads to a set of *N* values for the deviation *D* for both alternative and established test methods. From this set of *D* the average can be easily determined. See Annex A for more details about EUT considerations and variations.

An estimate of the mean of the deviation of the alternative test method is given by

$$\overline{D}_{\mathrm{ATM}} = \frac{1}{N}\sum_{i=1}^{N} D_{\mathrm{ATM}i} \tag{3}$$

where

- D_{ATM} is the set of deviations of the alternative test method;
- $\overline{D}_{\mathrm{ATM}}$ is the average deviation of the alternative test method;
- N is the number of EUTs considered, and shall be as large as possible for statistical reasons;
- i is the index of any one EUT;
- $D_{\mathrm{ATM}i}$ is the deviation from the reference quantity of the measurement result of EUT *i*, as produced by the alternative test method [Equation (1)].

An estimate of the mean of the deviation of the established test method is given by

$$\overline{D}_{\mathrm{ETM}} = \frac{1}{N}\sum_{i=1}^{N} D_{\mathrm{ETM}i} \quad (4)$$

where

D_{ETM} is the set of deviations of the established test method;

$\overline{D}_{\mathrm{ETM}}$ is the average deviation of the established test method;

N, i are the same as in Equation (3);

$D_{\mathrm{ETM}i}$ is the deviation from the reference quantity of the measurement result of EUT i, as produced by the established test method [Equation (2)].

6.6 Estimate the standard uncertainties of the test methods

The methods comparison procedure must consider uncertainties, as are associated with every measurement result. Because the results from the established test method itself have uncertainties, care must be taken that these uncertainties are not transferred to results from the alternative test methods as part of the conversion procedure. Otherwise, the use of alternative test methods would be burdened with uncertainties that are characteristics of the established test method.

The uncertainty of emission measurements consists of several components. On one hand, the measurement equipment contributes several uncertainties, as documented in CISPR 16-4-2. On the other hand the test set-up combined with the radiation characteristics of the EUT causes an inherent uncertainty, u_{inherent}. For example, in radiated emissions measurements, for some types of EUT radiation patterns, an OATS test (established test method) may fail to capture the radiated emission peak lobe. Deviations between the results of a test method and the reference quantity depend on the radiation characteristics of the EUT, but the radiation characteristics of an arbitrary EUT are not known *a priori*. The resulting uncertainty u_{inherent} can be estimated only if the behaviour of EUTs with different characteristics is examined. Analogously to as in 6.4, the deviations from the reference quantity of a set of N EUTs can be used for estimating the standard deviation as a measure for the inherent uncertainties**.**

Using the formula for experimental standard deviation, the inherent uncertainty of the alternative test method is given by:

$$u_{\mathrm{ATM,inherent}} = s(D_{\mathrm{ATM}}) = \sqrt{\frac{\sum_{i=1}^{N}(D_{\mathrm{ATM}i} - \overline{D}_{\mathrm{ATM}})^2}{N-1}} \quad (5)$$

where

$u_{\mathrm{ATM,inherent}}$ is the inherent uncertainty of the alternative test method;

$s(D_{\mathrm{ATM}})$ is the experimental standard deviation of the set D_{ATM};

N, i, D_{ATM}, $D_{\mathrm{ATM}i}$ are the same as in Equation (3).

Analogously, the inherent uncertainty of the established test method is given:

$$u_{\mathrm{ETM,inherent}} = s(D_{\mathrm{ETM}}) = \sqrt{\frac{\sum_{i=1}^{N}(D_{\mathrm{ETM}i} - \overline{D}_{\mathrm{ETM}})^2}{N-1}} \quad (6)$$

where

$u_{\mathrm{ETM,inherent}}$ is the inherent uncertainty of the established test method;

$s(D_{\mathrm{ETM}})$ is the experimental standard deviation of the set D_{ETM};

N, i, D_{ETM}, $D_{\mathrm{ETM}i}$ are the same as in Equation (4).

6.7 Estimate the expanded uncertainties of the test methods

The expanded measurement uncertainty is obtained from the multiplication of the combined standard uncertainties by a coverage factor k. The combined standard uncertainty of the alternative test method u_{ATM} can be calculated from

$$u_{\mathrm{ATM}} = \sqrt{u_{\mathrm{ATM,m}}^2 + u_{\mathrm{ATM,intrinsic}}^2 + u_{\mathrm{ATM,inherent}}^2} \quad (7)$$

where

$u_{\mathrm{ATM,m}}$ is the combined standard uncertainty of the alternative test method contributed by measurement instrumentation;

$u_{\mathrm{ATM,inherent}}$ is the inherent uncertainty of the alternative test method, according to Equation (5);

$u_{\mathrm{ATM,intrinsic}}$ is the intrinsic uncertainty of the alternative test method.

Using the coverage factor k, the expanded uncertainty of the alternative test method is estimated:

$$U_{\mathrm{ATM}} = k \cdot u_{\mathrm{ATM}} \quad (8)$$

where

U_{ATM} is the expanded uncertainty of the alternative test method;

k is the coverage factor;

u_{ATM} is the combined standard uncertainty of the alternative test method according to Equation (7).

Analogously the combined standard uncertainty of the established test method u_{ETM} can be obtained,

$$u_{\mathrm{ETM}} = \sqrt{u_{\mathrm{ETM,m}}^2 + u_{\mathrm{ETM,intrinsic}}^2 + u_{\mathrm{ETM,inherent}}^2} \quad (9)$$

where

$u_{\mathrm{ETM,m}}$ is the combined standard uncertainty of the established test method contributed by measurement instrumentation;

$u_{\mathrm{ETM,inherent}}$ is the EUT-dependent uncertainty of the established test method, according to Equation (6);

$u_{\mathrm{ETM,intrinsic}}$ is the intrinsic uncertainty of the established test method.

The expanded uncertainty of the established test method is given by

$$U_{\mathrm{ETM}} = k \cdot u_{\mathrm{ETM}} \quad (10)$$

where

U_{ETM} is the expanded uncertainty of the established test method;

k is the coverage factor;

u_{ETM} is the combined standard uncertainty of the established test method according to Equation (9).

6.8 Calculate the average conversion factor

For each EUT i a frequency dependent conversion factor $K_i(f)$ can be calculated using

$$K_i(f) = D_{ATMi}(f) - D_{ETMi}(f) \tag{11}$$

where

$D_{ATMi}(f)$ is the deviation from the reference quantity of the measurement result of EUT i, as produced by the alternative test method [Equation (1)];

$D_{ETMi}(f)$ is the deviation from the reference quantity of the measurement result of EUT i, as produced by the established test method [Equation (2)].

The average conversion factor can be calculated from the average deviations of the alternative and the established test methods:

$$\overline{K}(f) = \overline{D}_{ATM}(f) - \overline{D}_{ETM}(f) \tag{12}$$

where

$K(f)$ is the set of conversion factors;

$\overline{K}(f)$ is the average of the conversion factors;

$\overline{D}_{ATM}(f)$ is the average deviation of the alternative test method from the reference quantity, in dB;

$\overline{D}_{ETM}(f)$ is the average deviation of the established test method from the reference quantity, in dB.

Substituting the averages by Equations (3) and (4) gives:

$$\overline{K} = \overline{D}_{ATM} - \overline{D}_{ETM} = \frac{1}{N}\sum_{i=1}^{N} D_{ATM\,i} - \frac{1}{N}\sum_{i=1}^{N} D_{ETM\,i} \tag{13}$$

Using Equations (1) and (2), the average conversion factor can be expressed in terms of the measurement results of the set of EUTs:

$$\overline{K} = \frac{1}{N}\sum_{i=1}^{N}(X_i - M_{ATM\,i}) - \frac{1}{N}\sum_{i=1}^{N}(X_i - M_{ETM\,i}) = \frac{1}{N}\sum_{i=1}^{N}(M_{ETM\,i} - M_{ATM\,i}) \tag{14}$$

where $\overline{K}$ is the same as in Equation (12) and M_{ETMi} and M_{ATMi} are the same as in Equation (1) and Equation (2).

6.9 Verify the calculated values

In many cases it is necessary to obtain both the deviations from the reference quantity, and their average and standard deviation values, from numerical simulations. It is strongly recommended to verify such calculations by measurements.

6.10 Apply the conversion

If the limit lines defined for the established test method are to be converted into limit lines for an alternative test method, the results from Equations (8), (10), and (12) or (14), respectively, are needed.

A limit line of an established test method can be converted into limit conditions for an alternative test method using the average conversion factor:

$$L_{\mathrm{ATM}}(f) = L_{\mathrm{ETM}}(f) - \overline{K}(f) \tag{15}$$

where

$\overline{K}(f)$ is the frequency-dependent average conversion factor according to Equation (12);

$L_{\mathrm{ETM}}(f)$ is the frequency-dependent limit of the established test method;

$L_{\mathrm{ATM}}(f)$ is the limit line of the alternative test method equivalent to the limit of the established test method, without consideration of the uncertainties.

To complete the process, the uncertainties of both alternative and established test methods have to be taken into account. Defining a difference, Δ, between the uncertainty of the alternative test method, U_{ATM}, and the uncertainty of the established test method U_{ETM}, i.e.,

$$\Delta = U_{\mathrm{ATM}}(f) - U_{\mathrm{ETM}}(f) \tag{16}$$

implies a rule for how to handle the measurement uncertainties. If the uncertainty of the alternative test method is larger than the uncertainty of the established test method, it shall be used to correct the limit of the alternative test method:

$$L_{\mathrm{ATM},U} = \begin{cases} L_{\mathrm{ATM}} - \Delta & \text{if } \Delta > 0 \\ L_{\mathrm{ATM}} & \text{if } \Delta \le 0 \end{cases} \tag{17}$$

where $L_{\mathrm{ATM},U}$ is the limit to be used for alternative measurements.

Annex A
(informative)

Remarks on EUT modelling

As discussed in 6.5 and 6.6, the characteristics of an EUT directly influence the measurement results, and thus influence the deviations from the reference quantity. Considering the example of radiated emission measurements, the radiation pattern of the EUT influences the probability of capture for a maximum emission using the peak search procedure of an open-area test site or a fully-anechoic room measurement. To obtain more universal results, it is necessary to consider multiple EUTs having different radiation characteristics for use in determining conversion parameters. This annex describes general considerations about EUT modelling for use in investigations about emission measurement methods.

A.1 Types of EUTs

Certain characteristics of EUTs typically have the most influence on the radiation behaviour. It is useful to categorize EUTs with equivalent primary characteristics into several EUT types, which can then be considered and investigated independently. One general classification is to group EUTs into the following three types, based on the test set-up:

a) tabletop equipment without cables;

b) tabletop equipment with cable(s);

c) floorstanding equipment.

A.2 Application of statistics

Each EUT category of Clause A.1 consists of many different devices and operating and performance characteristics. To best cover these widely-varying characteristics, applying statistical methods is helpful. With a statistical approach, universally valid values for average conversion parameters and the uncertainties can be obtained. The uncertainty resulting from the unknown radiation characteristics of an EUT, u_{inherent}, can only be determined by considering a range of different EUTs and analysing the resulting data statistically. An example of such a statistical approach is given in Annex B.

Annex B
(informative)

Examples of application of the test method comparison procedure

B.1 Example 1 – Measurements at 3 m-separation in fully anechoic room compared to 10 m-separation measurements on open-area test site

In the following subclause headings, numbers in parentheses refer to subclauses in the main body of this document.

B.1.1 Small EUTs without cables

B.1.1.1 Select the reference quantity *X* (see 6.2)

The protection requirement is to minimize the risk that the disturbance field strength radiated by an EUT interferes with radio services. A measure for this interference potential of the EUT is the electric field strength emitted by the EUT. Because the EUT final-use set-up in general is unknown or is variable, it is necessary to search for the maximum field strength in all directions from the EUT and for all polarisations. Therefore the reference quantity is selected to be the maximum far-field electric field-strength emitted under free space conditions, independent of direction or polarisation. At a distance from the EUT of d_{ref} = 10 m and for the frequency range and EUT sizes considered here, far-field conditions can be assumed. Figure B.1 displays this scheme for defining the reference quantity. It is noted that in reality it is difficult or nearly impossible to perform such measurements, but this set-up and reference quantity is very amenable to numerical simulations. This reference quantity definition is applicable in the frequency range of 30 MHz to 1 GHz.

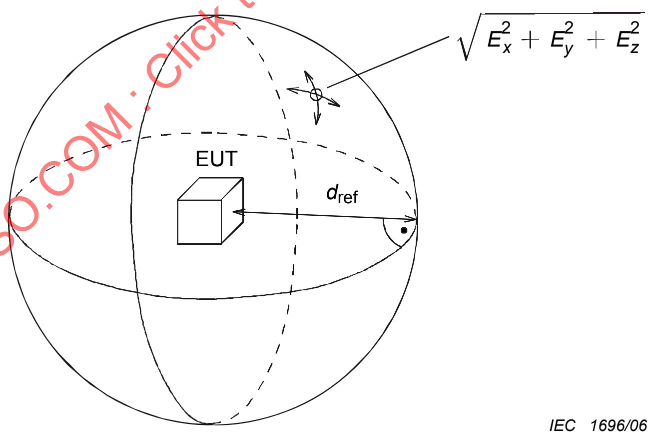


Figure B.1 – Example reference quantity

B.1.1.2 Describe the test methods and measurands (see 6.3)

Alternative test method – 3 m fully anechoic room (FAR): Figure B.2 shows the EUT and antenna set-up for a fully anechoic room measurement for frequencies of 30 MHz to 1 GHz. The receiving antenna is located at a distance d_{far} = 3 m from the EUT. The antenna is positioned at a fixed height corresponding to the vertical centre of the EUT. To detect the maximum field strength, the EUT is rotated in azimuth in the horizontal plane, and both horizontal and vertical polarisations of radiated field are measured. The FAR is a shielded enclosure with absorbing material on the walls, ceiling, and floor. Therefore, ideally the antenna receives only the direct emission radiated from the EUT.

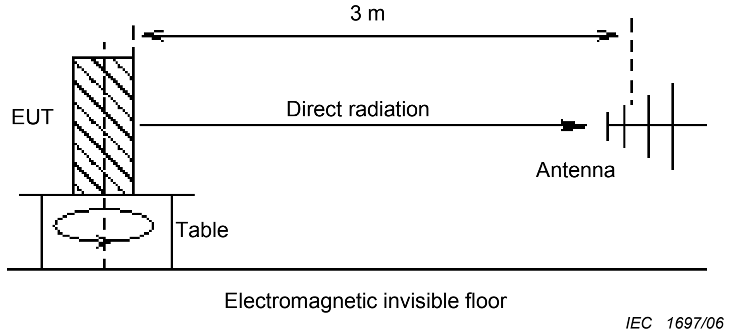


Figure B.2 – EUT and antenna set-up for fully anechoic room emission measurement

Established test method – 10 m open-area test site (OATS): Figure B.3 displays the measurement set-up for an open-area test site for the frequency range of 30 MHz to 1 GHz. The receiving antenna is located at a distance d_{oats} = 10 m to the EUT. To detect the maximum field strength, the EUT is rotated, and the antenna height is varied between 1 m and 4 m. The set-up is placed on a conducting ground plane. The perimeter and surroundings of the OATS and set-up is free of any reflecting objects, therefore ideally the antenna receives only the direct radiation and the ground reflected signal.

Semi-anechoic rooms that meet the CISPR normalized site attenuation (NSA) site-validation criteria can be used to perform compliance tests, and therefore semi-anechoic room could be selected as the established test method instead. The example results shown below remain applicable in this case, because the estimation of the inherent uncertainty assumes conditions of an ideal test site. Considered ideally, a semi-anechoic room and an open-area test site would both ideally provide free-field reflection-free (except ground) conditions.

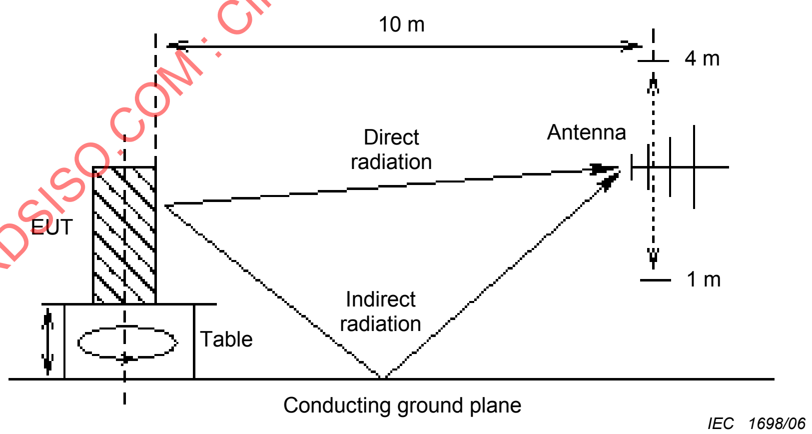


Figure B.3 – EUT and antenna set-up for open-area test site measurement

B.1.1.3 Determine the deviations of the measured quantities from the reference quantity (see 6.4)

The results of the measurement depend strongly on the radiation characteristics of the EUT. Therefore an investigation on the characteristics of the different measurement set-ups must include a wide range of differently radiating EUTs. In the following a statistical model for tabletop EUTs without external cables is used.

In general, any EUT radiation pattern can be approximated by superposing the radiated fields from elementary radiators, such as electrically-short dipoles. Therefore, a quantity of electrically-short dipoles with varying characteristics (direction of axis, amplitude, phase shift, position) will generate statistically different radiation patterns. An example arrangement is shown in Figure B.4. Specifically, the EUT model used here is based on the following concepts: a certain number of dipoles are located inside a certain volume, and their positions, directions and excitations are varied statistically to generate a statistical distribution of radiation characteristics. This statistical EUT model is one practical and reasonable approach among others to simulate tabletop equipment.

Four different virtual-EUT volumes [(30 cm)^3, (60 cm)^3, (90 cm)^3, (120 cm)^3] were simulated to investigate the effect of different EUT models on the resulting emissions. These volumes can be considered to represent the maximum volumes of typical tabletop EUTs. The number of elementary radiators applicable to represent real-world EUT characteristics is indeterminable, thus the ideal number of radiators to be located in the chosen volumes is unknown. Therefore, effects for varying numbers of elementary radiators is investigated. Effects expected from a variation of the numbers of radiators are as follows:

- for one radiator, the behaviour of a dipole is modelled;
- an increasing number of radiators leads to increasingly complex radiation patterns;
- an infinite number of radiators will behave like one equivalent dipole.

Simulations done for 1, 2, 5, 10, 30, and 50 radiators mainly show the following three characteristics:

- the results for 1 or 2 radiators produces the worst-case results only for some frequencies;
- the results for 10, 30, or 50 are the worst case for nearly the entire frequency range;
- the differences between the results for 10, 30, and 50 radiators are very small, for example compared to the differences between the results for 10 and 2 radiators.

From these observations it can be concluded that simulations with more than 50 radiators probably will not give different results. Therefore the results of the carried out simulations are taken in order to get a safe approximation of the worst case.

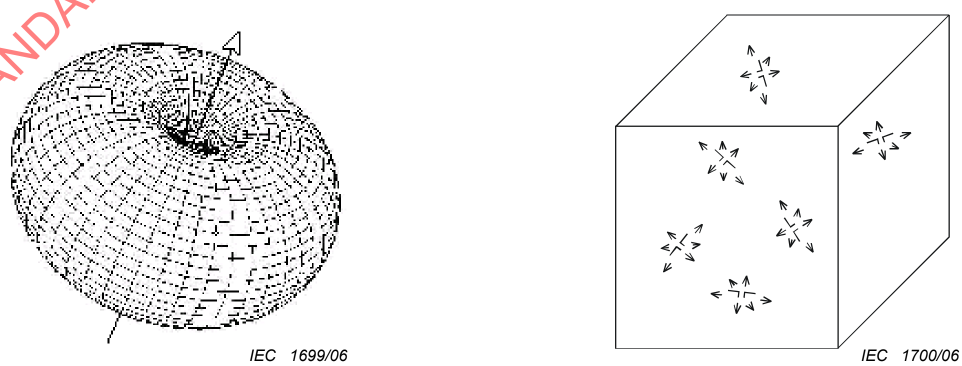


Figure B.4 – Radiation characteristics of elementary radiator (left), and scheme of EUT-model (right)

For each pair of volume and number of radiators, a set of N = 1 000 individual EUTs are generated.

NOTE 1 In general, the number of individual EUTs should be as large as possible. On the other hand, the simulation time has to be finite. A number of 1 000 individual EUTs is deemed to be a reasonable compromise: Based on nonparametric statistics theory, a number of 1 000 individuals enables a confidence level of 99,9% for the estimations of the bounds of interval holding 95% of the simulated values. These bounds are important values to estimate the standard deviation and thus the inherent uncertainty. For more details, see [2] or Chapter 3 of [1].

For each EUT i of such a set, e.g. of the set belonging to a volume of (30 cm)^3 with 5 radiators, the reference quantity X_i and the field strengths $E_{\mathrm{FAR(3m)}i}$ for FAR and $E_{\mathrm{OATS(10m)}i}$ for OATS are calculated, which are equivalent to measured field strength values.

NOTE 2 Because the statistical EUT model yields individual EUTs with larger horizontal or larger vertical field components, the calculated field strengths are determined the same way as in real-world measurements: The maximum value is taken, independent from its polarisation. As a consequence, the polarisation of the field strength values varies statistically, and the derived conversion covers both horizontal and vertical polarisations.

From these results, the deviations for the alternative test method from 6.4, Equation (1),

$$D_{\mathrm{ATM}i} = D_{\mathrm{FAR(3m)}i} = X_i - E_{\mathrm{FAR(3m)}i} \quad \text{(B.1)}$$

where

$E_{\mathrm{FAR(3m)}i}$ is the field-strength for 3 m FAR test method for EUT i,

X_i, $D_{\mathrm{ATM}i}$, i are the same as in 6.4 Equation (1),

$D_{\mathrm{FAR(3m)}i}$ is the deviation from the reference quantity X of the 3 m FAR test method result for EUT i,

and for the established test method according to 6.4, Equation (2),

$$D_{\mathrm{ETM}i} = D_{\mathrm{OATS(10m)}i} = X_i - E_{\mathrm{OATS(10m)}i} \quad \text{(B.2)}$$

where

$E_{\mathrm{OATS(10m)}i}$ is the field-strength for 10 m OATS test method for EUT i,

X_i, $D_{\mathrm{ETM}i}$, i are the same as in 6.4 Equation (2),

$D_{\mathrm{OATS(10m)}i}$ is the deviation from the reference quantity X of the 10 m OATS test method result for EUT i,

are calculated.

B.1.1.4 Determine the average values of the deviations (see 6.5)

For both alternative and established test methods, the average deviations can be calculated using Equation (3) and Equation (4) from 6.5, respectively. This is done for every set of 1 000 EUTs:

$$\overline{D}_{\mathrm{ATM}} = \overline{D}_{\mathrm{set,\,FAR(3m)}} = \frac{1}{1000}\sum_{i=1}^{1000} D_{\mathrm{FAR(3m)}\,i} \quad \text{(B.3)}$$

$$\overline{D}_{\mathrm{ETM}} = \overline{D}_{\mathrm{set,\,OATS(10m)}} = \frac{1}{1000}\sum_{i=1}^{1000} D_{\mathrm{OATS(10m)}\,i} \quad \text{(B.4)}$$

where

$\overline{D}_{\text{set, ATM}}$ is the average deviation of the alternative test method for the set of 1 000 EUTs;

$\overline{D}_{\text{set, ETM}}$ is the average deviation of the established test method for the set of 1 000 EUTs;

$\overline{D}_{\text{set, FAR(3m)}}$ is the average deviation of the 3 m FAR test method for the set of 1 000 EUTs;

$\overline{D}_{\text{set, OATS(10m)}}$ is the average deviation of the 10 m OATS test method for the set of 1 000 EUTs;

$D_{\text{FAR(3m)}i}$, $D_{\text{OATS(10m)}i}$, i are the same as in Equations (B.1) and (B.2), respectively.

In order to estimate the worst-case emissions, for each volume the maximum average deviation for both test methods is determined using

$$\overline{D}_{\text{max vol, FAR(3m)}} = \max_{\text{number of radiators}} \overline{D}_{\text{set, FAR(3m)}}; \quad \overline{D}_{\text{max vol, OATS(10m)}} = \max_{\text{number of radiators}} \overline{D}_{\text{set, OATS(10m)}} \qquad \text{(B.5)}$$

where

$\overline{D}_{\text{set, FAR(3m)}}$ is the same as in Equation (B.3);

$\overline{D}_{\text{set, OATS(10m)}}$ is the same as in Equation (B.4);

$\overline{D}_{\text{max vol, FAR(3m)}}$ is the maximum average deviation of the 3 m FAR test method for one assumed EUT volume;

$\overline{D}_{\text{max vol, OATS(10m)}}$ is the maximum average deviation of the 10 m OATS test method for one assumed EUT volume.

The example maximum deviations are displayed in Figure B.5.

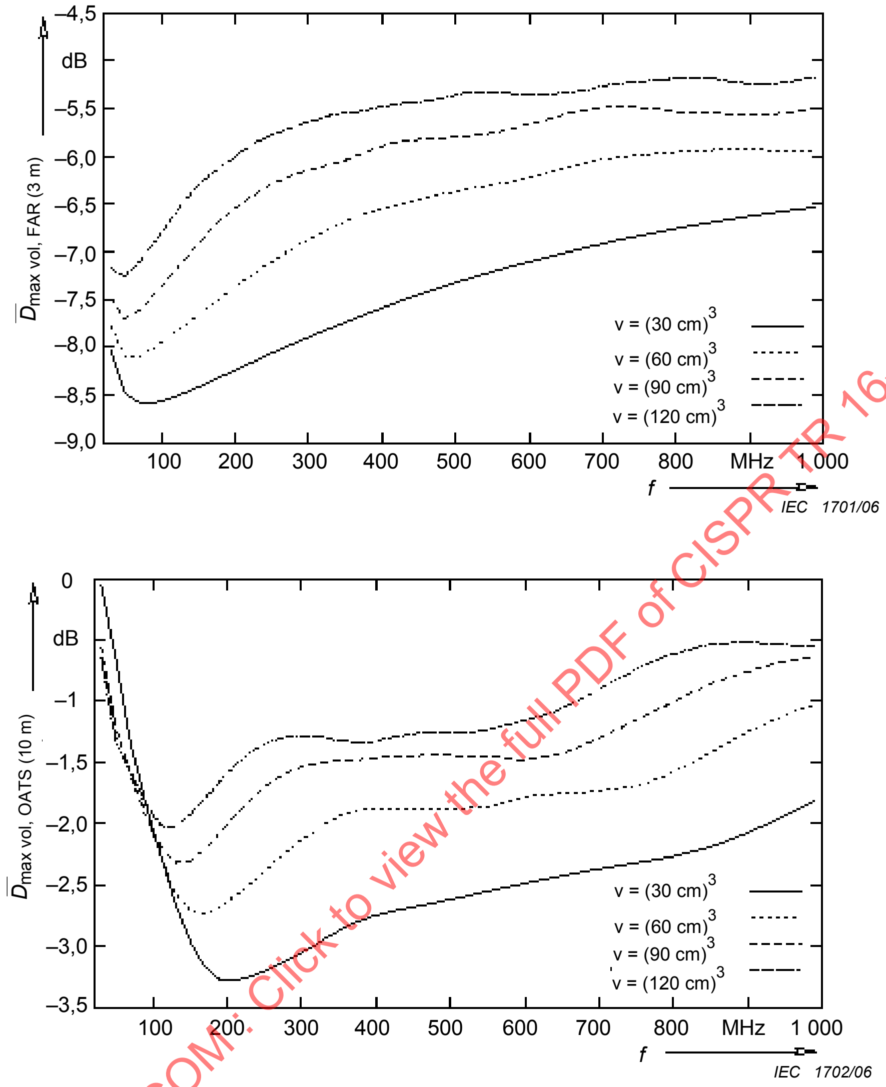


Figure B.5 – Maximum average deviations for 3 m FAR (top) and 10 m OATS (bottom)

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

Instrumentation uncertainty: For the alternative test method (3 m FAR), the instrumentation uncertainty has 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 can be used [4]. The other numeric values are taken from CISPR 16-4-2:2003, because these are 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 16-4-2:2003.

Table B.1 – Instrumentation uncertainty of the 3 m fully anechoic chamber test method

Input quantity	X_i	Uncertainty of x_i		$u(x_i)$	c_i	$c_i \cdot u(x_i)$
		dB	Probability distribution function	dB		dB
Receiver reading	V_r	±0,1	k = 1	0,10	1	0,10
Attenuation: antenna-receiver	L_c	±0,1	k = 2	0,05	1	0,05
Biconical antenna factor	AF	±2,0	k = 2	1,0	1	1,0
Receiver corrections:						
Sine wave voltage	δVsw	±1,0	k = 2	0,50	1	0,50
Pulse amplitude response	δVpa	±1,5	Rectangular	0,87	1	0,87
Pulse repetition rate response	δVpr	±1,5	Rectangular	0,87	1	0,87
Noise floor proximity	δVnf	±0,5	k = 2	0,25	1	0,25
Mismatch: antenna-receiver	δM	+0,9 / -1,0	U-shaped	0,67	1	0,67
Biconical antenna corrections:						
AF frequency interpolation	δAF_f	±0,3	Rectangular	0,17	1	0,17
AF height deviations	δAF_h	±0,0		0,00	1	0,00
Directivity difference	$\delta A_{dir,h}$	±0,0		0,00	1	0,00
Phase center location	δAph	±0,0		0,00	1	0,0
Cross-polarisation	δAcp	±0,0		0,00	1	0,0
Balance (hor.)	$\delta Abal$	±0,3	Rectangular	0,17	1	0,17
Balance (ver.)	$\delta A_{bal,v}$	±0,9	Rectangular	0,52	1	0,52
Log-periodic antenna corrections:						
AF frequency interpolation	δAF_f	±0,3	Rectangular	0,17	1	0,17
AF height deviations	δAF_h	±0,0		0,00	1	0,00
Directivity difference	$\delta A_{dir,h}$	+0,2 / -0,0	Rectangular	0,05	1	0,05
Phase center location	δAph	±0,5	Rectangular	0,29	1	0,29
Cross-polarisation	δAcp	±0,9	Rectangular	0,52	1	0,52
Balance	$\delta Abal$	±0,0		0,00	1	0,00
Site corrections:						
Site imperfections	δSA	±4,0	Triangular	1,63	1	1,63
Separation distance at 3 m	δd	±0,3	Rectangular	0,17	1	0,17
Table height at 3 m	δh	±0,1	k = 2	0,05	1	0,05

Intrinsic uncertainty: Numeric values for intrinsic uncertainties are still under consideration in CISPR 16-4-1:2003; therefore this uncertainty contribution is not included in this example.

Uncertainty due to unknown EUT characteristics: The standard inherent uncertainty u_{inherent} can be calculated for alternative and established test methods using Equation (5) and Equation (6) from 6.6, respectively. Because the cumulative distribution functions of the deviations have strong asymmetric shapes, the straightforward application of the equations would yield a estimate of the uncertainty that is too low. The sample cumulative distribution function (CDF) in Figure B.6 illustrates this underestimation. If the CDF were symmetric, the interval $\left[\overline{D}_{\text{ETM}}; k_{\text{ETM}} \cdot s(D_{\text{ETM}})\right]$ would cover the upper half of the 95 % interval.

As can be seen from the figure, this is not true – actually $k_{\mathrm{ETM}} \cdot s(D_{\mathrm{ETM}})$ underestimates the upper bound of the 95% interval. To avoid this, the standard deviation, s_+, is introduced, which is calculated using only values larger than the average.

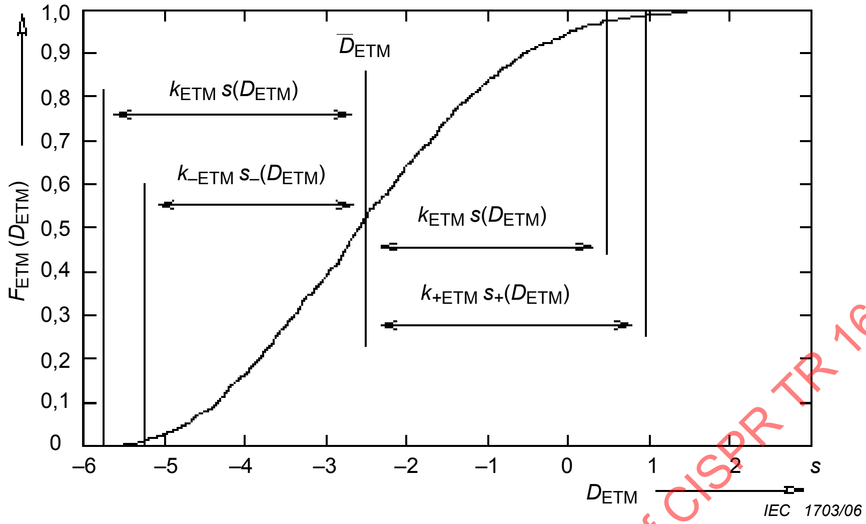


Figure B.6 – Sample cumulative distribution function

The number of these values is denoted N_+, and the approximated standard deviation is denoted s_+. The index of a given EUT i = 1…N is mapped to a new index $j = 1 \ldots N_+$. The standard deviation is calculated for every set of EUTs using

$$s_{+\mathrm{set}}(D_{\mathrm{FAR(3m)}}) = \sqrt{\frac{\sum_{i=1}^{N_+}(D_{\mathrm{FAR(3m)}\,j} - \overline{D}_{\mathrm{set,\,FAR(3m)}})^2}{N_+ - 1}} \qquad \text{(B.6)}$$

where

$D_{\mathrm{FAR(3m)}\,i}$, $\overline{D}_{\mathrm{set,\,FAR(3m)}}$ are the same as in Equation (B.3);

N_+ is the number of values larger than the average value;

$s_{+\mathrm{set}}(D_{\mathrm{FAR(3m)}})$ is the one-side standard deviation of the deviations for one set of 1 000 EUTs of the 3 m FAR test method,

and

$$s_{+\mathrm{set}}(D_{\mathrm{OATS(10m)}}) = \sqrt{\frac{\sum_{i=1}^{N_+}(D_{\mathrm{OATS(10m)}\,j} - \overline{D}_{\mathrm{set,\,OATS(10m)}})^2}{N_+ - 1}} \qquad \text{(B.7)}$$

where

$D_{\mathrm{OATS(10m)}\,i}$, $\overline{D}_{\mathrm{set,\,OATS(10m)}}$ are the same as in Equation (B.4);

N_+ is the number of values larger than the average value;

$s_{+\mathrm{set}}(D_{\mathrm{OATS(10m)}})$ is the one-side standard deviation of the deviations for one set of 1 000 EUTs of the 10 m OATS test method.

This approach gives a worst-case estimation; more precise results can be obtained by considering the skew of the CDF.

As done for the average deviations, from the approximated standard deviations of the deviations for each volume, the maximum value is determined. This maximum is taken as a safe approximation of the uncertainty.

$$u_{\mathrm{ATM,inherent}} = u_{\mathrm{FAR(3m),inherent}} \approx s_{\mathrm{+max,vol}}(D_{\mathrm{FAR(3m)}}) = \max_{\text{number of radiators}} s_{\mathrm{+set}}(D_{\mathrm{FAR(3m)}}) \qquad \text{(B.8)}$$

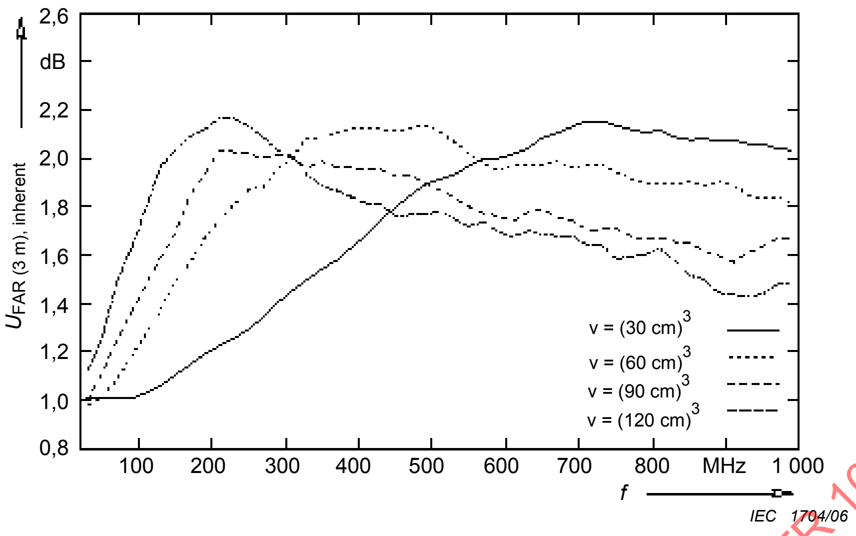
$$u_{\mathrm{ETM,inherent}} = u_{\mathrm{OATS(10m),inherent}} \approx s_{\mathrm{+max,vol}}(D_{\mathrm{OATS(10m)}}) = \max_{\text{number of radiators}} s_{\mathrm{+set}}(D_{\mathrm{OATS(10m)}}) \qquad \text{(B.9)}$$

where

$s_{\mathrm{+set}}(D_{\mathrm{FAR(3m)}})$	is the same as in Equation (B.6);
$s_{\mathrm{+set}}(D_{\mathrm{OATS(10m)}})$	is the same as in Equation (B.7);
$s_{\mathrm{+max,vol}}(D_{\mathrm{FAR(3m)}})$	is the maximum approximated standard deviation of the deviations of the 3 m FAR test method for one assumed EUT volume;
$s_{\mathrm{+max,vol}}(D_{\mathrm{OATS(10m)}})$	is the maximum approximated standard deviation of the deviations of the 10 m OATS test method for one assumed EUT volume;
$u_{\mathrm{FAR(3m),inherent}}$	is the inherent uncertainty of the 3 m FAR test method;
$u_{\mathrm{ATM,inherent}}$	is given in Table 2;
$u_{\mathrm{OATS(10m),inherent}}$	is the inherent uncertainty of the 10 m OATS test method;
$u_{\mathrm{ETM,inherent}}$	is given in Table 2.

The values are displayed in Figure B.7 and are given numerically in Tables B.2 and B.3.

NOTE It should be noted, that the large uncertainty of the OATS test method results from the fact, that the values include both horizontal and vertical polarisation. Smaller uncertainties could be obtained if the polarisations are considered separately. Such a consideration needs a sophisticated rule, in which case conversion factors for horizontal, vertical or both polarisations can be applied.



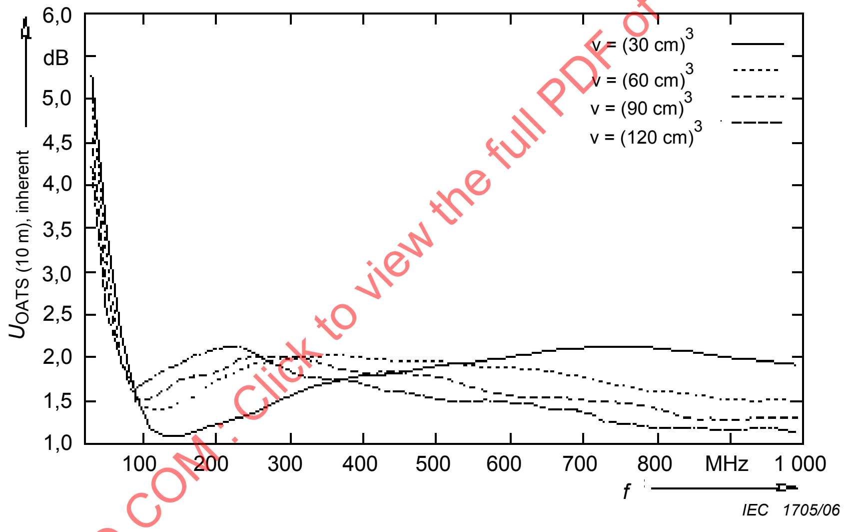


Figure B.7 – Uncertainties due to the unknown EUT characteristic for 3 m FAR (top) and 10 m OATS (bottom)

From the set of calculated deviations, and from the standard deviations, a 95 % tolerance interval for both test methods can be determined. Using their widths and the standard deviations, the coverage factor k can be approximated. For the alternative test method the factor is

$$k_{\text{ATM}} = k_{+\text{FAR(3m)}} \approx 2{,}2 \qquad \text{(B.10)}$$

where

k_{ATM} is the coverage factor for the alternative test method;

$k_{+\text{FAR(3m)}}$ is the coverage factor for the 3 m FAR test method derived from the values larger than the average;

and for the established test method it is

$$k_{ETM} = k_{+OATS(10m)} \approx 2{,}2 \qquad \text{(B.11)}$$

where

k_{ETM} is the coverage factor for the established test method;

$k_{+OATS(10m)}$ is the coverage factor for the 10 m OATS test method derived from the values larger than the average.

Again only the values larger than the average are used.

Table B.2 – Uncertainties in dB due to the unknown EUT characteristic for 3 m FAR

Frequency MHz	v = (30 cm)^3	v = (60 cm)^3	v = (90 cm)^3	v = (120 cm)^3
30	1,00	0,97	0,99	1,12
50	1,00	1,01	1,11	1,25
70	1,00	1,08	1,24	1,48
90	1,00	1,17	1,36	1,62
110	1,02	1,27	1,47	1,79
130	1,06	1,37	1,58	1,96
150	1,10	1,48	1,69	2,03
170	1,14	1,56	1,84	2,08
190	1,19	1,66	1,93	2,12
210	1,22	1,74	2,03	2,16
230	1,25	1,80	2,02	2,16
250	1,29	1,86	2,01	2,12
270	1,34	1,88	2,00	2,08
290	1,40	1,95	2,01	2,03
310	1,45	2,00	2,00	2,00
330	1,49	2,08	1,96	1,93
350	1,54	2,08	1,98	1,88
370	1,57	2,10	1,96	1,86
390	1,63	2,12	1,95	1,83
410	1,68	2,12	1,95	1,81
430	1,74	2,11	1,95	1,80
450	1,79	2,11	1,92	1,76
470	1,84	2,12	1,93	1,76
490	1,88	2,13	1,89	1,76
510	1,91	2,11	1,86	1,77
530	1,93	2,06	1,83	1,74
550	1,96	2,02	1,79	1,71
570	1,99	1,98	1,77	1,73
590	1,99	1,94	1,76	1,69
610	2,01	1,97	1,73	1,67
630	2,03	1,97	1,77	1,69
650	2,08	1,97	1,78	1,68
670	2,10	1,98	1,75	1,67
690	2,12	1,96	1,74	1,68
710	2,15	1,97	1,70	1,64
730	2,15	1,97	1,70	1,64
750	2,13	1,94	1,71	1,58
770	2,11	1,91	1,67	1,59
790	2,10	1,89	1,66	1,60
810	2,11	1,89	1,67	1,62
830	2,08	1,89	1,65	1,57
850	2,07	1,90	1,65	1,52
870	2,07	1,88	1,61	1,49
890	2,07	1,90	1,59	1,44
910	2,07	1,88	1,56	1,43
930	2,05	1,84	1,60	1,42
950	2,05	1,83	1,63	1,43
970	2,03	1,84	1,66	1,47
990	2,03	1,81	1,67	1,48

Table B.3 – Uncertainties in dB due to the unknown EUT characteristic for 10 m OATS

Frequency MHz	v = (30 cm)^3	v = (60 cm)^3	v = (90 cm)^3	v = (120 cm)^3
30	5,27	4,55	4,55	4,20
50	3,48	2,84	2,84	2,54
70	2,28	1,96	1,96	1,95
90	1,55	1,49	1,49	1,64
110	1,17	1,52	1,52	1,74
130	1,08	1,62	1,62	1,86
150	1,07	1,74	1,74	1,92
170	1,13	1,78	1,78	2,01
190	1,20	1,80	1,80	2,06
210	1,24	1,86	1,86	2,11
230	1,29	1,97	1,97	2,11
250	1,35	2,00	2,00	2,05
270	1,43	2,00	2,00	1,95
290	1,51	2,01	2,01	1,89
310	1,58	2,01	2,01	1,79
330	1,65	1,96	1,96	1,76
350	1,69	1,91	1,91	1,75
370	1,73	1,85	1,85	1,74
390	1,77	1,83	1,83	1,71
410	1,79	1,81	1,81	1,67
430	1,80	1,84	1,84	1,61
450	1,81	1,83	1,83	1,60
470	1,85	1,79	1,79	1,57
490	1,88	1,79	1,79	1,53
510	1,91	1,75	1,75	1,50
530	1,93	1,70	1,70	1,48
550	1,94	1,64	1,64	1,49
570	1,97	1,60	1,60	1,50
590	1,98	1,56	1,56	1,48
610	2,01	1,53	1,53	1,46
630	2,04	1,53	1,53	1,45
650	2,07	1,52	1,52	1,40
670	2,09	1,53	1,53	1,38
690	2,10	1,50	1,50	1,38
710	2,11	1,49	1,49	1,33
730	2,12	1,48	1,48	1,25
750	2,12	1,47	1,47	1,23
770	2,12	1,45	1,45	1,22
790	2,11	1,41	1,41	1,19
810	2,09	1,37	1,37	1,17
830	2,07	1,31	1,31	1,18
850	2,06	1,28	1,28	1,18
870	2,02	1,29	1,29	1,17
890	2,01	1,27	1,27	1,15
910	1,97	1,27	1,27	1,15
930	1,97	1,29	1,29	1,17
950	1,95	1,30	1,30	1,19
970	1,93	1,30	1,30	1,15
990	1,91	1,29	1,29	1,13

B.1.1.6 Estimate the expanded uncertainties of the test methods (see 6.7)

The instrumentation uncertainties and the uncertainties due to the EUT characteristics are combined into one standard uncertainty using Equations (7) and (9) from 6.7. The differences of the instrumentation uncertainty for different frequency ranges and polarisations are negligible, so that one uncertainty for all cases is sufficient. The combined and the expanded uncertainties are not given here numerically, because the EUT-dependent uncertainty is frequency-dependent. Figure B.14 displays the expanded uncertainties for the alternative and established test methods for a coverage factor of k = 2.

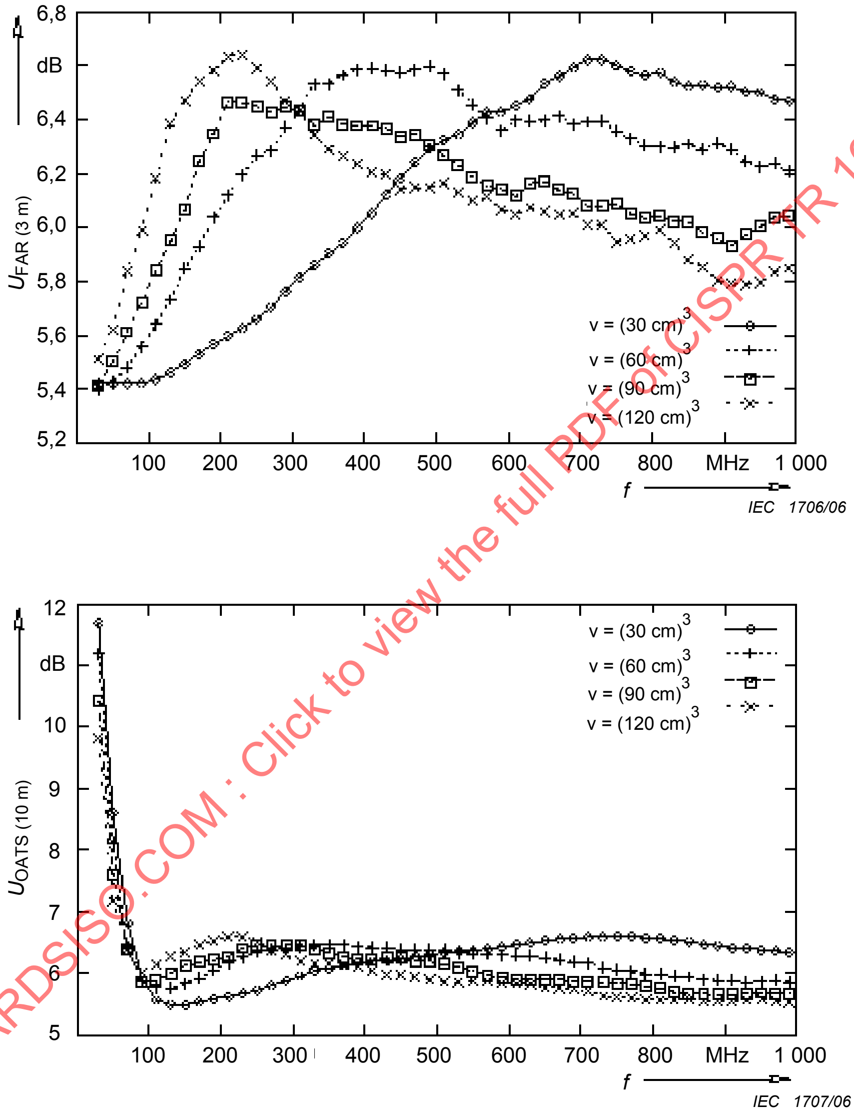


Figure B.8 – Expanded uncertainties (k = 2) of alternative (3 m FAR, top) and established (10 m OATS, bottom) test methods

B.1.1.7 Calculate the average conversion factor (see 6.8)

Using 6.8 Equation (14), the average conversion factor can be calculated from the measurement results of the EUTs. For each set of EUTs the average conversion factors are given by

$$\overline{K}_{\text{set}} = \frac{1}{N}\sum_{i=1}^{N}(E_{\text{OATS(10m)}i} - E_{\text{FAR(3m)}i}) \qquad \text{(B.12)}$$

where

N, i are given in Table 2;

$E_{FAR(3m)i}$ is the same as in Equation (B.1);

$E_{OATS(10m)i}$ is the same as in Equation (B.2);

$\overline{K}_{set}$ is the average conversion factor for a set of EUTs.

From this the maximum values for each volume are searched,

$$\overline{K}_{max,\,vol} = \max_{\text{numbers of radiators}} \overline{K}_{set} \quad \text{(B.13)}$$

where

$\overline{K}_{set}$ is the same as in Equation (B.12);

$\overline{K}_{max,\,vol}$ is the maximum average conversion factor for one assumed EUT volume.

These values are displayed in Figure B.9, and numerical values are given in Table B.4.

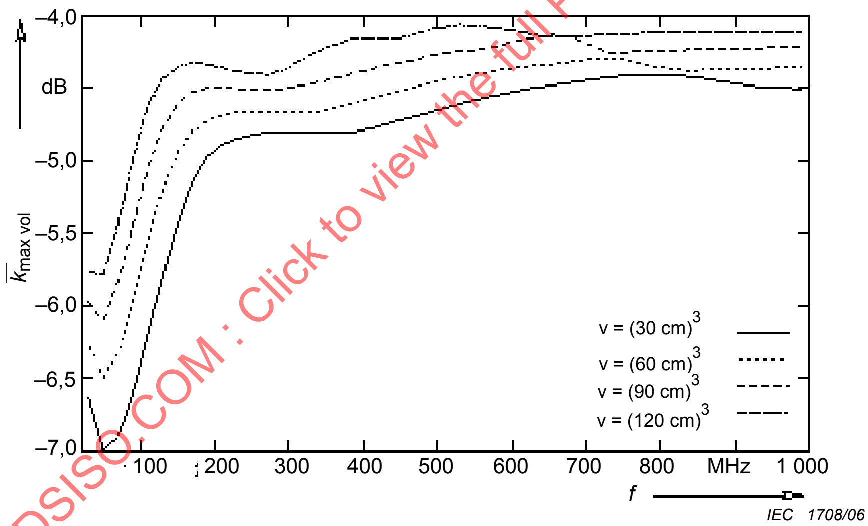


Figure B.9 – Maximum average conversion factors for different volumes

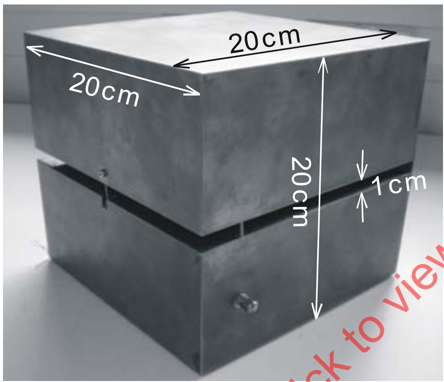
Table B.4 – Maximum average conversion factors in dB between 10 m OATS and 3 m FAR

Frequency in MHz	*v* = (30 cm)^3	*v* = (60 cm)^3	*v* = (90 cm)^3	*v* = (120 cm)^3
30	–6,63	–6,26	–5,97	–5,76
50	–6,99	–6,48	–6,10	–5,78
70	–6,90	–6,31	–5,83	–5,43
90	–6,59	–5,96	–5,44	–4,98
110	–6,20	–5,56	–5,05	–4,62
130	–5,80	–5,20	–4,77	–4,43
150	–5,43	–4,94	–4,61	–4,35
170	–5,14	–4,80	–4,52	–4,32
190	–4,97	–4,73	–4,50	–4,34
210	–4,88	–4,68	–4,49	–4,36
230	–4,85	–4,67	–4,51	–4,38
250	–4,82	–4,66	–4,51	–4,40
270	–4,80	–4,66	–4,51	–4,41
290	–4,80	–4,67	–4,50	–4,38
310	–4,80	–4,67	–4,49	–4,32
330	–4,81	–4,67	–4,47	–4,26
350	–4,81	–4,65	–4,44	–4,22
370	–4,81	–4,63	–4,42	–4,19
390	–4,80	–4,60	–4,39	–4,15
410	–4,77	–4,57	–4,36	–4,16
430	–4,75	–4,54	–4,34	–4,15
450	–4,72	–4,51	–4,33	–4,15
470	–4,69	–4,49	–4,30	–4,12
490	–4,67	–4,46	–4,28	–4,10
510	–4,63	–4,44	–4,25	–4,08
530	–4,61	–4,42	–4,24	–4,06
550	–4,58	–4,40	–4,24	–4,07
570	–4,56	–4,39	–4,22	–4,08
590	–4,54	–4,37	–4,19	–4,09
610	–4,52	–4,36	–4,17	–4,11
630	–4,50	–4,34	–4,15	–4,13
650	–4,48	–4,33	–4,13	–4,15
670	–4,47	–4,33	–4,14	–4,14
690	–4,45	–4,31	–4,17	–4,14
710	–4,44	–4,30	–4,21	–4,13
730	–4,42	–4,29	–4,25	–4,13
750	–4,41	–4,30	–4,25	–4,13
770	–4,41	–4,32	–4,25	–4,12
790	–4,40	–4,35	–4,24	–4,12
810	–4,41	–4,36	–4,24	–4,11
830	–4,41	–4,38	–4,23	–4,11
850	–4,43	–4,38	–4,23	–4,11
870	–4,44	–4,37	–4,23	–4,11
890	–4,46	–4,37	–4,23	–4,11
910	–4,47	–4,37	–4,23	–4,11
930	–4,49	–4,36	–4,22	–4,11
950	–4,50	–4,36	–4,22	–4,12
970	–4,50	–4,36	–4,22	–4,12
990	–4,50	–4,36	–4,22	–4,12

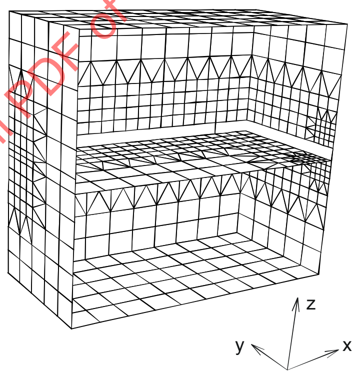
B.1.1.8 Verify the calculated values (see 6.9)

The numerical values presented above are from simulations with the statistical EUT model; thus a verification of these theoretical values is necessary. Since it is impossible in a reasonable time to produce the same large number of measurement results as was used for the statistical simulations, at least a certain number of measurements should be done to support the calculated results.

The results are derived in terms of deviations from the reference quantity. For even a single EUT only, it is almost impossible to measure this selected reference quantity over the full surrounding sphere. Due to these limitations, a special-purpose generic EUT is used for measurements to verify the theoretical results. The radiation characteristics for this EUT, and hence the reference quantity as well as the measurement results, can be calculated. The latter is important for the identification and evaluation of any possible unexpected measurement results. The EUT is constructed as a cube with a 0,2 m side length. To represent real-world EUT radiation effects, the cube has a slot, which is excited by a comb generator with an emissions frequency spacing of 10 MHz. Figure B.10 shows a picture and the simulation model (cut-view) of the specimen EUT.



IEC 1709/06

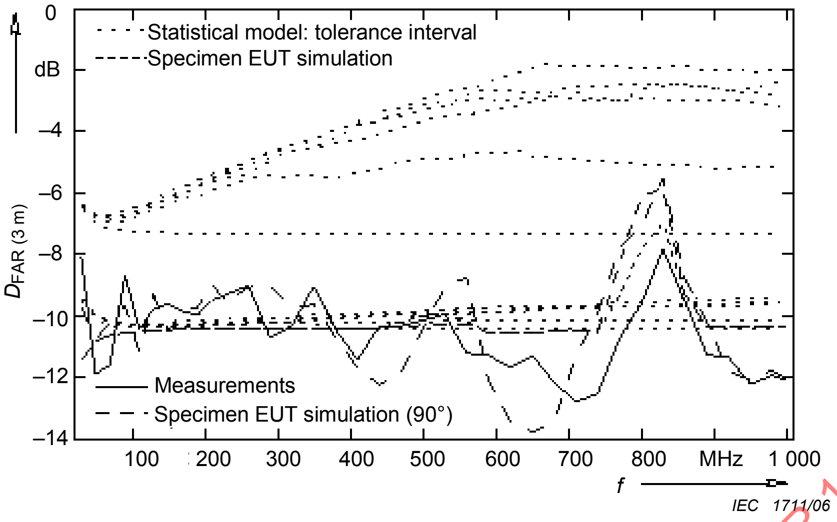


IEC 1710/06

Figure B.10 – Photo (left) and cut-view of simulation model (right) of the specimen EUT

The measurements were performed for two different orientations of the specimen EUT: one measurement series with the orientation shown in Figure B.10, and the other measurement series with the EUT rotated by 90° around the *x*-axis.

Figure B.11 shows the deviations from the reference quantity for the results of alternative and established test method. The statistical EUT model with $v = (30\ \text{cm})^3$ is chosen for comparison with the values of the specimen EUT. For each number of radiators, a 95% tolerance interval is shown (dotted lines). For the specimen EUT, the measured as well as the calculated deviations from the calculated reference quantity are shown, for both orientations of the EUT. Except for one data point, the measured values deviate from the tolerance interval by up to 3,5 dB. This deviation is smaller than the instrumentation measurement uncertainty given in CISPR 16-4-2. One measured value (OATS measurement with rotated EUT at 120 MHz) deviates by 8,5 dB from the tolerance interval. These deviations were not seen in the results from the simulations with the specimen EUT. Consequently, these deviations are expected to be due to measurement problems. Then it can be said that the measured results for the specimen EUT support the statistically-derived deviations from the reference quantity, and hence the derived conversion factors and the uncertainties.



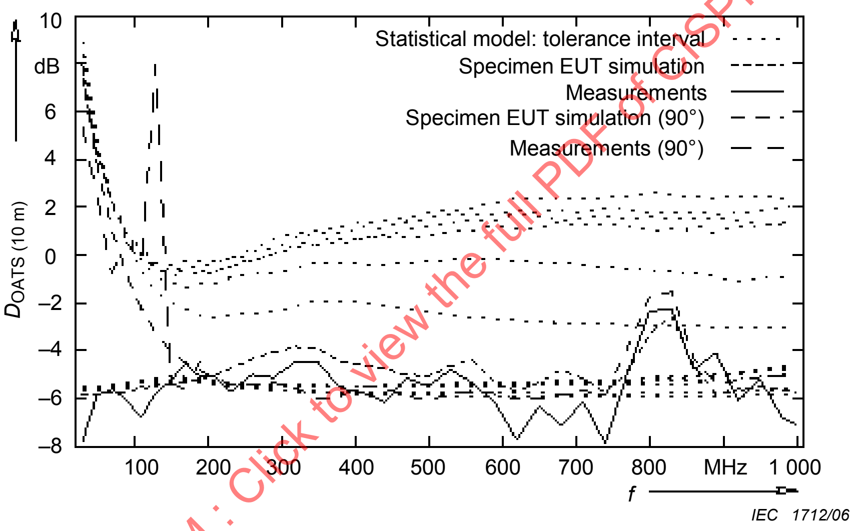


Figure B.11 – Deviations of the specimen EUT: 3 m fully anechoic room (top) and 10 m open area test site (bottom)

B.1.1.9 Apply the conversion (see 6.10)

Figure B.12 shows a sample of measured values with their expanded uncertainties from a FAR emission measurement, for an EUT with maximum cube-edge dimension of 0,3 m. The converted limits according to 6.10 Equation (15) are shown in Figure B.13. Based on the largest dimension of the EUT, the average conversion factors for (30 cm)^3 are applied (see Figure B.9). The comparison of the measured values with the converted limits must consider the differences between the uncertainties of the alternative and established test methods. Figure B.14 displays the expanded uncertainties of 10 m OATS and 3 m FAR for the (30 cm)^3 EUT volume. As can be seen, the uncertainty of the FAR is at some frequencies about 0,1 dB larger than the uncertainty of the OATS. At these frequencies the converted limit has to be corrected with the amount of the difference according to 6.10 Equation (17). The measured values then can be compared with the corrected and converted limit line, as shown in Figure B.15. The EUT fails due to the emission values at 150 MHz and 550 MHz.

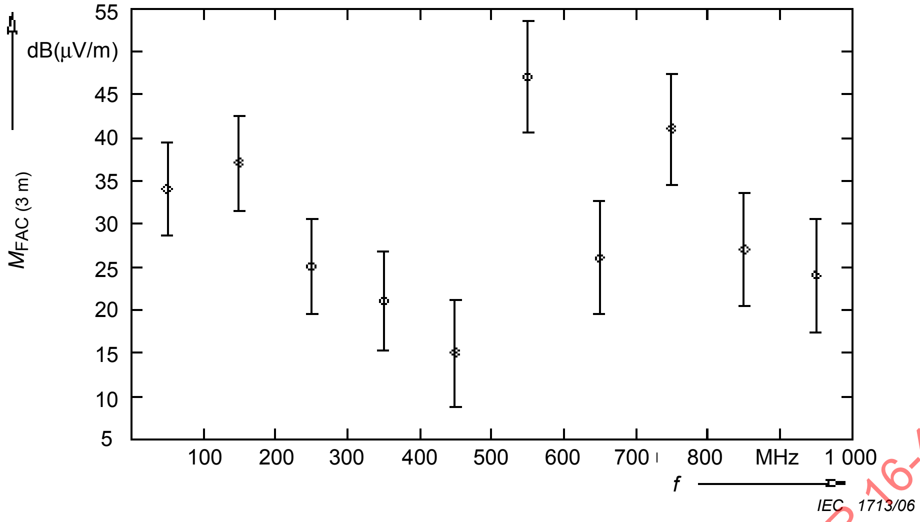


Figure B.12 – Sample FAR measurement

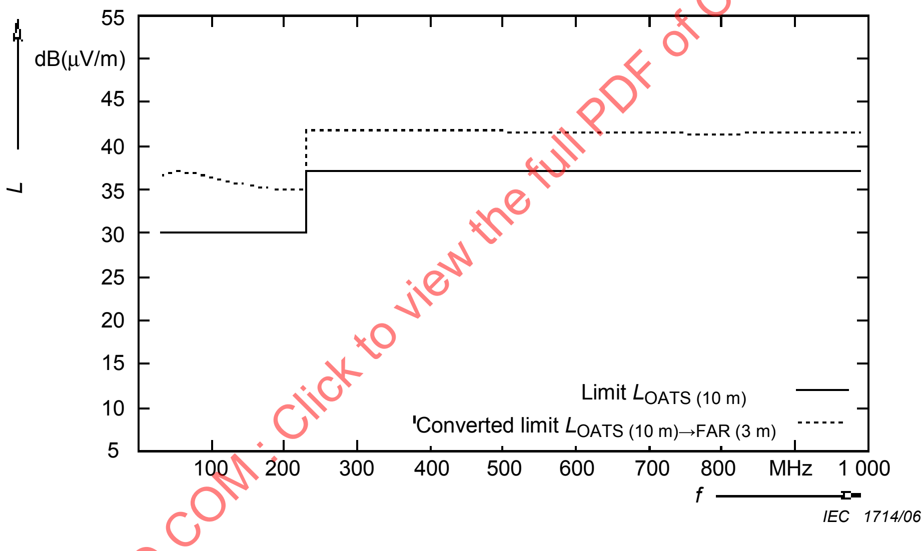


Figure B.13 – OATS 10 m limit line converted to FAR 3 m conditions

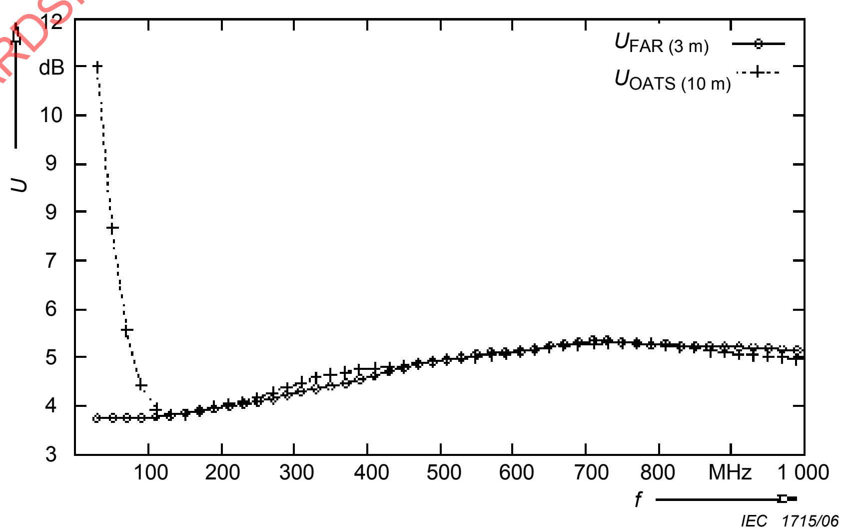


Figure B.14 – Expanded uncertainties

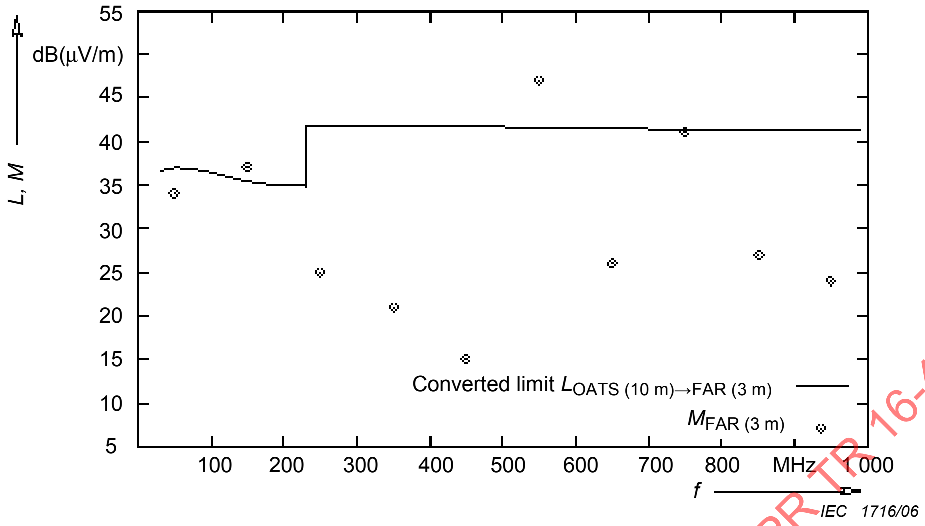


Figure B.15 – Comparison of the measured values with the corrected converted limit

B.1.2 Small EUTs with cables

Results different from those shown in B.1.1 are expected, but are under investigation.

B.2 Example 2 – 3 m open-area test site measurements compared to 10 m open-area test site measurements

B.2.1 Small EUTs without cables

B.2.1.1 Select the reference quantity *X* (see 6.2)

As above, the reference quantity is selected as free-space electric field – see B.1.1.1.

B.2.1.2 Describe the test methods and measurands (see 6.3)

Alternative test method: 3 m open-area test site, OATS (3 m). Figure B.16 displays the measurement set-up of an OATS with 3 m distance for measurements in the frequency range from 30 MHz to 1 GHz. The receiving antenna is located at a distance of $d_{\text{OATS(3m)}}$ = 3 m to the EUT. To detect the maximum field strength, the EUT is rotated in azimuth and the antenna height is varied between 1 and 4 meters. The set-up is placed on a conducting ground plane. The perimeter and surroundings of the OATS and set-up is free of any reflecting objects, therefore ideally the antenna receives only the direct radiation and the ground reflected signal.

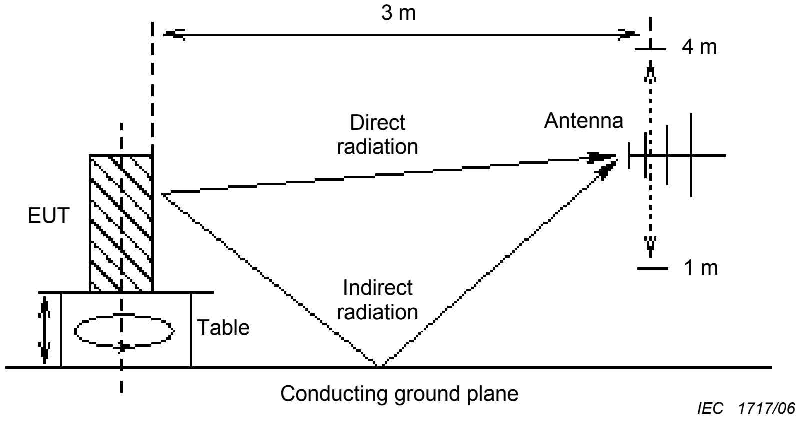


Figure B.16 – EUT and antenna set-up of 3 m open area test site measurement

Established test method: 10 m open-area test site, OATS (10 m). See B.1.1.2

B.2.1.3 Determine the deviations of the measured quantities from the reference quantity (see 6.4)

A description of the statistical model used for the small EUT is given in B.1.1.3. From the simulation results, the deviations between the alternative test method results and the reference quantity values are obtained using

$$D_{\mathrm{ATM}i} = D_{\mathrm{OATS(3m)}i} = X_i - E_{\mathrm{OATS(3m)}i} \qquad \text{(B.14)}$$

where

$E_{\mathrm{OATS(3m)}i}$ is the field-strength for 3 m OATS test method for EUT i;

X_i, $D_{\mathrm{ATM}i}$, i are the same as in 6.4 Equation (1);

$D_{\mathrm{OATS(3m)}i}$ is the deviation from the reference quantity X of the 3 m FAR test method result for EUT i,

and for the established test method using Equation (B.2) from B.1.1.3.

B.2.1.4 Determine the average values of the deviations (see 6.5)

Calculations for the established test method are done in the way as in B.1.1.4. For the alternative test method the average deviations can be calculated using Equation (3) from 6.5. This is done for every set of 1 000 EUTs using:

$$\overline{D}_{\mathrm{set,\,ATM}} = \overline{D}_{\mathrm{set,\,OATS(3m)}} = \frac{1}{1000}\sum_{i=1}^{1000} D_{\mathrm{OATS(3m)}i} \qquad \text{(B.15)}$$

where

$\overline{D}_{\mathrm{set,\,ATM}}$ is the average deviation of the alternative test method for the set of 1 000 EUTs;

$\overline{D}_{\mathrm{set,\,OATS(3m)}}$ is the average deviation of the 3 m OATS test method for the set of 1 000 EUTs;

$D_{\mathrm{OATS(3m)i}}$, i are the same as in Equation (B.14).