

PD IEC/TR 61000-1-6:2012

Incorporating corrigendum October 2014



BSI Standards Publication

Electromagnetic compatibility (EMC)

Part 1-6: General — Guide to the
assessment of measurement uncertainty

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Foreword

This Published Document is the UK implementation of IEC/TR 61000-1-6:2012, incorporating corrigendum October 2014.

The UK participation in its preparation was entrusted to Technical Committee GEL/210, EMC - Policy committee.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2014

ISBN 978 0 580 88429 0

ICS 33.100.01

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This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 July 2012.

Amendments/corrigenda issued since publication

Date	Text affected
30 November 2014	Implementation of IEC corrigendum October 2014: Footnote in Figure 17 updated



TECHNICAL REPORT



BASIC EMC PUBLICATION

Electromagnetic compatibility (EMC) – Part 1-6: General – Guide to the assessment of measurement uncertainty

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE **XB**

ICS 33.100

ISBN 978-2-83220-204-3

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 1-6: General – Guide to the assessment of measurement uncertainty

FOREWORD

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IEC 61000-1-6, which is a technical report, has been prepared by the IEC technical committee 77: Electromagnetic compatibility in corporation with CISPR (International Special Committee on Radio Interference).

It forms Part 1-6 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*.

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

Enquiry draft	Report on voting
77/397/DTR	77/409/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.

A list of all the parts of the IEC 61000 series, published under the general title *Electromagnetic compatibility (EMC)* can be found on the IEC website.

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

The committee has decided that the contents of this publication will remain unchanged until the stability 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.

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.

INTRODUCTION

IEC 61000 is published in separate parts, according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)
Definitions, terminology

Part 2: Environment

Description of the environment
Classification of the environment
Compatibility levels

Part 3: Limits

Emission limits
Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques
Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines
Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as international standards or as technical specifications or technical reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 1-6: General –

Guide to the assessment of measurement uncertainty

1 Scope

This part of IEC 61000 provides methods and background information for the assessment of measurement uncertainty. It gives guidance to cover general measurement uncertainty considerations within the IEC 61000 series.

The objectives of this Technical Report are to give advice to technical committees, product committees and conformity assessment bodies on the development of measurement uncertainty budgets; to allow the comparison of these budgets between laboratories that have similar influence quantities; and to align the treatment of measurement uncertainty across the EMC committees of the IEC.

Any contributing factor to measurement uncertainty that is mentioned within this Technical Report shall be treated as an example: the technical committee responsible for the preparation of a basic immunity standard is responsible for identifying the factors that contribute to the measurement uncertainty of their basic test method.

It gives a description for

- a method for the assessment of measurement uncertainty (MU),
- mathematical formulas for probability density functions,
- analytical assessment of statistical evaluations,
- correction of measured data,
- documentation.

This Technical Report is not intended to summarize all measurement uncertainty influence quantities nor is it intended to define how measurement uncertainty is to be taken into account in determining compliance with an EMC requirement.

NOTE Some of the examples given in this report are taken from IEC publications other than the IEC 61000 series that have already implemented the evaluation procedure presented here. These examples are used to illustrate the principles.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*, corrected 1st edition, 2008

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

NOTE Several of the most relevant terms and definitions from IEC 60050-161 are included among the terms and definitions below.

3.1.1

combined standard uncertainty

standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the input quantities in a measurement model

[SOURCE: ISO/IEC Guide 99:2007, definition 2.31, modified – Admitted term became the preferred (and only) term.]

3.1.2

confidence level

probability, generally expressed as a percentage, that the true value of a statistically estimated quantity falls within a pre-established interval about the estimated value

[SOURCE: IEC 60050-393:2003, 393-18-31]

3.1.3

coverage factor

numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

[SOURCE: ISO/IEC Guide 98-3:2008, definition 2.3.6, modified – NOTE was deleted.]

3.1.4

coverage interval

interval containing the set of quantity values of a measurand with a stated probability, based on the information available

[SOURCE: ISO/IEC Guide 99:2007, definition 2.36, modified – True quantity values was changed to quantity values.]

3.1.5

coverage probability

probability that the set of quantity values of a measurand is contained within a specified coverage interval

[SOURCE: ISO/IEC Guide 99:2007, definition 2.37, modified – True quantity values was changed to quantity values.]

3.1.6

distribution function

function giving, for every value ξ , the probability that the random variable X be less than or equal to ξ :

$$G(\xi) = \Pr(X \leq \xi)$$

[SOURCE: ISO/IEC Guide 98-3, Supplement 1:2008, definition 3.2]

3.1.7

error

measured quantity value minus a reference quantity value

[SOURCE: ISO/IEC Guide 99:2007, definition 2.16, modified – Second admitted term became the preferred (and only) term.]

3.1.8

expanded uncertainty

quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

[SOURCE: ISO/IEC Guide 98-3:2008, definition 2.3.5, modified – Notes 1 to 3 were deleted.]

3.1.9

electromagnetic compatibility

EMC

ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:1990, 161-01-07]

3.1.10

emission

phenomenon by which electromagnetic energy emanates from a source

[SOURCE: IEC 60050-161:1990, 161-01-08, modified – The addition "electromagnetic" in the term was deleted.]

3.1.11

emission level

emission level of a disturbing source

level of a given electromagnetic disturbance emitted from a particular device, equipment or system

[SOURCE: IEC 60050-161:1990, 161-03-11]

3.1.12

emission limit

emission limit from a disturbing source

specified maximum emission level of a source of electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-03-12]

3.1.13

immunity

immunity to a disturbance

ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.1.14

immunity limit

specified minimum immunity level

[SOURCE: IEC 60050-161:1990, 161-03-15]

3.1.15

immunity test level

level of a test signal used to simulate an electromagnetic disturbance when performing an immunity test

[SOURCE: IEC 60050-161:1990, 161-04-41]

3.1.16

indication

quantity value provided by a measuring instrument or a measuring system

[SOURCE: ISO/IEC Guide 99:2007, definition 4.1, modified – Notes 1 and 2 were deleted.]

3.1.17

influence quantity

quantity that is not the measurand but that affects the result of the measurement

[SOURCE: IEC 60050-394:2007, 394-40-27, modified – Note was deleted.]

3.1.18

instrumentation uncertainty

IU

measurement instrumentation uncertainty

MIU

parameter, associated with the disturbance quantity generated during an emission measurement or applied during an immunity test that characterizes the dispersion of the values that could reasonably be attributed to the measurand, induced by all relevant influence quantities that are related to the measurement instrumentation and the test facility

Note 1 to entry: This term is intended to be applicable to both emission measurements and immunity tests. The CISPR 16 series of documents also employs the term 'measurement instrumentation uncertainty' (MIU).

Note 2 to entry: Based on IEC 60359:2001, definition 3.1.4.

3.1.19

intrinsic uncertainty of the measurand

minimum uncertainty that can be assigned in the description of a measured quantity

Note 1 to entry: In theory, the intrinsic uncertainty of the measurand would be obtained if the measurand was measured using a measurement system having a negligible measurement instrumentation uncertainty.

Note 2 to entry: No quantity can be measured with continually lower uncertainty, inasmuch as any given quantity is defined or identified at a given level of detail. If one tries to measure a given quantity at an uncertainty lower than its own intrinsic uncertainty one is compelled to redefine it with higher detail, so that one is actually measuring another quantity. See also ISO/IEC Guide 98-3:2008, D.1.1.

Note 3 to entry: The result of a measurement carried out with the intrinsic uncertainty of the measurand may be called the best measurement of the quantity in question.

[SOURCE: IEC 60359:2001, definition 3.1.11, modified – An additional explanation has been added, i.e. Note 1 to entry.]

3.1.20

level

level of a time varying quantity

value of a quantity, such as a power or a field quantity, measured and/or evaluated in a specified manner during a specified time interval

[SOURCE: IEC 60050-161:1990, 161-03-01, modified – The NOTE was deleted.]

3.1.21

limits of error of a measuring instrument

extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system

[SOURCE: ISO/IEC Guide 99:2007, definition 4.26, modified – The term has been clarified and Notes 1 and 2 have been deleted.]

3.1.22

measurand

particular quantity subject to measurement

[SOURCE: IEC 60050-311:2001, 311-01-03]

3.1.23

measurement accuracy

accuracy of measurement

DEPRECATED: precision of measurement

closeness of agreement between a measured quantity value and the true quantity value of a measurand

Note 1 to entry: 'accuracy' is a qualitative concept.

[SOURCE: IEC 60050-311:2001, 311-06-08, modified – The term has been changed and replaced by two terms, Note 1 has been deleted and Note 2 replaced by an explanation.]

3.1.24

measurement precision

closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions

[SOURCE: ISO/IEC Guide 99:2007, definition 2.15, modified – Notes 1 to 4 have been deleted.]

3.1.25

measurement result

set of quantity values being attributed to a measurand together with any other available relevant information

[SOURCE: IEC 60050-311:2001, 311-01-01, modified – The term has been clarified and the definition extended. Notes 1 to 5 have been deleted.]

3.1.26

measuring system

complete set of measuring instruments and other equipment assembled to carry out specified measurements

[SOURCE: IEC 60050-311:2001, 311-03-06]

3.1.27

measurement trueness

closeness of agreement between the average of an infinite number of replicate measured quantity values and the reference quantity value

[SOURCE: ISO/IEC Guide 99:2007, definition 2.14, modified – Only preferred term is given and Notes 1 to 3 have been deleted.]

3.1.28

measurement uncertainty

MU

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

[SOURCE: ISO/IEC Guide 99:2007, definition 2.26, modified – Only preferred term is given and Notes 1 to 4 have been deleted.]

3.1.29

probability density function

PDF

derivative, when it exists, of the distribution function

$$g(\xi) = \frac{dG(\xi)}{d\xi}$$

Note 1 to entry: $g(\xi)d\xi$ is the 'probability element'; $g(\xi)d\xi = \Pr(\xi < X < \xi + d\xi)$

[SOURCE: ISO/IEC Guide 98-3:2008, definition 3.3, modified – Equation has been changed.]

3.1.30

random error

difference between a measurement and the mean that would result from an infinitely large number of measurements of the same measurand carried out under repeatability conditions

[SOURCE: IEC 60050-394:2007, 394-40-33, modified – Definition was changed and Notes 1 and 2 have been deleted.]

3.1.31

repeatability

repeatability of results of measurements

closeness of agreement between the results of successive measurements of the same measurand, carried out under the same conditions of measurement, i.e.:

- by the same measurement procedure,
- by the same observer,
- with the same measuring instruments, used under the same conditions,
- in the same laboratory,
- at relatively short intervals of time

[SOURCE: IEC 60050-311:2001, 311-06-06, modified – Note has been deleted.]

3.1.32

reproducibility of measurements

closeness of agreement between the results of measurements of the same value of a quantity, when the individual measurements are made under different conditions of measurement:

- principle of measurement,
- method of measurement,
- observer,
- measuring instruments,
- reference standards,
- laboratory,
- under conditions of use of the instruments, different from those customarily used,
- after intervals of time relatively long compared with the duration of a single measurement.

Note 1 to entry: The term 'reproducibility' also applies to the instance where only certain of the above conditions are taken into account, provided that these are stated.

[SOURCE: IEC 60050-311:2001, 311-06-07, modified – Note 1 has been deleted and Note 2 has been renumbered Note 1 to entry.]

3.1.33

sensitivity coefficient

relationship between a change in an output estimate, y , for a corresponding change in an input estimate, x_i .

3.1.34

standard deviation of a single measurement in a series of measurements

parameter characterising the dispersion of the result obtained in a series of n measurements of the same measurand

$$s(q_j) = \sqrt{\frac{1}{(n-1)} \sum_{j=1}^n (q_j - \bar{q})^2}$$

where $\bar{q}$ is the mean value of n measurements

[SOURCE: ISO/IEC Guide 98-3:2008, definition B.2.17, modified – Term, definition and equation have been modified and Notes 1 to 4 have been deleted.]

3.1.35

standard deviation of the arithmetic mean of a series of measurements

parameter characterising the dispersion of the arithmetic mean of a series of independent measurements of the same value of a measured quantity, given by the formula:

$$s(\bar{q}) = \sqrt{\frac{1}{n \cdot (n-1)} \sum_{j=1}^n (q_j - \bar{q})^2}$$

Note 1 to entry: $s(\bar{q})$ is the standard uncertainty for type A evaluation (see 5.3), if $\bar{q}$ is used as the estimate.

3.1.36

standard uncertainty

measurement uncertainty expressed as a standard deviation

[SOURCE: ISO/IEC Guide 99:2007, definition 2.30, modified – Admitted term became the preferred (and only) term.]

3.1.37

systematic error

difference between the arithmetic mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions and the true value of the measurand.

[SOURCE: IEC 60050-394:2007, 394-40-32, modified – Definition was changed and the Note has been deleted.]

3.1.38

tolerance

maximum variation of a value permitted by specifications, regulations, etc. for a given specified influence quantity

3.1.39

true value

actual value of the quantity being measured

Note 1 to entry: This can never be known absolutely but can be approximated (within the bounds of uncertainty) by traceability to national standards.

[SOURCE: IEC 60050-311:2001, 311-01-04, modified – Complement to term was deleted, definition has been changed, Notes 1 to 4 have been deleted and Note 1 to entry has been added.]

3.1.40

type A evaluation

evaluation of a component of measurement uncertainty by a statistical analysis of measured quantity values obtained under defined measurement conditions

[SOURCE: ISO/IEC Guide 99:2007, definition 2.28, modified – Admitted term became the preferred (and only) term and Notes 1 to 3 have been deleted.]

3.1.41

type B evaluation

evaluation of a component of measurement uncertainty determined by means other than a Type A evaluation of measurement uncertainty

[SOURCE: ISO/IEC Guide 99:2007, definition 2.29, modified – Admitted term became the preferred (and only) term and Examples and Note have been deleted.]

3.2 Symbols

X	Generic quantity
a^+	Upper bound of quantity X
a^-	Lower bound of quantity X
d	Number of axes of field probe
N	Number of repeated indications
ν	Number of degrees of freedom, $\nu = N - 1$
ν_X	Coefficient of variation of X
M	Number of samples of N repeated indications
P	Coverage probability
p	Probability value, $p = (1 - P) / 2$
Q_i	Random indication
$\bar{Q}$	Mean of a sample of N indications

$\overline{Q}_j$	Mean of the j -th sample of N indications
$\overline{\overline{Q}}$	Mean of M samples of N indications
$s(Q_i)$	Experimental standard deviation
$s(\overline{Q})$	Experimental standard deviation of the mean, $s(\overline{Q}) = s(Q_i) / \sqrt{N}$
$u(Q_i)$	Type A (evaluation of the) standard uncertainty, $u(Q_i) = \eta(v) \cdot s(Q_i)$
$\eta(v)$	Coefficient which transforms the experimental standard deviation to the Type A standard uncertainty
$u(\overline{Q})$	Type A (evaluation of the) standard uncertainty of the mean, $u(\overline{Q}) = u(Q_i) / \sqrt{N}$
$t_p(v)$	Upper critical value of the Student's t PDF with v degrees of freedom corresponding to probability p in one tail
$X_{\min}$	Lower value of a (specification, tolerance, coverage) interval for quantity X
$X_{\max}$	Upper value of a (specification, tolerance, coverage) interval for quantity X
$G(X)$	Distribution function of quantity X , $G(\hat{X}) = \Pr(X \leq \hat{X})$, where $\Pr(\cdot)$ stands for "probability that"
$g(X)$	Probability density function (PDF) of quantity X , $g(X) = dG(X) / dX$
$\langle X \rangle$	Expected value of quantity X , $\langle X \rangle = \int X \cdot g(X) dX$
x	Best estimate of quantity X , $x = \langle X \rangle$
σ_x^2	Variance of quantity X , $\sigma_x^2 = \langle (X - \langle X \rangle)^2 \rangle = \int (X - x)^2 \cdot g(X) dX$
$u(x)$	Type B (evaluation of the) standard uncertainty, $u(x) = \sigma_x$
X_i	Influence quantity to a mathematical measurement model
x_i	Best estimate of the influence quantity to a mathematical measurement model
δX_i	Correction for influence quantity X_i
Y	Output quantity from a mathematical measurement model
y	Best estimate of the measurand, corrected for all recognized and significant systematic effects
c_i	Sensitivity coefficient, partial derivative, with respect to X_i , of the measurement model, evaluated at the best estimates x_i of the input quantities X_i
$u(x_i)$	Standard uncertainty of the best estimate of the influence quantity X_i
$u_c(y)$	Combined standard uncertainty of the best estimate of the measurand
k	Coverage factor
$U(y)$	Expanded uncertainty of the best estimate of the measurand, $U(y) = k \cdot u_c(y)$

3.3 Abbreviations

CLT	Central Limit Theorem
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EUT	Equipment Under Test
FAR	Fully Anechoic Room
GUM	Guide to the expression of Uncertainty in Measurement
IEC	International Electrotechnical Commission
IFU	Intrinsic Field Uncertainty

IUM	Intrinsic Uncertainty of the Measurand
LPU	Law of Propagation of Uncertainty
MIU	Measurement Instrumentation Uncertainty
MU	Measurement Uncertainty
OATS	Open Area Test Site
PDF	Probability Density Function
RSS	Root of the Sum of Squares
SAC	Semi-Anechoic Chamber
SCU	Standards Compliance Uncertainty
VSWR	Voltage Standing Wave Ratio

4 General

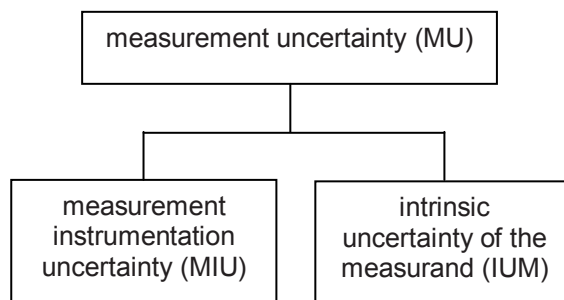
4.1 Overview

This Technical Report presents background material on the principles of Measurement Uncertainty (MU) and guidelines on the calculation and application of MU values. The Technical Report is intended as an aid to those preparing EMC standards under the IEC 61000 series.

4.2 Classification of uncertainty contributions

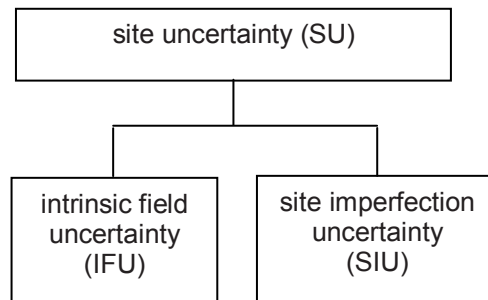
An estimated value of an electrical or electromagnetic (EM) quantity becomes more meaningful when a quantitative statement of uncertainty and confidence is reported together with this value. Further discussion is focused here on the experimental evaluation of uncertainty, rather than evaluation through numerical calculation (e.g. Monte Carlo methods or simulation) that may provide an alternative or additional method for the evaluation of uncertainty.

MU can be subdivided into different components (see Figure 1).



IEC 1303/12

Figure 1 – Classification of uncertainty components associated with the experimental evaluation of uncertainty in EMC testing and measurement



IEC 1304/12

Figure 2 – Classification of uncertainty components associated with site uncertainty (e.g. reverberation chambers)

Figure 1 shows a classification of contributions to the MU, which consists of two components:

- a) measurement instrumentation uncertainty (MIU), which represents the contribution by the instrumentation (e.g., antennas/probes, analyzers, cables, test facility) and
- b) the intrinsic uncertainty of the measurand (IUM), which represents the contribution by the EUT (e.g. instability, setup, lack of definition of the setup).

Figure 2 shows a classification of contributions to the site uncertainty for e.g. reverberation chambers, which consists of two components:

- c) intrinsic field uncertainty (IFU), which represents the contribution inherent to the complexity (IFU for radiated phenomena, where applicable) and
- d) imperfections of the test site (SIU).

NOTE Site uncertainty and site imperfection uncertainty are the same in the case of a semi-anechoic chamber or a fully anechoic room.

MU thus contributes only if a process of measurement (i.e. quantification of an EM quantity) actually takes place. By contrast, SU is always present whenever an EM excitation has been generated because the EM quantity of interest is then physically existent and fluctuating, irrespective of whether or not a process of measurement takes place. For example, the wall reflections generated by an ideal calibrated reference radiator placed in a test site produce random spatial fluctuations of the field included in the SU. These reflections can be residual (as e.g. in a FAR) or intentional (as e.g. in a reverberation chamber) and are present irrespective whether any additional monitoring antenna or probe is present or not.

The process of calibration/validation of the test site verifies that the level of site imperfections is within acceptable bounds, but it does neither influence nor eliminate the contribution of the SU. Measurement uncertainty may consist of a MIU contribution and the site imperfection contribution (e.g. NSA measurement in a FAR).

NOTE 1 In this classification, the term “instrumentation” is more restricted than in other documents, e.g., CISPR 16-4-1. In a FAR, the site uncertainty is caused solely by site imperfections and is incorporated within MIU in CISPR 16-4-1 and CISPR 16-4-2. For other test sites (including multi-path EM environments, e.g., reverberation chambers and more general fading channels), even the idealized site may exhibit inherent field uncertainty as an additional component to site imperfections. An explicit model and example of IFU is described in 5.2.3.4.

NOTE 2 In an anechoic environment, the MU of the complete test is also known as the standards compliance uncertainty (SCU) in CISPR 16-4-1. In ISO/IEC Guide 99:2007, the IUM is referred to as the definitional uncertainty (DU).

4.3 Limitations of the GUM

The “Guide to the expression of uncertainty in measurement” (GUM), see ISO/IEC 98-3:2008, provides the theoretical framework within which this Technical Report was developed. The GUM uncertainty approach has, however, fundamental limitations. If these limitations are

exceeded the results produced are no longer valid. Essentially, the theoretical framework of the GUM is based on (see [1]):

- a) the Law of Propagation of Uncertainties (LPU), and
- b) the Central Limit Theorem (CLT).

To insure that an uncertainty evaluation made according to the procedure described in ISO/IEC 98-3 may be correct, the assumptions required for the validity of both LPU and CLT shall be satisfied. The Supplement 1 to ISO/IEC 98-3 describes a numerical technique aimed at extending the validity of the uncertainty evaluations to cases where the application of ISO/IEC 98-3 does not produce reliable results.

CLT applies when

- a) the measurement model is linear or quasi-linear, that is, it should be verified, at least to an approximation consistent with fitness for purpose, that the measurand can be expressed as

$$Y = c_0 + c_1X_1 + c_2X_2 + \dots + c_nX_n$$

- b) input quantities are independent,
- c) $|c_i u(x_i)|$ have comparable magnitude,
- d) n is sufficiently large (say $n \geq 3$).

If the requirements a) through d) are satisfied then Y approximately follows a normal PDF having an expected value y and a standard uncertainty $u(y)$, where

$$y = c_0 + c_1x_1 + c_2x_2 + \dots + c_nx_n$$

and

$$u(y) = [(c_1u(x_1))^2 + (c_2u(x_2))^2 + \dots + (c_nu(x_n))^2]^{1/2}$$

4.4 Principles

When performing either an emission measurement or an immunity test, a measurement instrumentation chain is required. The MIU is a fundamental property of this instrumentation chain.

At the most fundamental level, the act of measurement involves the acquisition of the numerical value of some measurand. The true value of the measurand is written hereafter simply as x .

To perform a measurement, some form of measurement instrumentation chain (forming the measurement system) is required. A measurement system will return a numerical value for the measurand, written hereafter simply as x' , that is referred to as the *estimate* of the *true value* of the measurand, x , because the two parameters are related according to the following equation:

$$\Pr(x' < X < x' + dx') = g(x')dx' \quad (1)$$

where the function of the true value, $g(x')$ is a fundamental characteristic of the measurement system. The function $g(x')$ is formally referred to as the PDF of the measurement system. The function $g(x')$ is fundamentally statistical in nature: that is, the function $g(x')$ defines the probability that a given value of x' will be returned by the measurement system for a given true value, x , of the measurand.

An example of the form of $g(x)$ that is typical for a complex measurement system is presented below (see Figure 3). Note the form displayed: It is Gaussian. This means that the measurement system is most likely to return an estimate of the value of the measurand, x' , that is equal to the true value of the measurand, x . However, the value returned by the measurement system, x' , can differ from the true value, x , according to the deterministic properties of $g(x)$.

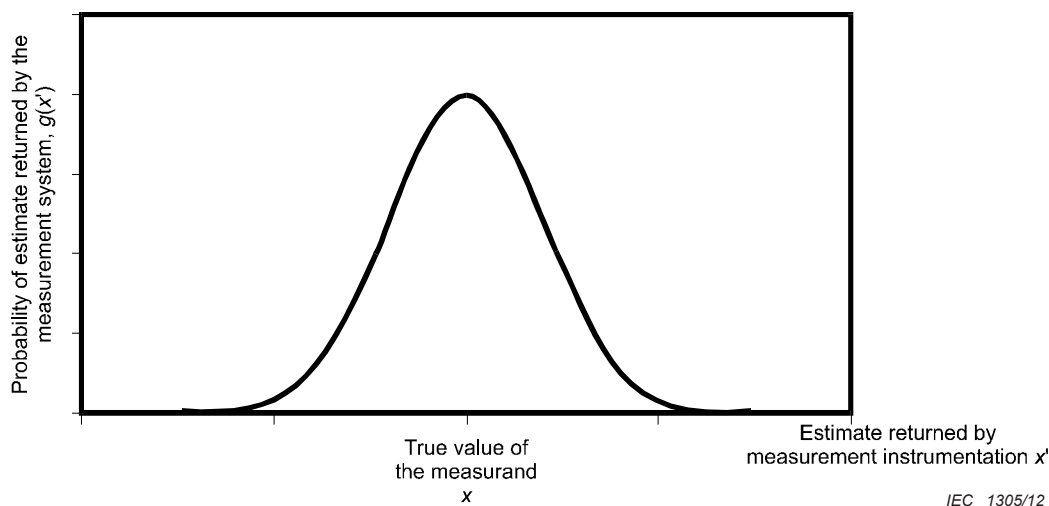


Figure 3 – Example of $g(x')$

The function, $g(x)$, of a complex measurement system has a fundamental impact upon the interpretation of the estimate returned by the measurement system. This is described with the aid of Figure 4 and the consideration of the five points (A, B, C, D and E) displayed.

The fundamental point is that when a measurement system returns an estimate, x' , of the true value of the measurand, x , no knowledge exists regarding the specific position of the estimate within the range of $g(x)$.

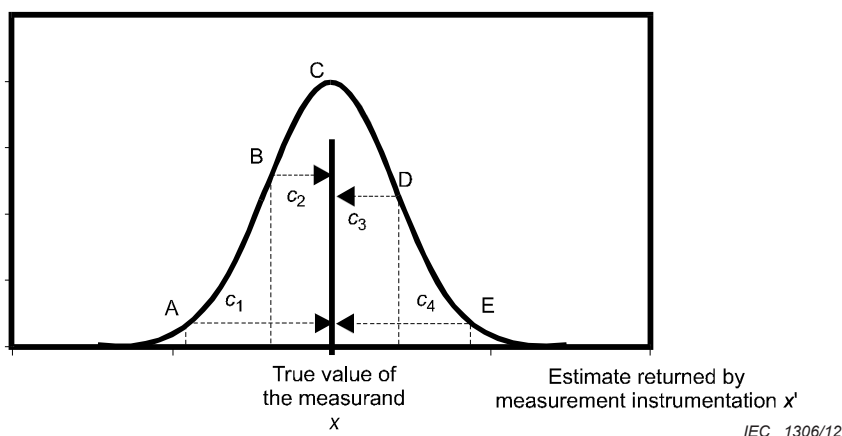


Figure 4 – Impact of $g(x)$ on interpretation of x'

Imagine that a measurand of true value, x , is subjected to a measurement using a measurement system with known function, $g(x)$, and the estimate, x' , is returned.

It is possible that, at the time of measurement, the relationship between the true value of the measurand, x , and the estimate returned by the measurement system, x' , was that

- shown as point A: in this case, the estimate, x' , has significantly underestimated the true value, x , and it would be necessary to make the correction c_1 to x' to find x ;

- shown as point B: in this case, the estimate, x' , has again underestimated the true value, x (although not as much as the previous case), and it would be necessary to make the correction c_2 to x' to find x ;
- shown as point C: in this case, the estimate, x' , has correctly reported the true value, x , and it is not necessary to correct x' to find x ;
- shown as point D: in this case, the estimate, x' , has overestimated the true value, x , and it would be necessary to make the correction c_3 to x' to find x ;
- shown as point E: in this case, the estimate, x' has significantly overestimated the true value, x , and it would be necessary to make the correction c_4 to x' to find x .

This means that the true value of the measurand could exist about the estimate returned by the measurement system in accordance with the PDF presented (see Figure 5).

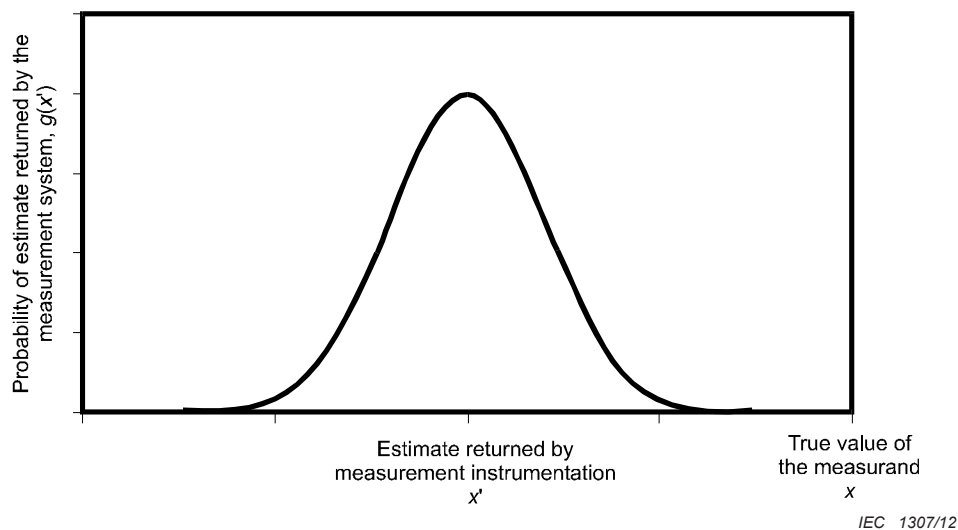


Figure 5 – Estimate returned by the measurement system

5 Measurement uncertainty budget development

5.1 Basic steps

Table 1 summarizes the steps for calculating the MU.

Table 1 – Basic steps for calculating MU

Step	Action	Test lab skill	Statistical tools
1	To write down an exact definition of the measurand (i.e. the quantity to be measured or injected)	Y	
2	To gather the input quantities X_i to MU (e.g. fishbone/Ishikawa diagram) Define the model equation	Y	
3	To provide the best estimate x_i and the PDF of the input quantities. All assumptions should be documented.	Y	
4	To calculate the standard uncertainty $u(x_i)$ of each influence quantity (using either Type A evaluation of uncertainty or Type B using simple division related to specific divisors for certain PDFs).		Y
5	To evaluate the sensitivity coefficients c_i of the input quantities.	Y	
6	To obtain the individual contributions to the standard uncertainty $u_i = c_i \cdot u(x_i)$ of each influence quantity.		Y

Step	Action	Test lab skill	Statistical tools
7	To combine the individual contributions to obtain the “combined standard uncertainty” u_c , i.e. using the root-sum of the squares (RSS) rule.		Y
8	To obtain the expanded uncertainty, U , for a given level of confidence $U = k \cdot u_c$, where k is the coverage factor for the required level of confidence.		Y

Comments on the steps:

Step 1

As an example in emission measurements on an open area test site, the measurand is not just the field strength at the location of the receiving antenna, but the “maximum electric field strength, in dB(μV/m), emitted by the EUT in horizontal and vertical polarisations at the specified horizontal distance from the EUT at a height of between 1 m and 4 m above a reflecting ground plane, with the EUT rotated 360° in azimuth”. A detailed definition of the measurand will also help to identify the input quantities. A definition similarly detailed may apply to a quantity to be injected on the EUT in an immunity test.

Step 2

A model equation will show how the measurand is calculated including all possible correction factors. An example taken from CISPR 16-4-2 for the measurement of the disturbance current

$$I = V_r + A_c + Y_T + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta Z_{cp} + \delta D_{AE} + \delta Z_{AE} + \delta V_{env},$$

where

V_r is the input voltage to the measuring receiver,

A_c is the attenuation of the connecting cable,

Y_T is the current probe transfer admittance,

$\delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf}$ are the receiver corrections (see CISPR 16-4-2),

δM is the mismatch correction,

δZ_{cp} is the correction for the current probe insertion impedance,

δD_{AE} is the correction for errors caused by disturbance from the auxiliary equipment (AE),

δZ_{AE} is the correction for errors due to the deviation of the AE impedance from the assumed ideal termination impedance, and

δV_{env} is the correction for the effect of the environment on the test setup.

All quantities in this example are given in logarithmic units.

A correction is the compensation for a systematic error. A correction may be known from calibration reports or from internally documented evaluations of the test laboratory. A correction with unknown magnitude that is considered to be equally likely to be positive or negative, is taken to be zero. All known corrections are assumed to have been applied, in accordance with the model. This is expressed with the model equation. Every correction (even a zero correction) also serves as an influence quantity having an associated uncertainty.

Step 3

The list should be written in the form of a table.

Step 4