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Electromagnetic compatibility (EMC) -
Part 1-6: General - Guidelines for the evaluation of measurement uncertainty in EMC testing

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Electromagnetic compatibility (EMC) - Part 1-6: General - Guidelines for the evaluation of measurement uncertainty in EMC testing

FOREWORD

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IEC TS 61000-1-6 has been prepared by IEC technical committee 77: Electromagnetic compatibility in cooperation with CISPR (International Special Committee on Radio Interference). It is a Technical Specification.

This first edition cancels and replaces the first edition of IEC TR 61000-1-6 published in 2012. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) purpose of and responsibilities in measurement uncertainty evaluation by testing and calibration laboratories, technical committees dealing with EMC requirements have been introduced;

b) classification of measurement uncertainty contributions (measurement uncertainty, measurement instrumentation uncertainty, intrinsic uncertainty of the measurand) has been revised;

c) new clauses devoted to measurement uncertainty in emission test methods and measurement uncertainty in immunity test methods and in calibration have been added;

d) methods of measurement uncertainty calculation have been enriched by introducing the GUM Supplement 1 (GUMS1) numerical approach based on Monte Carlo method;

e) measurement uncertainty budget development has been revised to include the basic steps to follow in case of application of the GUM method or of the GUMS1 method;

f) a clause specifically devoted to the measurement model function has been added to emphasize the importance of the measurement model and to provide guidance when the measurement model is unknown;

g) the clause on probability density functions has been revised to include the Student-t probability density function;

h) the clause on Type A and Type B evaluations of uncertainty has been revised to improve readability;

i) the clause on the conversion from linear quantities to decibel and vice versa has been revised to improve readability and make some corrections;

j) the clause on the applicability of measurement uncertainty has been modified to improve readability and to remove statements conflicting with conformity assessments standards;

k) Annex A and Annex B have been revised by including results of GUMS1 application;

l) new annexes have been introduced, namely Annex C (on metrological confirmation of measurement equipment), Annex D (on sampling statistics, moved from the main text to this annex to improve readability of the whole document), Annex E (on robust statistics for processing interlaboratory comparison data, with example), Annex F (including an example of application of MU for the assessment of the risk of an out of tolerance of measurement equipment) and Annex G (including an example of application of MU for the evaluation of in-tolerance probability as a function of tolerance to uncertainty ratio – TUR).

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
77/637/DTS	77/640/RVDTS

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

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,

– withdrawn, or

– revised.

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).

Further reading:

– European Telecommunications Standards Institute (ETSI) [1]
– European Accreditation (EA) [2]
– UK Accreditation Service (UKAS) [3]
– M. Kendall and A. Stuart [4]
– I. A. Harris and F. L. Warner [5]
– C.F.M. Carobbi [6]

1 Scope

This part of IEC 61000 provides methods and background information for the evaluation of measurement uncertainty in electromagnetic compatibility (EMC) tests and calibrations. It gives guidance to cover general measurement uncertainty considerations within the IEC 61000 series [7].

The objective of this document is to give advice to EMC technical committees dealing with EMC tests, testing laboratories and calibration laboratories on the development of measurement uncertainty budgets; to allow uniform development and comparability of these budgets between laboratories; and to align the treatment of measurement uncertainty across the technical committees of the IEC dealing with EMC tests.

Any contributing factor to measurement uncertainty that is mentioned within this document will be treated as an example: the EMC committee responsible for the preparation of a basic immunity or emission standard is responsible for identifying the factors that contribute to the measurement uncertainty of the relevant test method.

This document provides:

– methods for the evaluation of measurement uncertainty (MU),
– mathematical formulae for probability density functions and their interpretation,
– examples of MU calculations,
– examples of MU applications,
– MU reporting information.

This document is not intended to summarize all measurement uncertainty influence quantities, nor is it intended to specify how measurement uncertainty will be taken into account in determining compliance with an EMC requirement.

NOTE Some of the examples given in this document are based on IEC publications (for example CISPR 16-4 series [8]) other than the IEC 61000 series [7] that have already implemented the evaluation procedure presented here. These examples are used to illustrate the principles.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) - Part 161: Electromagnetic 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*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161:1990 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/
– ISO Online browsing platform: available at https://www.iso.org/obp

NOTE Several of the most relevant terms and definitions from IEC 60050-161:1990 are included among the terms and definitions below.

3.1.1
combined standard measurement uncertainty
combined standard uncertainty
standard measurement uncertainty that is obtained using the individual standard measurement uncertainties associated with the input quantities in a measurement model

Note 1 to entry: In case of correlations of input quantities in a measurement model, covariances must also be taken into account when calculating the combined standard measurement uncertainty; see also ISO/IEC Guide 98-3:2008 [9], 2.3.4.

[SOURCE: ISO/IEC Guide 99:2007 [10], 2.31, modified – The preferred term "combined standard measurement uncertainty" has been deleted.]

3.1.2
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 [9], 2.3.6, modified – The note was deleted.]

3.1.3
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 [10], 2.36, modified – In the definition, "true quantity values" was changed to "quantity values" and the notes were deleted.]

3.1.4
coverage probability
probability that the set of quantity values of a measurand is contained within a specified coverage interval

Note 1 to entry: The coverage probability is also termed "level of confidence" in the GUM.

[SOURCE: ISO/IEC Guide 99:2007 [10], 2.37, modified – In the definition, "true quantity values" was changed to "quantity values" and Note 1 was deleted.]

3.1.5
direct (method of) measurement
method of measurement in which the value of a measurand is obtained directly, without the necessity for supplementary calculations based on a functional relationship between the measurand and other quantities actually measured

Note 1 to entry: The value of the measurand is considered to be obtained directly even when the scale of a measuring instrument has values which are linked to corresponding values of the measurand by means of a table or a graph.

Note 2 to entry: The method of measurement remains direct even if it is necessary to make supplementary measurements to determine the values of influence quantities in order to make corrections.

[SOURCE: IEC 60050-311:2001 [11], 311-02-01]

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: $G_X(\xi) = \Pr(X \leq \xi)$

[SOURCE: ISO/IEC Guide 98-3:2008/Suppl 1:2008 [12], 3.2]

3.1.7
error
measured quantity value minus a reference quantity value

[SOURCE: ISO/IEC Guide 99:2007 [10], 2.16, modified – Second admitted term became the preferred (and only) term and Note 1 and Note 2 have been deleted.]

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 [9], 2.3.5, modified – Notes 1 to 3 have been 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/AMD8:2018 [13], 161-01-07]

3.1.10
emission
phenomenon by which electromagnetic energy emanates from a source

[SOURCE: IEC 60050-161:1990/AMD9:2019 [14], 161-01-08, modified – In the term, "electromagnetic" 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 [15], 161-03-11, modified – In the term, "(from a disturbing source)" has been removed and "emission limit of a disturbing source" has been added as an admitted term.]

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 [15], 161-03-12, modified – In the term, "(from a disturbing source)" has been removed and "emission limit from a disturbing source" has been added as an admitted term.]

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 [15], 161-01-20, modified – In the term, "(to a disturbance)" has been removed and "immunity to a disturbance" has been added.]

3.1.14
immunity level
maximum level of a given electromagnetic disturbance incident on a particular device, equipment or system for which it remains capable of operating at a required degree of performance

[SOURCE: IEC 60050-161:1990 [15], 161-03-14]

3.1.15
immunity limit
specified minimum immunity level

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

3.1.16
immunity test level
level of a test signal used to simulate an electromagnetic disturbance when performing an immunity test

[SOURCE: IEC 60050-161:1990 [15], 161-04-41, modified – In the term, "severity level (deprecated)" has been removed.]

3.1.17
indication
quantity value provided by a measuring instrument or a measuring system

Note 1 to entry: An indication may be presented in visual or acoustic form or may be transferred to another device. An indication is often given by the position of a pointer on the display for analog outputs, a displayed or printed number for digital outputs, a code pattern for code outputs, or an assigned quantity value for material measures.

Note 2 to entry: An indication and a corresponding value of the quantity being measured are not necessarily values of quantities of the same kind.

[SOURCE: ISO/IEC Guide 99:2007 [10], 4.1.]

3.1.18
indirect (method of) measurement
method of measurement in which the value of a quantity is obtained from measurements made by direct methods of measurement of other quantities linked to the measurand by a known relationship

[SOURCE: IEC 60050-311:2001 [11], 311-02-02]

3.1.19
influence quantity
quantity that is not the measurand but that affects the result of the measurement

[SOURCE: ISO/IEC Guide 98-3:2008 [9], B.2.10, modified – Examples were deleted.]

3.1.20
input quantity
quantity that must be measured, or a quantity, the value of which can be otherwise obtained, in order to calculate a measured quantity value of a measurand

EXAMPLE When the length of a steel rod at a specified temperature is the measurand, the actual temperature, the length at that actual temperature, and the linear thermal expansion coefficient of the rod are input quantities in a measurement model.

Note 1 to entry: An input quantity in a measurement model is often an output quantity of a measuring system.

Note 2 to entry: Indications, corrections and influence quantities can be input quantities in a measurement model.

[SOURCE: ISO/IEC Guide 99:2007 [10], 2.50, modified – The term "input quantity in a measurement model" has been removed.]

3.1.21
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 [16], 3.1.4.

3.1.22
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 [9], 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 [16], 3.1.11, modified – An additional explanation has been added, i.e., Note 1 to entry.]

3.1.23
level
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 [15], 161-03-01, modified – In the term "(of a time varying quantity)" has been removed and the note has been removed.]

3.1.24
limit of error
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 [10], 4.26, modified – In the term "maximum permissible measurement error" and "maximum permissible error" have been removed, and Notes 1 and 2 have been removed.]

3.1.25
measurand
particular quantity subject to measurement

[SOURCE: IEC 60050-311:2001 [11], 311-01-03]

3.1.26
measurement accuracy
accuracy of measurement
accuracy
closeness of agreement between a measured quantity value and a true quantity value of a measurand

Note 1 to entry: The concept ‘measurement accuracy’ is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

Note 2 to entry: The term “measurement accuracy” should not be used for measurement trueness and the term measurement precision should not be used for ‘measurement accuracy’, which, however, is related to both these concepts.

Note 3 to entry: ‘Measurement accuracy’ is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand.

Note 4 to entry: A reference value for the measurand can be used as a true quantity value.

[SOURCE: ISO/IEC Guide 99:2007 [10], 2.13, modified – Note 4 has been added.]

3.1.27
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 [10], 2.15, modified – In the term "precision" has been removed as an admitted term and Notes 1 to 4 have been deleted.]

3.1.28
measurement result
set of quantity values being attributed to a measurand together with any other available relevant information

[SOURCE: IEC 60050-311:2001 [11], 311-01-01, modified – The term has been clarified and the definition extended and Notes 1 to 5 have been deleted.]

3.1.29
measuring system
complete set of measuring instruments and other equipment assembled to carry out specified measurements

[SOURCE: IEC 60050-311:2001 [11], 311-03-06]

3.1.30
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 [10], 2.14, modified – Only the preferred term is given and Notes 1 to 3 have been deleted.]

3.1.31
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 [10], 2.26, modified – Only the preferred term is given, the abbreviated term "MU" has been added and Notes 1 to 4 have been deleted.]

3.1.32
probability density function
PDF
derivative, when it exists, of the distribution function
$g_X(\xi) = \frac{\mathrm{d}G_X(\xi)}{\mathrm{d}\xi}$

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

[SOURCE: ISO/IEC Guide 98-3:2008 [9], C.2.5, modified – In the term "(for a continuous random variable") has been deleted and PDF has been added and the formula has been changed.]

3.1.33
random measurement error
random error of measurement
random error
component of measurement error that in replicate measurements varies in an unpredictable manner

Note 1 to entry: A reference quantity value for a random measurement error is the average that would ensue from an infinite number of replicate measurements of the same measurand.

Note 2 to entry: Random measurement errors of a set of replicate measurements form a distribution that can be summarized by its expectation, which is generally assumed to be zero, and its variance.

Note 3 to entry: Random measurement error equals measurement error minus systematic measurement error.

[SOURCE: ISO/IEC Guide 99:2007 [10], 2.19.]

3.1.34
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 [11], 311-06-06, modified – In the term, "(of results of measurements)" has been deleted and "repeatability of results of measurements" has beed added and the note has been deleted.]

3.1.35
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 [11], 311-06-07, modified – In the term, the parentheses for "of measurements" have been removed and Note 1 has been deleted and Note 2 has been renumbered Note 1 to entry.]

3.1.36
sensitivity coefficient
relationship between a change in an output estimate, y , for a corresponding change in an input estimate, x_i

3.1.37
sample standard deviation
parameter characterising the dispersion of the result obtained in a series of measurements of the same measurand

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

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

3.1.38
sample standard deviation of the mean
standard error of the mean
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: $s(\overline{q}) = \sqrt{\frac{1}{n\cdot(n-1)}\sum_{j=1}^{n} \left(q_j - \overline{q}\right)^2}$

3.1.39
standard uncertainty
measurement uncertainty expressed as a standard deviation

[SOURCE: ISO/IEC Guide 99:2007 [10], 2.30, modified – The second admitted term became the preferred (and only) term.]

3.1.40
systematic error
mean that would result from an infinite number of measurements of the same measurand carried out underrepeatability conditions minus a true value of the measurand

Note 1 to entry: Systematic error is equal to error minus random error.

Note 2 to entry: Like true value, systematic error and its causes cannot be completely known.

[SOURCE: ISO/IEC Guide 98-3:2008 [9], B.2.22, modified – Note 3, reference to VIM and the Guide comment have been removed.]

3.1.41
tolerance
maximum variation of a value permitted by specifications, regulations, etc., for a given specified influence quantity

3.1.42
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 [11], 311-01-04, modified – In the term, "(of a quantity)" was deleted, definition has been changed, Notes 1 to 4 have been deleted and Note 1 to entry has been added.]

3.1.43
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 [10], 2.28, modified – Admitted term became the preferred (and only) term and Notes 1 to 3 have been deleted.]

3.1.44
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 [10], 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	Degrees of freedom, $\nu = N - 1$
v_X	Coefficient of variation of X
M	Number of samples of N repeated indications
P	Coverage probability
p	Probability value, $p = (1 - P)/2$