

American National Standard Guide for Electromagnetic Compatibility—Computations and Treatment of Measurement Uncertainty

C63[®]

Sponsored by the
Accredited Standards Committee C63[®] — Electromagnetic Compatibility

Sponsored by the
Accredited by the American National Standards Institute

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

ANSI C63.23-2012

13 March 2013

American National Standard Guide for Electromagnetic Compatibility—Computations and Treatment of Measurement Uncertainty

Accredited Standards Committee C63[®] – Electromagnetic Compatibility

accredited by the

American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

Approved 3 December 2012

American National Standards Institute

C63[®]

Abstract: Methods for estimating measurement uncertainty of emissions measurement results are provided, for use in conjunction with the basic methods of ANSI C63.4. Included in this document are both Type A and Type B uncertainty evaluation methods.

Keywords: ANSI C63.23, electromagnetic compatibility (EMC), emissions, immunity, measurement uncertainty, metrology, Type A evaluation, Type B evaluation

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2013 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 13 March 2013. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 978-0-7381-8222-3 STD98135
Print: ISBN 978-0-7381-8251-3 STDPD98135

IEEE prohibits discrimination, harassment and bullying. For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.
No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review and users are cautioned to obtain the latest editions.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (978) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Errata

Users are encouraged to check the IEEE Errata URL (<http://standards.ieee.org/findstds/errata/index.html>), and the one for ASC C63[®] at http://www.c63.org/explanations_interpretations_request.htm, for errata periodically.

Interpretations

Current interpretations can be accessed at the following URLs: http://www.c63.org/explanations_interpretations_request.htm.

For more information about the committee that produced and maintains this standard, visit the ANSI Accredited Standards Committee C63[®] web site at <http://www.c63.org>.

Notice to users

Laws and regulations

Users of these documents should consult all applicable laws and regulations. Compliance with the provisions of this guide does not imply compliance to any applicable regulatory requirements. Implementers of the guide are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

Updating of IEEE documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at <http://standards.ieee.org/index.html> or contact the IEEE at the address listed previously. For more information about the IEEE Standards Association or the IEEE standards development process, visit the IEEE-SA Website at <http://standards.ieee.org/index.html>.

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this guide may require use of subject matter covered by patent rights. By publication of this guide, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this guide are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this guide was published, Accredited Standards Committee C63[®]—Electromagnetic Compatibility had the following membership:

Daniel Hoolihan, Chair
Jerry Ramie, Secretary

<i>Organization Represented</i>	<i>Name of Representative</i>
Alcatel–Lucent Technologies	Dheena Moongilan
Alliance for Telecommunications Industry Solutions (ATIS).....	Mel Frerking
.....	James Turner (<i>Alt.</i>)
American Council of Independent Laboratories (ACIL)	Harry Hodes
.....	John Repella (<i>Alt.</i>)
American Radio Relay League (ARRL)	Edward F. Hare
.....	Kermit Carlson (<i>Alt.</i>)
Apple, Inc.	Fraidun Akhi
.....	Indrandil Sen (<i>Alt.</i>)
AT&T	David Chapman
Bureau Veritas	Jonathan Stewart
.....	Mairal Hussain (<i>Alt.</i>)
Cisco Systems	Andy Griffin
.....	David Case (<i>Alt.</i>)
Dell Inc.	Richard Worley
Electric Power Research Institute	Phil Keebler
ETS-Lindgren	Zhong Chen
.....	Michael Foegelle (<i>Alt.</i>)
Federal Communications Commission (FCC)	William Hurst
Food and Drug Administration (FDA).....	Jeffrey L. Silberberg
.....	Don Witters (<i>Alt.</i>)
Information Technology Industry Council (ITIC)	John Hirvela
.....	Joshua Rosenberg (<i>Alt.</i>)
Institute of Electrical and Electronics Engineers, Inc. (IEEE)	Donald N. Heirman
IEEE-Electromagnetic Compatibility Society (EMCS)	H. Stephen Berger
.....	Donald Sweeney (<i>Alt.</i>)
Motorola Mobility.....	Tom Knipple
Motorola Solutions	William Elliott
.....	Deanna Zakharia (<i>Alt.</i>)
National Institute of Standards and Technology (NIST).....	Dennis Camell
Polycom	Jeff Rodman
.....	Tony Griffiths (<i>Alt.</i>)
Research in Motion (RIM).....	Masud Attayi
.....	Daoud Attayi (<i>Alt.</i>)
Samsung Telecommunications	Tony Riveria
.....	Kendra Green (<i>Alt.</i>)
Society of Automotive Engineers (SAE)	Poul Andersen
.....	Gary Fenical (<i>Alt.</i>)
Sony Ericsson Mobile Communications	Mats Hansson
.....	Jon Kenny (<i>Alt.</i>)
Telecommunication Certification Body (TCB) Council	Art Wall
.....	William Stumpf (<i>Alt.</i>)
Telecommunications Industry Association (TIA).....	Stephen Whitesell
TUV-America, Inc.	Chip Fleury
.....	David Schaefer (<i>Alt.</i>)
UL LLC	Robert Delisi
.....	Jeffrey Moser (<i>Alt.</i>)
U.S. Department of Defense—Joint Spectrum Center	Marcus Shellman
.....	Michael Duncanson (<i>Alt.</i>)
U.S. Department of the Navy—SPAWAR	Chris Dilay
.....	David Hilton (<i>Alt.</i>)

Individual Members	Daniel Hoolihan
.....	John Lichtig
.....	Werner Schaefer
.....	Ralph M. Showers
.....	David Zimmerman
Members Emeritus	Warren Kesselman
.....	Herbert Mertel
.....	H. R. (Bob) Hofmann

At the time this guide was completed, ASC C63[®] Subcommittee 1 had the following membership:

Dennis Camell, *Chair*
Harry Hodes, *Vice Chair*
Janet O'Neil, *Secretary*

Mark Arthurs
Masud Attayi
Zhong Chen
Bob DeLisi
Dean Ghizzone
Andy Griffin
Tim Harrington
Donald Heirman

H. R. (Bob) Hofmann
Daniel Hoolihan
Greg Kiemel
Victor Kuczynski
Rick Lombardi
Randy Long
Doug Parker
Ghery Pettit

Nate Potts
Werner Schaefer
Ralph M. Showers
Dan Sigoium
Jeffrey L. Silberberg
William Stumpf
Art Wall
Stephen Whitesell

At the time this guide was completed, the ASC C63[®] Subcommittee 1 Measurement Uncertainty Working Group had the following membership:

Bob DeLisi, *Chair*
Dennis Camell, *Vice Chair*

Tim Harrington
Donald Heirman
Daniel Hoolihan

Victor Kuczynski
Doug Parker

Nate Potts
Werner Schaefer
Michael J. Windler

Introduction

This introduction is not part of ANSI C63.23-2012, American National Standard Guide for Electromagnetic Compatibility—Computations and Treatment of Measurement Uncertainty.

ANSI C63.23 is intended to provide measurement laboratories with guidelines and generally accepted laboratory practices in the determination of EMI measurement uncertainties. The primary application of this edition of ANSI C63.23 is for use with ANSI C63.4.

This guide may apply to other C63[®] standards as appropriate.

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	2
2. Normative references.....	2
3. Definitions	3
4. Basic concepts	5
4.1 Introduction to measurement uncertainty	5
4.2 Concepts of uncertainty	5
4.3 Application of uncertainty values in conformity assessment.....	7
5. EMC measurement uncertainty calculations	8
5.1 General	8
5.2 Uncertainty contributors common to all conducted and radiated emission EMC measurements— Type B evaluation.....	9
5.3 Uncertainty contributors for conducted emission measurements at a mains port using an LISN— Type B evaluation.....	12
5.4 Uncertainty contributors for radiated emission measurements in the frequency range 30 MHz to 1000 MHz on an open-area test site (OATS) or in a semianechoic chamber (SAC)—Type B evaluation	13
5.5 Uncertainty contributors for radiated emission measurements in the frequency range above 1 GHz— Type B evaluation.....	17
5.6 Type A evaluations of contributors	19
5.7 Example spreadsheets.....	26
Annex A (informative) Aspects of measurement uncertainty theory	29
Annex B (informative) Bibliography.....	41

American National Standard Guide for Electromagnetic Compatibility—Computations and Treatment of Measurement Uncertainty

IMPORTANT NOTICE: IEEE Standards documents are not intended to ensure safety, health, or environmental protection, or ensure against interference with or from other devices or networks. Implementers of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, and interference protection practices and all applicable laws and regulations.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

1. Overview

1.1 Scope

In standardized emissions compliance measurements, the emission level of an equipment under test (EUT) is measured, after which compliance with the associated limit is determined. The measured emission level is an approximation of the true level due to uncertainties induced by various contributors. In emissions compliance testing, major relevant contributors related to the EUT or to the measurement procedure happen to be unspecified and no quantitative information is available about their values, for example, operator skills, quality system of the laboratory performing the test, environmental conditions, production tolerance of the EUT model, operation of the EUT, and so on. This document concentrates on the measurement instrumentation uncertainty, which is a subpart of the total uncertainty of the measurement, and it includes only the effects of those contributors that are related to the measurement instrumentation.

This application guide provides methods for determining the uncertainty of measurement for electromagnetic interference (EMI) measurement results. This guide provides information on the application of Type A statistical evaluations. For Type B applications, this guide also provides information on where to obtain specified published information that can lead to an evaluation of uncertainty. The

current document provides information on the range 150 kHz to 30 MHz for conducted emissions on main lines, and 30 MHz to 18 000 MHz for radiated emissions measurements.

1.2 Purpose

This document provides recommended methods for estimating the uncertainty of EMI measurements as performed in accordance with C63[®] standards (e.g., ANSI C63.4¹), for the purposes of this edition, or similar standards that do not already contain recommended methods for estimating measurement uncertainty.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C63.2, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz Specifications.²

ANSI C63.4, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

ANSI C63.14, American National Standard Dictionary of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3).

CISPR 16-1-1:2007, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-1: Radio Disturbance and Immunity Measuring Apparatus—Measuring Apparatus.³

CISPR 16-1-2:2006, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-2: Radio Disturbance and Immunity Measuring Apparatus—Ancillary Equipment—Conducted Disturbances.

CISPR 16-1-4:2010, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-4: Radio Disturbance and Immunity Measuring Apparatus—Antennas and Test Sites for Radiated Disturbance Measurements—Edition 3.0.

CISPR 16-4-2, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 4-2: Uncertainties, Statistics and Limit Modeling—Uncertainty in EMC Measurements.

ISO 21748:2004, Guidance for the Use of Repeatability, Reproducibility and Trueness Estimates in Measurement Uncertainty Estimation.⁴

ISO 21749:2005, Measurement and Uncertainty for Metrological Applications—Repeated Measurements and Nested Experiments.

¹ Information on references can be found in Clause 2.

² ANSI publications are available from the American National Standards Institute (<http://www.ansi.org/>).

³ CISPR documents are available from the International Electrotechnical Commission (<http://www.iec.ch/>). They are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

⁴ ISO publications are available from the ISO Central Secretariat (<http://www.iso.org/>). ISO publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

3. Definitions

For the purposes of this document, the following terms and definitions apply. ANSI C63.14 and the *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁵ General terms and definitions used in the expression of uncertainty are provided in ISO/IEC Guide 98-3:2008 [B16]⁶ (GUM), and important general terms and definitions related to measurement are contained in ISO/IEC Guide 99:2007 [B17] (VIM).

analysis of variance (ANOVA): A collection of statistical models and their associated procedures in which the observed variance is partitioned into components due to different explanatory variables. ANOVA is a general technique that can be used to test the hypothesis that the means among two or more groups are equal, under the assumption that the sampled populations are normally distributed.

a priori distribution: A distribution in which the probability curve is an isosceles triangle symmetrical about the center of the base [e.g., the result of casting (rolling) a pair of fair dice]. *Syn.:* **triangular distribution.**

combined standard uncertainty, $u_c(y)$: Standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variance or covariance of these other quantities weighted according to how the measurement result varies with changes in these quantities.

conformity assessment: Demonstration that specified requirements relating to a product, process, system, person, or body are fulfilled. [ISO/IEC 17000:2004 [B15], 2.1 and 0.5, MOD]

NOTE 1—The subject field of conformity assessment includes activities such as testing, inspection, and certification, as well as the accreditation of conformity assessment bodies.⁷

NOTE 2—The expression “object of conformity assessment” or “object” is used in ISO/IEC 17000:2004 [B15] to encompass any particular material, product, installation, process, system, person, or body to which conformity assessment is applied.

NOTE 3—ISO/IEC 17000:2004 [B15] does not include a definition of “conformity” on the grounds that it is not necessary to do so. “Conformity” does not feature in the definition of “conformity assessment.” The concept of “conformity assessment” is concerned with “fulfillment of specified requirements,” not with the wider concept of “conformity.” A definition of the term “specified requirement” is included in ISO/IEC 17000-2004 [B15]. In English, the term “compliance” is used to distinguish the action of doing what is required (e.g., an organization “complies” by making something conform or by fulfilling a regulatory requirement).

correction factor: Numerical factor by which the uncorrected result of a measurement is mathematically adjusted to compensate for an assumed systematic error (e.g., in EMC measurements), the loss in a signal cable that is usually measured and stated in decibels and added to an uncorrected result that is also measured and stated in decibels.

NOTE—Because the systematic error cannot be known perfectly, the compensation cannot be complete.

coverage factor, k : Numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty. When $k = 2$, the confidence level approximates 95% (in case of normal, Gaussian, probability distribution).

⁵ The IEEE Standards Dictionary Online subscription is available at http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

⁶ The numbers in brackets correspond to those of the bibliography in Annex B.

⁷ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

NOTE—The coverage factor k is typically in the range of 2 to 3, but different values may be used depending on the desired confidence level and on the type of probability distribution of the combined standard uncertainty.

degrees of freedom— ν_i, ν_{eff} : The degrees of freedom ν_i of the standard uncertainties based on Type B evaluation are, by definition, infinite. If the uncertainty is obtained from a limited number of data points or observations, as in the case of a Type A evaluation, then $\nu_i = n - 1$ (see ANSI/NCSL Z540-1-1994 [B3], CISPR/TR 16-4-1:2009 [B7], UKAS LAB 34:2002 [B21], UKAS M 3003:2007 [B22], and ISO/IEC Guide 98-3:2008 [B16]). The effective degrees of freedom ν_{eff} are the “combined” degrees of freedom of the combined standard uncertainty when it is made up of a combination of Type B and Type A evaluations.

drift: The unwanted change of the value of a measurable characteristic of a device over a specified period of time when the values of all other characteristics of the device are kept constant. For example, drift may be the change in the device response with use or age, or since the last calibration or measurement. This may take the form of a change in readout, usually gradual, without associated change in any influence quantity.

error (of measurement): Result of a measurement minus the true value of the measurand.

NOTE 1—The quantity is sometimes called absolute error of measurement when it is necessary to distinguish it from relative error.

NOTE 2—Because a true value cannot be determined, in practice a conventional true value is used, if available.

expanded uncertainty, U : Quantity defining the interval about the result of a measurement within which the values that could reasonably be attributed to the measurand may be expected to lie with a high-specified level of confidence. Expanded uncertainty is obtained by multiplying the combined standard uncertainty by a coverage factor k .

influence quantity: Quantity that is not necessarily included in the specification of the measurand but that nonetheless affects the result of the measurement (e.g., frequency in the measurement of an alternating electric potential difference) or temperature of a micrometer used to measure length.

measurand: Specific quantity subject to measurement.

measurement uncertainty: Non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand based on the information used. *Syn.: uncertainty of measurement; uncertainty.*

NOTE 1—Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for, but instead, associated measurement uncertainty components are incorporated.

NOTE 2—The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

NOTE 3—Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

NOTE 4—In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty (for example, different measurement uncertainty values for a radiated emissions measurement result may apply in different frequency ranges).

NOTE 5—This definition of measurement uncertainty (i.e., as repeated from 2.26 of ISO/IEC Guide 99:2007 [B17]), and for situations where uncertainty components arising from sampling are not considered, corresponds to the term and definition for standards compliance uncertainty given in 3.1.16 of CISPR 16-4-1:2009 [B7].

4. Basic concepts

4.1 Introduction to measurement uncertainty

Measurement uncertainty is the best estimated quantity by which a measured value differs from the true value of a parameter under evaluation. Correction factors (or biases; see the definition in A.1.4) are typically used to improve correlation between measurement devices and systems and the reference quantity to which they have been calibrated. Additionally, a correction factor is always accompanied by a measurement uncertainty. The need for such factors is an indication that the true value cannot be directly and completely obtained from the instrumentation and with the method of measurement used. Correction factors determined during equipment calibration processes determine the bias to be applied to the measurement result, and they are subject to measurement uncertainty.

Determining the operational characteristics of the EUT with respect to electromagnetic compatibility compliance requires both emission and immunity measurements. This guide, however, only focuses on emission measurement, which is covered in, for example, ANSI C63.4. The measurements or evaluations involve the use of various instrumentation and techniques, requiring operator interaction and decisions. The measurement (or evaluation) process produces both random and systematic effects that influence the ultimate outcome of the measurement. Examples of systematic effects are bias of the measurement result by cable loss, parallax when reading a D'Arsonval meter, or habits and preferences of the operator. An example of a random effect is the influence of noise contribution to the measured amplitude if the amplitude of the measurand is close to the system noise floor. Additional papers on the treatment of uncertainty components (influence quantities) are listed in an informative bibliography (i.e., see Annex B).

An evaluation of each effect included in a measurement enables the identification of influence factors (i.e., elements that contribute to the uncertainty of the measurement), and a thorough description of each effect can assist in assignment of an appropriate value and weighting factor indicating how the overall measurement uncertainty budget may be affected. Each element of the measurement process involves an uncertainty of measurement that can be assigned a value and described by the owner of the process. The combinations of the elements of uncertainty form the basis of an uncertainty budget for a particular measurement process.

4.2 Concepts of uncertainty

4.2.1 General

Measurement uncertainty is a parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the true value of the measurand. It shows the spread of values above and below the measurement result within which the true value of the measurand may be expected to lie. It can be considered to be a measure of the possible error in the value of the measurand provided by the result of a measurement; however, the true value of a measurand can never be known. Measurement uncertainty should not be confused with correction or correlation factors. Correction and correlation factors are quantities added to measurement values to create agreement between established standard values and measurement device readings (these can also be described as biases; see A.1.4).