CISPR/TR 16-4-1

Edition 2.0 2009-02

TECHNICAL REPORT

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

PRICE CODE XE

ICS 33.100.10; 33.100.20

ISBN 978-2-88910-014-9

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 7
INTRODUCTION 9
1 Scope 10
2 Normative references 10
3 Terms, definitions, and abbreviations 11
3.1 Terms and definitions 12
3.2 Abbreviations 15
4 Basic considerations on uncertainties in emission measurements 15
4.1 Introductory remarks 15
4.2 Types of uncertainties in emission measurements 17
4.2.1 General 17
4.2.2 Purpose of uncertainty considerations 18
4.2.3 Categories of uncertainty sources 19
4.2.4 Summary of types of uncertainties 22
4.2.5 Influence quantities 22
4.2.6 The measurand and the intrinsic uncertainty 23
4.3 Relation between standards compliance uncertainty and interference probability 25
4.3.1 General 25
4.3.2 The measurand and the associated limit 25
4.3.3 Process of determination and application of uncertainties 26
4.4 Assessment of uncertainties in a standardised emission measurement 27
4.4.1 The process of uncertainty estimation 27
4.4.2 Step 1: Definition of the purpose of the uncertainty consideration 27
4.4.3 Step 2: Identifying the measurand, its uncertainty sources and influence quantities 28
4.4.4 Step 3: Evaluate the standard uncertainty of each relevant influence quantity 29
4.4.5 Step 4: Calculation of the combined and expanded uncertainty 30
4.5 Verification of the uncertainty budget 31
4.5.1 Introductory remarks 31
4.5.2 Test laboratory comparison and the measurement compatibility requirement 32
4.5.3 Interlaboratory comparison and statistical evaluation 34
4.5.4 Application of a ‘calculable EUT’ 35
4.5.5 Application of a ‘reference EUT’ 35
4.6 Reporting of the uncertainty 35
4.6.1 General 35
4.6.2 Reporting results of uncertainty assessments 36
4.6.3 Uncertainty statements in routine compliance measurement results 36
4.6.4 Reporting of the expanded uncertainty 36
4.7 Application of uncertainties in the compliance criterion 37
4.7.1 Introductory remarks 37
4.7.2 Manufacturers’ compliance criterion for compliance measurements 41
4.7.3 Compliance criteria for mass-produced products (80 %/80 % rule) 41
4.7.4 Compliance criteria for quality assurance tests using a reference EUT 42
4.7.5 Application of uncertainties in re-testing 42

5 Basic considerations on uncertainties in immunity testing 44
6 Voltage measurements 44
6.1 Introductory remarks 44
6.2 Voltage measurements (general) 44
6.2.1 Introductory remarks 44
6.2.2 Voltage measurements basics 44
6.2.3 The disturbance source and types of voltage 46
6.3 Voltage measurements using a voltage probe 48
6.4 Voltage measurement using a V-terminal artificial mains network 48
6.4.1 Introductory remarks 48
6.4.2 Basic circuit diagram of the voltage measurement 49
6.4.3 Voltage measurement and standards compliance uncertainty 50
6.4.4 Combined uncertainty 51
6.4.5 The compliance criterion 52
6.4.6 Influence quantities 52
7 Absorbing clamp measurements 56
7.1 General 56
7.1.1 Objective 56
7.1.2 Introductory remarks 57
7.2 Uncertainties related to the calibration of the absorbing clamp 57
7.2.1 General 57
7.2.2 The measurand 58
7.2.3 Uncertainty sources 58
7.2.4 Influence quantities 59
7.2.5 Application of the uncertainty budget 63
7.2.6 Typical examples of an uncertainty budget 63
7.2.7 Verification of the uncertainty budget 64
7.3 Uncertainties related to the absorbing clamp measurement method 64
7.3.1 General 64
7.3.2 The measurand 64
7.3.3 Uncertainty sources 65
7.3.4 Influence quantities 66
7.3.5 Application of the uncertainty budget 68
7.3.6 Typical examples of the uncertainty budget 68
7.3.7 Verification of the uncertainty budget 69
8 Radiated emission measurements using a SAC or an OATS in the frequency range of 30 MHz to 1 000 MHz 71
8.1 General 71
8.1.1 Objective 71
8.1.2 Introductory remarks 71
8.2 Uncertainties related to the SAC/OATS radiated emission measurement method 72
8.2.1 General 72
8.2.2 The measurand 73
8.2.3 Uncertainty sources 74
8.2.4 Influence quantities 75
8.2.5 Application of the uncertainty estimate 86
8.2.6 Typical examples of the uncertainty estimate 86

8.2.7 Verification of the uncertainty estimate 87
9 Conducted immunity measurements 88
10 Radiated immunity measurements 88

Annex A (informative) Compliance uncertainty and interference probability 89
Annex B (informative) Numerical example of the consequences of Faraday's law 91
Annex C (informative) Possible amendments to CISPR publications with regards to voltage measurements 93
Annex D (informative) Analysis method of results of an interlaboratory test 96
Annex E (informative) Uncertainty budgets for the clamp calibration methods 97
Annex F (informative) Uncertainty budget for the clamp measurement method 99
Annex G (informative) Uncertainty estimates for the radiated emission measurement methods 101
Annex H (informative) Results of various round robin tests for SAC/OATS-based radiated emission measurements 106
Annex I (informative) Additional information about distinctions between the terms measurement uncertainty and standards compliance uncertainty 112

Bibliography 114

Figure 1 – Illustration of the relation between the overall uncertainty of a measurand due to contributions from the measurement instrumentation uncertainty and the intrinsic uncertainty of the measurand 17
Figure 2 – The process of emission compliance measurements and the associated (categories of) uncertainty sources (see also Table 2) 20
Figure 3 – Relationship between uncertainty sources, influence quantities and uncertainty categories 25
Figure 4 – Involvement of the subcommittees CISPR/H and CISPR/A in the determination of the measurands and application of uncertainties 26
Figure 5 – The uncertainty estimation process 27
Figure 6 – Example of a fishbone diagram indicating the various uncertainty sources for an absorbing clamp compliance measurement in accordance with CISPR 16-2-2 29
Figure 7 – Illustration of the minimum requirement (interval compatibility requirement) for the standards compliance uncertainty 33
Figure 8 – Graphical representation of four cases in the compliance determination process without consideration of measurement uncertainty during limits setting 38
Figure 9 – Graphical representation of four cases in the compliance determination process with consideration of measurement uncertainty during limits setting. 39
Figure 10 – Generic relation between overall uncertainty of measurand and some major categories of uncertainties 39
Figure 11 – Graphical representation MIU compliance criterion for compliance measurements, per CISPR 16-4-2 41
Figure 12 – Basic circuit of a voltage measurement 45
Figure 13 – Basic circuit of a loaded disturbance source (N = 2) 46
Figure 14 – Relation between the voltages 47
Figure 15 – Basic circuit of the V-AMN voltage measurement (N = 2) 49
Figure 16 – Basic circuit of the V-AN measurement during the reading of the received voltage $U_{\mathbf{m}}$ (the numbers refer to Figure 15) 50

Figure 17 – The absolute value of the sensitivity coefficient c_2 as a function of the phase angle difference φ of the impedances Z_{13} and Z_{d0} for several values of the ratio $|Z_{13}/Z_{d0}|$ 51

Figure 18 – Variation of the parasitic capacitance, and hence of the CM-impedance, by changing the position of the reference plane (non-conducting EUT housing) 53

Figure 19 – Influence quantities in between the EUT (disturbance source) and the V-AMN 55

Figure 20 – Schematic overview of the original clamp calibration method 58

Figure 21 – Diagram that illustrates the uncertainty sources associated with the original clamp calibration method 59

Figure 22 – Schematic overview of the clamp measurement method 64

Figure 23 – Diagram that illustrates the uncertainty sources associated with the clamp measurement method 65

Figure 24 – Measurement results of an absorbing clamp RRT performed by six test laboratories in the Netherlands using a drill as EUT 70

Figure 25 – Schematic of a radiated emission measurement set-up in a SAC 72

Figure 26 – Uncertainty sources associated with the SAC/OATS radiated emission measurement method 74

Figure A.1 – Measured field strength distributions X1 and Y1, emission limit and level to be protected of relevance in the determination of the corresponding interference probability determined by distributions X2 and Y2 90

Figure B.1 – Voltage and current limits as given in CISPR 15:2005, Tables 2b and 3, and the ratio U_L/I_L 92

Figure B.2 – Factor K_S derived from the data in Figure B.1 and Equation (B.4) 92

Figure C.1 – Schematic diagram of a V-AMN yielding an improved figure-of-merit about the actual compliance probability via two current probes 95

Figure H.1 – Expanded uncertainties of emission measurement results for five different emulated EUTs each with five different cable termination conditions [24] 108

Figure H.2 – Interlaboratory comparison measurement results of twelve 10 m SACs [see “HP (2000)” in Table H.1] 108

Figure H.3 – ILC measurement results radiated emission SAC/OATS 3 m (11 sites) [32] 109

Figure H.4 – ILC measurement results radiated emission SAC/OATS 3 m (14 sites) [13], [25] 110

Figure H.5 – Measured correlation curve of 3 m and 10 m SAC/OATS-emission measurement of a battery-fed table-top type of EUT, compared with the free-space rule-of-thumb ratio [13], [25] 111

Table 1 – Structure of clauses related to the subject of standards compliance uncertainty 9

Table 2 – Categories of uncertainty sources in standardised emission measurements 20

Table 3 – Example of detailed standard induced uncertainty sources for a radiated emission measurement 21

Table 4 – Different types of uncertainties used within CISPR at present 22

Table 5 – Examples (not exhaustive) of the translation of ‘uncertainty sources’ into ‘influence quantities’ for an emission measurement on an OATS per CISPR 22 23

Table 6 – Influence quantities associated with the uncertainty sources given in Figure 21 for the original clamp calibration method 60

Table 7 – Influence quantities associated with the uncertainty sources given in Figure 23 for the clamp measurement method 66

Table 8 – Measurement results of an absorbing clamp RRT performed by six test laboratories in Germany using a vacuum cleaner motor as EUT 70

Table 9 – Summary of various MIU and SCU values (expanded uncertainties) for the clamp measurement method derived from different sources of information 71

Table 10 – Influence quantities for the SAC/OATS radiated emission measurement method associated with the uncertainty sources of Figure 26 76

Table 11 – Relation between/and type of EUT and set-up-related uncertainties 77

Table 12 – Example of uncertainty estimate associated with the NSA measurement method, 30 MHz to 1 000 MHz 82

Table 13 – Relationship between intrinsic and apparent NSA 83

Table E.1 – Uncertainty budget for the original absorbing clamp calibration method in the frequency range 30 MHz to 300 MHz 97

Table E.2 – Uncertainty budget for the original absorbing clamp calibration method in the frequency range 300 MHz to 1 000 MHz 98

Table F.1 – Uncertainty budget for the absorbing clamp measurement method in the frequency range 30 MHz to 300 MHz 99

Table F.2 – Uncertainty budget for the absorbing clamp measurement method in the frequency range 300 MHz to 1 000 MHz 100

Table G.1 – Uncertainty estimate for the radiated emission measurement method in the frequency range 30 MHz to 200 MHz at a measurement distance of 3 m 102

Table G.2 – Uncertainty estimate for the radiated emission measurement method in the frequency range 200 MHz to 1 000 MHz at a measurement distance of 3 m 103

Table G.3 – Uncertainty data of some influence quantities for the radiated emission measurement method in the frequency range 30 MHz to 200 MHz at measurement distances of 3 m, 10 m, or 30 m 104

Table G.4 – Uncertainty data of some influence quantities for the radiated emission measurement method in the frequency range 200 MHz to 1 000 MHz at measurement distances of 3 m, 10 m, or 30 m 105

Table H.1 – Summary of various MIU and SCU uncertainty values for the SAC/OATS-based radiated emission measurement method, assembled from various sources 107

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 4-1: Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests

FOREWORD

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

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

CISPR 16-4-1, which is a technical report, has been prepared by CISPR subcommittee A: Radio-interference measurements and statistical methods, of IEC technical committee CISPR: International special committee on radio interference.

This second edition of CISPR 16-4-1 cancels and replaces the first edition published in 2003, and its Amendments 1 (2004) and 2 (2007). It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition. The provisions available for application of uncertainties in the determination of the

compliance criterion are explained more generally and a procedure is added for re-testing an approved EUT by another test house.

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

Enquiry draft	Report on voting
CISPR/A/818/DTR	CISPR/A/831/RVC

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

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

A list of all parts of the CISPR 16 series can be found, under the general title *Specification for radio disturbance and immunity measuring apparatus and methods*, on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

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

INTRODUCTION

The result of the application of basic considerations (Clauses 4 and 5) in this part to existing or new CISPR standards will lead to proposals to improve and harmonise the uncertainty aspects of those CISPR standards. Such proposals will also be published as reports within this part and will give the background and rationale for improvement of certain CISPR standards. Clause 6 is an example of such a report.

The structure of clauses related to the CISPR standards compliance uncertainty work is depicted in Table 1. Clause 4 deals with the basic considerations of standards compliance uncertainties in emission measurements. Clauses 6, 7 and 8 contain uncertainty considerations related to voltage, absorbing clamp and radiated emission measurements, respectively.

Uncertainty work will also be considered for immunity compliance tests in the future. Clauses 5, 9 and 10 are reserved for this material. SCU (see 3.1.16) considerations of immunity tests differ from the emission SCU considerations in particular points. For instance, in an immunity test, the measurand is often a functional attribute of the EUT and not a specific quantity. This may cause additional specific SCU considerations. Priority has been given to the uncertainty evaluations for emission measurements at this stage of the work.

Table 1 – Structure of clauses related to the subject of standards compliance uncertainty

STANDARDS COMPLIANCE UNCERTAINTY			
Clause 1, 2, and 3: General			
EMISSION			**IMMUNITY**
Clause 4	Basic considerations	Clause 5	Basic considerations
Clause 6	Voltage measurements	Clause 9	Conducted immunity tests
Clause 7	Absorbing clamp measurements	Clause 10	Radiated immunity tests
Clause 8	Radiated emission measurements		

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 4-1: Uncertainties, statistics and limit modelling – Uncertainties in standardized EMC tests

1 Scope

This part of CISPR 16-4 gives guidance on the treatment of uncertainties to those who are involved in the development or modification of CISPR electromagnetic compatibility (EMC) standards. In addition, this part provides useful background information for those who apply the standards and the uncertainty aspects in practice.

The objectives of this part are to:

a) identify the parameters or sources governing the uncertainty associated with the statement that a given product complies with the requirement specified in a CISPR recommendation. This uncertainty will be called “standards compliance uncertainty” (SCU, see 3.1.16);

b) give guidance on the estimation of the magnitude of the standards compliance uncertainty;

c) give guidance for the implementation of the standards compliance uncertainty into the compliance criterion of a CISPR standardised compliance test.

As such, this part can be considered as a handbook that can be used by standards writers to incorporate and harmonise uncertainty considerations in existing and future CISPR standards. This part also gives guidance to regulatory authorities, accreditation bodies and test engineers to judge the performance quality of an EMC test-laboratory carrying out CISPR standardised compliance tests. The uncertainty considerations given in this part can also be used as guidance when comparing test results (and their uncertainties) obtained by using different alternative test methods.

The uncertainty of a compliance test also relates to the probability of occurrence of an electromagnetic interference (EMI) problem in practice. This aspect is recognized and introduced briefly in this part. However, the problem of relating uncertainties of a compliance test to the occurrence of EMI in practice is not considered within the scope of this part.

The scope of this part is limited to all the relevant uncertainty considerations of a standardized EMC compliance test.

2 Normative references

The following referenced documents are indispensable for the application 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) – Chapter 161: Electromagnetic Compatibility*

IEC 60050-300:2001, *International Electrotechnical Vocabulary (IEV) – Electrical and electronic measurements and measuring instruments – Part 311: General terms relating to measurements – Part 312: General terms relating to electrical measurements – Part 313: Types of electrical measuring instruments – Part 314: Specific terms according to the type of instrument*

IEC 60359:2001, *Electrical and electronic measurement equipment – Expression of performance*

CISPR 16-1-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Conducted disturbances*

CISPR 16-1-3:2004, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-3: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Disturbance power*

CISPR 16-1-4:2007, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Radiated disturbances*

CISPR 16-1-5:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-5: Radio disturbance and immunity measuring apparatus – Antenna calibration test sites for 30 MHz to 1 000 MHz*

CISPR 16-2-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-2: Methods of measurement of disturbances and immunity – Measurement of disturbance power*
Amendment 1 (2004)
Amendment 2 (2005)

CISPR 16-2-3:2006, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements*

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

CISPR/TR 16-4-3:2004, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-3: Uncertainties, statistics and limit modelling – Statistical considerations in the determination of EMC compliance of mass-produced products*

CISPR 22:2008, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

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

ISO/IEC Guide 99:2007, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*