

# CONSOLIDATED VERSION

## VERSION CONSOLIDÉE



INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE  
COMITÉ INTERNATIONAL SPÉCIAL DES PERTURBATIONS RADIOÉLECTRIQUES

BASIC EMC PUBLICATION  
PUBLICATION FONDAMENTALE EN CEM

**Specification for radio disturbance and immunity measuring apparatus and methods –  
Part 4-2: Uncertainties, statistics and limit modelling – Measurement instrumentation uncertainty**

**Spécifications des méthodes et des appareils de mesure des perturbations radioélectriques et de l'immunité aux perturbations radioélectriques –  
Partie 4-2: Incertitudes, statistiques et modélisation des limites – Incertitudes de mesure de l'instrumentation**



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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY  
MEASURING APPARATUS AND METHODS –****Part 4-2: Uncertainties, statistics and limit modelling –  
Measurement instrumentation uncertainty**

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**This Consolidated version of CISPR 16-4-2 bears the edition number 2.1. It consists of the second edition (2011-06) [documents CISPR/A/942/FDIS and CISPR/A/952/RVD] and its corrigendum (2013-04), its amendment 1 (2014-02) [documents CISPR/A/1049/FDIS and CISPR/A/1058/RVD] and its amendment 2 (2018-08) [documents CISPR/A/1257/FDIS and CISPR/A/1259/RVD]. The technical content is identical to the base edition and its amendments.**

**In this Redline version, a vertical line in the margin shows where the technical content is modified by amendments 1 and 2. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.**

International Standard CISPR 16-4-2 has been prepared by CISPR subcommittee A: Radio-interference measurements and statistical methods.

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

- Methods of conducted disturbance measurements
  - on the mains port using a voltage probe,
  - on the telecommunication port using an AAN (ISN),
  - on the telecommunication port using a CVP, and
  - on the telecommunication port using a current probe.
- Methods of radiated disturbance measurements
  - in the frequency range 30 MHz to 1 000 MHz using a FAR, and
  - in the frequency range 1 GHz to 18 GHz using a FAR.

This publication has the status of a basic EMC standard in accordance with IEC Guide 107:2009, *Electromagnetic compatibility – Guide to the drafting of electromagnetic compatibility publications*.

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.

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## INTRODUCTION

The CISPR 16-4 series, *Specification for radio disturbance and immunity measuring apparatus and methods – Uncertainties, statistics and limit modelling*, contains information related to uncertainties, statistics and limit modelling, and consists of the following five parts:

- Part 4-1: Uncertainties in standardized EMC tests,
- Part 4-2: Measurement instrumentation uncertainty,
- Part 4-3: Statistical considerations in the determination of EMC compliance of mass-produced products,
- Part 4-4: Statistics of complaints and a model for the calculation of limits for the protection of radio services, and
- Part 4-5: Conditions for the use of alternative test methods.

For practical reasons, standardized electromagnetic compatibility (EMC) tests are simplified representations of possible electromagnetic interference (EMI) scenarios that a product may encounter in practice. Consequently, in an EMC standard, the measurand, the limit, measurement instruments, measurement set-up, measurement procedure and measurement conditions are simplified but are still meaningful (representative). Here meaningful means that there is a statistical correlation between compliance of the product with a limit, based on a standardized EMC test using standardized test equipment, and a high probability of actual EMC of the same product during its life cycle. Part 4-4 provides methods based on statistics to derive meaningful disturbance limits to protect radio services.

In general, a standardized EMC test should be developed such that reproducible results are obtained if different parties perform the same test with the same EUT. However, various uncertainty sources limit the reproducibility of a standardized EMC.

Part 4-1 is a technical report that consists of a collection of informative reports that address all relevant uncertainty sources that may be encountered during EMC compliance tests. Typical examples of uncertainty sources are the EUT itself, the measurement instrumentation, the set-up of the EUT, the test procedures and the environmental conditions.

Part 4-2 describes a specific category of uncertainties, i.e. measurement instrumentation uncertainties. In this part, examples of MIU budgets are given for most of the CISPR measurement methods. Also in this part, normative requirements are given on how to apply the MIU when determining compliance of an EUT with a disturbance limit (i.e. conformity assessment decision).

Part 4-3 is a technical report that describes the statistical treatment of test results when compliance tests are performed on samples of mass-produced products. This treatment is known as the 80 %/80 % rule.

Part 4-4 is a technical report that contains CISPR recommendations for the collation of statistical data on interference complaints and for the classification of interference sources. Also, models for the calculation of limits for various modes of interference coupling are given.

Part 4-5 is a technical report describing a method to enable product committees to develop limits for alternative test methods, using conversions from established limits.

## **SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –**

### **Part 4-2: Uncertainties, statistics and limit modelling – Measurement instrumentation uncertainty**

#### **1 Scope**

This part of CISPR 16-4 specifies the method of applying Measurement Instrumentation Uncertainty (MIU) when determining compliance with CISPR disturbance limits. The material is also relevant to any EMC test when interpretation of the results and conclusions reached will be impacted by the uncertainty of the measurement instrumentation used during testing.

NOTE In accordance with IEC Guide 107, CISPR 16-4-2 is a basic EMC standard for use by product committees of the IEC. As stated in Guide 107, product committees are responsible for determining the applicability of the EMC standard. CISPR and its sub-committees are prepared to co-operate with technical committees and product committees in the evaluation of the applicability of this standard for specific products.

The annexes contain the background material used in providing the amount of MIU found in generating the CISPR values shown in Clauses 4 through 8 and hence provide valuable background material for those needing both initial and further information on MIU and how to take individual uncertainties in the measurement chain into account. The annexes, however, are not intended to be a tutorial or user manual or to be copied when making uncertainty calculations. For that purpose, the references shown in the bibliography, or other widely recognized documents, may be used.

Measurement instrumentation specifications are given in the CISPR 16-1 series, while the methods of measurement are covered in the CISPR 16-2 series. Further information and background on CISPR and radio disturbances is given in CISPR 16-3. The other parts of the CISPR 16-4 series contain further information on uncertainties in general, statistics and limit modelling. See the introduction of this part for more information on the background and on the content of the CISPR 16-4 series.

#### **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.

CISPR 11, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 12, *Vehicles, boats and internal combustion engines – Radio disturbance characteristics – Limits and methods of measurement for the protection of off-board receivers*

CISPR 13, *Sound and television broadcast receivers and associated equipment – Radio disturbance characteristics – Limits and methods of measurement*

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

CISPR 16-1-3, *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, *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*

CISPR 16-2-1, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

CISPR 16-2-2, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-2: Methods of measurement of disturbances and immunity – Measurement of disturbance power*

CISPR 16-2-3:2010 2016, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements*

CISPR 16-3, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 3: CISPR technical reports*

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

CISPR 16-4-3, *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 Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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

### **3 Terms, definitions, symbols and abbreviations**

#### **3.1 Terms and definitions**

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 98-3 and ISO/IEC Guide 99, as well as the following apply.

NOTE General terms and definitions used in the expression of uncertainty are contained in ISO/IEC Guide 98-3. General metrology definitions are contained in ISO/IEC Guide 99. Relevant basic definitions are not repeated here.

### 3.1.1

#### measurement instrumentation uncertainty

##### MIU

parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand, induced by all relevant input quantities that are related to the measurement instrumentation

### 3.1.2

#### small EUT

equipment, either positioned on a table top or standing on the floor that, including its cables, fits in a cylindrical test volume of 1,5 m in diameter and 1,5 m in height measured from the floor

## 3.2 Symbols

For the purposes of this document, the symbols given in Clauses 3, 5, 6, 7 and 8 apply, as well as the following.

### 3.2.1 General symbols

|                    |                                                                                                                                                                 |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $X_i$              | input quantity                                                                                                                                                  |
| $x_i$              | estimate of $X_i$                                                                                                                                               |
| $\delta X_i$       | correction for input quantity                                                                                                                                   |
| $u(x_i)$           | standard uncertainty of $x_i$                                                                                                                                   |
| $c_i$              | sensitivity coefficient                                                                                                                                         |
| $y$                | result of a measurement (the estimate of the measurand), corrected for all recognised significant systematic effects, in logarithmic units, e.g. dB( $\mu$ V/m) |
| $u_c(y)$           | (combined) standard uncertainty of $y$ , in dB                                                                                                                  |
| $U(y)$             | expanded uncertainty of $y$ , in dB                                                                                                                             |
| $U_{\text{cispr}}$ | CISPR criterion for the expanded MIU evaluated in this standard for each specific measurement method, in dB                                                     |
| $U_{\text{lab}}$   | expanded MIU determined by the test laboratory, in dB                                                                                                           |
| $k$                | coverage factor                                                                                                                                                 |
| $a^+$              | upper abscissa of a probability distribution                                                                                                                    |
| $a^-$              | lower abscissa of a probability distribution                                                                                                                    |

### 3.2.2 Symbols for measured quantities

|     |                                                        |
|-----|--------------------------------------------------------|
| $E$ | disturbance electric field strength, in dB( $\mu$ V/m) |
| $I$ | disturbance current, in dB( $\mu$ A)                   |
| $P$ | disturbance power, in dB(pW)                           |
| $V$ | disturbance voltage, in dB( $\mu$ V)                   |

### 3.2.3 Symbols for input quantities common to all disturbance measurements

|                 |                                                                                                                |
|-----------------|----------------------------------------------------------------------------------------------------------------|
| $a_c$           | attenuation of the connection between the receiver and the ancillary equipment (e.g. AMN, antenna etc.), in dB |
| $\delta M$      | correction for the error caused by mismatch, in dB                                                             |
| $V_r$           | receiver voltage reading, in dB( $\mu$ V)                                                                      |
| $\delta V_{sw}$ | correction for receiver sine wave voltage inaccuracy, in dB                                                    |
| $\delta V_{pa}$ | correction for imperfect receiver pulse amplitude response, in dB                                              |
| $\delta V_{pr}$ | correction for imperfect receiver pulse repetition rate response, in dB                                        |
| $\delta V_{nf}$ | correction for the effect of the receiver noise floor, in dB                                                   |

### 3.3 Abbreviations

For the purposes of this document, the following abbreviations apply.

NOTE Abbreviations not shown here are defined at their first occurrence in this document.

|              |                                                                                                                                                                         |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AAN          | asymmetric artificial network                                                                                                                                           |
| AE           | associated equipment (equipment connected to the AE port of the ancillary equipment; ancillary equipment is a transducer, e.g. an AAN; see definitions in CISPR 16-2-1) |
| AF           | antenna factor                                                                                                                                                          |
| AMN          | artificial mains network                                                                                                                                                |
| AN           | artificial network                                                                                                                                                      |
| CDNE         | coupling decoupling network for emission measurement                                                                                                                    |
| CP           | current probe                                                                                                                                                           |
| CVP          | capacitive voltage probe                                                                                                                                                |
| EUT          | equipment under test                                                                                                                                                    |
| FAR          | fully anechoic room                                                                                                                                                     |
| FSOATS       | free-space OATS (refer to CISPR16-1-4)                                                                                                                                  |
| LCL          | longitudinal conversion loss                                                                                                                                            |
| LLAS         | large loop antenna system                                                                                                                                               |
| LPDA         | logarithmic periodic (log-periodic) dipole array                                                                                                                        |
| LV           | low voltage                                                                                                                                                             |
| MIU          | measurement instrumentation uncertainty                                                                                                                                 |
| OATS         | open area test site                                                                                                                                                     |
| PRF          | pulse repetition frequency                                                                                                                                              |
| RF           | radio frequency                                                                                                                                                         |
| SAC          | semi-anechoic chamber                                                                                                                                                   |
| S/N          | signal to noise ratio                                                                                                                                                   |
| VDF          | voltage division factor                                                                                                                                                 |
| VP           | voltage probe                                                                                                                                                           |
| VSWR         | voltage standing wave ratio                                                                                                                                             |
| V-AMN        | artificial mains V-network                                                                                                                                              |
| $\Delta$ -AN | artificial $\Delta$ -network (' $\Delta$ ' is pronounced 'delta')                                                                                                       |

## 4 Compliance criterion for the MIU

### 4.1 General

MIU shall be taken into account, as described in this clause, when determining compliance or non-compliance of an EUT with a disturbance limit.

The MIU for a test laboratory shall be evaluated for the measurements addressed in Clauses 5 through 8, taking into consideration each of the input quantities listed there. The standard uncertainty  $u(x_i)$  in dB, and the sensitivity coefficient  $c_i$ , shall be evaluated for the estimate  $x_i$  of each quantity. The combined standard uncertainty  $u_c(y)$  of the estimate  $y$  of the measurand shall be calculated using

$$u_c(y) = \sqrt{\sum_i c_i^2 u^2(x_i)} \quad (1)$$

The expanded MIU  $U_{\text{lab}}$  for a test laboratory shall be calculated for each type of measurement using

$$U_{\text{lab}} = U(y) = 2 u_c(y) \quad (2)$$

If  $U_{\text{lab}}$  is less than or equal to  $U_{\text{CISPR}}$  in Table 1, then the test report may either state the value of  $U_{\text{lab}}$  or state that  $U_{\text{lab}}$  is less than  $U_{\text{CISPR}}$ .

If  $U_{\text{lab}}$  exceeds  $U_{\text{CISPR}}$  of Table 1, then the test report shall contain the value of  $U_{\text{lab}}$  (in dB) for the measurement instrumentation actually used for the measurements.

NOTE Equation (2) means that a coverage factor  $k = 2$  is applied that yields approximately a 95 % level of confidence for the near-normal distribution typical of most measurement results.

**Table 1 – Values of  $U_{\text{cispr}}$**

| Measurement                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                       | $U_{\text{cispr}}$ | Table      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|--------------------|------------|
| Conducted disturbance at AC mains and other port power using a V-AMN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | (9 kHz to 150 kHz)    | 3,8 dB             | B.1        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | (150 kHz to 30 MHz)   | 3,4 dB             | B.2        |
| Conducted disturbance at AC mains port using a voltage probe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | (9 kHz to 30 MHz)     | 2,9 dB             | B.3        |
| Conducted disturbance at telecommunication port using AAN                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | (150 kHz to 30 MHz)   | 5,0 dB             | B.4        |
| Conducted disturbance at telecommunication port using CVP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | (150 kHz to 30 MHz)   | 3,9 dB             | B.5        |
| Conducted disturbance at telecommunication port using CP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | (150 kHz to 30 MHz)   | 2,9 dB             | B.6        |
| Conducted disturbance at telecommunication port using CP and CVP                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | (150 kHz to 30 MHz)   | 4,0 dB             | B.5        |
| Disturbance power                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | (30 MHz to 300 MHz)   | 4,5 dB             | C.1        |
| Radiated disturbance (disturbance current in a LLAS)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | (9 kHz to 30 MHz)     | 3,3 dB             | F.1        |
| Radiated disturbance (electric field strength at an OATS or in a SAC)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | (30 MHz to 1 000 MHz) | 6,3 dB             | D.1 to D.4 |
| Radiated disturbance (electric field strength in a FAR)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | (30 MHz to 1 000 MHz) | 5,3 dB             | D.5 to D.6 |
| Radiated disturbance (electric field strength in a FAR)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | (1 GHz to 6 GHz)      | 5,2 dB             | E.1        |
| Radiated disturbance (electric field strength in a FAR)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | (6 GHz to 18 GHz)     | 5,5 dB             | E.2        |
| Conducted disturbance at mains port using CDNE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | (30 MHz to 300 MHz)   | 3,8 dB             | B.7        |
| <p>NOTE 1 The values of <math>U_{\text{cispr}}</math> are based on the expanded uncertainties in the annexes that were evaluated by considering uncertainties associated with the quantities listed in the measurement-specific subclause. If there are different values in the annexes, then the value taken as <math>U_{\text{cispr}}</math> is the maximum value (e.g. maximum of Tables D.1 through D.4).</p> <p>NOTE 2 In the frequency range below 1 GHz, the values of <math>U_{\text{cispr}}</math> were calculated for measurements using the quasi-peak detector, assuming that values for the average detector and r.m.s.-average detector would not exceed these values. Above 1 GHz, the value of <math>U_{\text{cispr}}</math> was calculated for measurements using the peak detector.</p> <p>NOTE 3 The value of <math>U_{\text{cispr}}</math> for conducted disturbances at telecommunication ports using CP and CVP is based on the expanded uncertainty in Table B.5 with consideration of additional uncertainties attributed to the CP transfer admittance <math>Y_T</math> and mismatch uncertainty CP-receiver <math>\delta M</math>; see comment B18).</p> <p>NOTE 4 The values of <math>U_{\text{cispr}}</math> for the OATS, SAC and FAR are based on a small EUT – an EUT fitting in a cylindrical test volume of 1,5 m in diameter and 1,5 m in height – for a 3 m measurement distance (per 3.1.2).</p> |                       |                    |            |

Nothing in this clause supersedes the requirement for measurement instrumentation to comply with specifications of the CISPR 16-1 series. Also, this clause does not replace the requirement to comply with CISPR 16-4-3.

## 4.2 Compliance assessment

Compliance or non-compliance with a disturbance limit shall be determined in the following manner.

If  $U_{\text{lab}}$  is less than or equal to  $U_{\text{cispr}}$  of Table 1, then:

- compliance is deemed to occur if no measured disturbance level exceeds the disturbance limit;
- non-compliance is deemed to occur if any measured disturbance level exceeds the disturbance limit.

If  $U_{lab}$  is greater than  $U_{cispr}$  of Table 1, then:

- compliance is deemed to occur if no measured disturbance level, increased by  $(U_{lab} - U_{cispr})$ , exceeds the disturbance limit;
- non-compliance is deemed to occur if any measured disturbance level, increased by  $(U_{lab} - U_{cispr})$ , exceeds the disturbance limit.

NOTE For the compliance assessment procedure described in this subclause, both the measured disturbance level and the disturbance limit are expressed in logarithmic units, e.g. dB( $\mu$ V/m).

## 5 Conducted disturbance measurements

### 5.1 Conducted disturbance measurements at a mains port using a ~~V~~ V-AMN (see also B.1)

#### 5.1.1 Measurand for measurements using a ~~V~~ V-AMN

$V$  Unsymmetric voltage, in dB( $\mu$ V), measured at the EUT port of the AMN relative to the reference ground plane

#### 5.1.2 Symbols of input quantities specific to measurements using a ~~V~~ V-AMN

$F_{AMN}$  Voltage division factor of the AMN, in dB

$\delta F_{AMNf}$  Correction for voltage division factor (VDF) frequency interpolation error, in dB

$\delta D_{mains}$  Correction for the error caused by AC mains and other power supply disturbances, in dB

$\delta V_{env}$  Correction for the effect of the environment, in dB

$\delta Z_{AMN}$  Correction for imperfect AMN impedance, in dB

#### 5.1.3 Input quantities to be considered for conducted disturbance measurements at a mains port using a ~~V~~ V-AMN

- Receiver reading
- Attenuation of the connection between AMN and receiver
- AMN voltage division factor
- AMN VDF frequency interpolation
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch effects between AMN receiver port and receiver
- AMN impedance
- Effect of ~~mains~~ disturbances originating from the laboratory AC mains or other power supply
- Effect of environment

### 5.2 Conducted disturbance measurements at a mains port using a VP (see also B.2)

#### 5.2.1 Measurand for measurements using a VP

$V$  Unsymmetric voltage, in dB( $\mu$ V), measured at the EUT power port – loaded with an impedance of 1 500  $\Omega$  – relative to the reference ground

### 5.2.2 Symbols of input quantities specific to measurements using a VP

|                    |                                                                                      |
|--------------------|--------------------------------------------------------------------------------------|
| $F_{VP}$           | Voltage division factor (VDF) of the voltage probe, in dB                            |
| $\delta F_{VPf}$   | Correction for the VDF frequency interpolation error, in dB                          |
| $\delta D_{mains}$ | Correction for the error caused by mains disturbances, in dB                         |
| $\delta V_{env}$   | Correction for the effect of the environment, in dB                                  |
| $\delta Z_{VP}$    | Correction for imperfect voltage probe impedance, in dB                              |
| $\delta Z_{mains}$ | Correction for the error caused by the mains impedance when compared with AMN, in dB |

### 5.2.3 Input quantities to be considered for conducted disturbance measurements at a mains port using a VP

- Receiver reading
- Attenuation of the connection between VP and receiver
- VP VDF
- VP VDF frequency interpolation
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch effects between VP receiver port and receiver
- VP impedance
- Effect of mains disturbances
- Effect of mains impedance when compared with AMN
- Effect of environment

## 5.3 Conducted disturbance measurements at a telecommunication port using an AAN (Y-network) (see also B.3)

NOTE The term “asymmetric artificial network (AAN)” is defined in CISPR 16-1-2. It is referred to as an impedance stabilization network (ISN) in CISPR 22. The term Y-network differentiates it from V- and  $\Delta$ -networks.

### 5.3.1 Measurand for measurements using an AAN

|     |                                                                                                                               |
|-----|-------------------------------------------------------------------------------------------------------------------------------|
| $V$ | Asymmetric (common mode) voltage, in dB( $\mu$ V), measured at the EUT port of the AAN referred to the reference ground plane |
|-----|-------------------------------------------------------------------------------------------------------------------------------|

### 5.3.2 Symbols of input quantities specific for measurements using an AAN

|                   |                                                                               |
|-------------------|-------------------------------------------------------------------------------|
| $F_{AAN}$         | Voltage division factor (VDF) of the AAN, in dB                               |
| $\delta F_{AANf}$ | Correction for the VDF frequency interpolation error, in dB                   |
| $\delta D_{AE}$   | Correction for the error caused by disturbances from the AE, in dB            |
| $\delta V_{env}$  | Correction for the effect of the environment, in dB                           |
| $\delta a_{LCL}$  | Correction for imperfect longitudinal conversion loss of the AAN, in dB       |
| $\delta Z_{AAN}$  | Correction for imperfect asymmetric (common mode) impedance of the AAN, in dB |

### 5.3.3 Input quantities to be considered for conducted disturbance measurements at a telecommunication port using an AAN

- Receiver reading

- Attenuation of the connection between AAN and receiver
- AAN VDF
- AAN VDF frequency interpolation
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch effects between AAN receiver port and receiver
- Asymmetric impedance of the AAN
- Longitudinal conversion loss (LCL) of the AAN
- Effect of disturbances from the AE
- Effect of environment

#### **5.4 Conducted disturbance measurements at a telecommunication port using a CVP (see also B.4)**

##### **5.4.1 Measurand for measurements using a CVP**

$V$  Asymmetric (common mode) voltage, in dB( $\mu$ V), measured at the telecommunication port referred to the reference ground

##### **5.4.2 Symbols of input quantities specific for measurements using a CVP**

|                    |                                                                                                           |
|--------------------|-----------------------------------------------------------------------------------------------------------|
| $F_{CVP}$          | Voltage division factor (VDF) of the CVP, in dB                                                           |
| $\delta F_{CVPf}$  | Correction for the CVP VDF frequency interpolation error, in dB                                           |
| $\delta D_{AE}$    | Correction for the error caused by disturbances from the AE, in dB                                        |
| $\delta V_{env}$   | Correction for the effect of the environment, in dB                                                       |
| $\delta F_{c pos}$ | Correction for the effect of cable position inside the CVP aperture on the voltage division factor, in dB |
| $\delta F_{c rad}$ | Correction for the effect of cable radius on voltage division factor, in dB                               |
| $\delta Z_{AE}$    | Correction for imperfect termination of the telecommunication port by the AE, in dB                       |
| $\delta Z_{CVP}$   | Correction for the effect of the CVP load impedance, in dB                                                |

##### **5.4.3 Input quantities to be considered for conducted disturbance measurements at a telecommunication port using a CVP**

- Receiver reading
- Attenuation of the connection between CVP and receiver
- CVP VDF
- CVP VDF frequency interpolation
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Effect of cable position inside the CVP aperture on VDF
- Effect of cable radius on VDF

- Effect of disturbances from the AE
- Effect of the AE impedance when compared with AAN
- Mismatch effects between CVP receiver port and receiver
- CVP load impedance
- Effect of environment

## 5.5 Conducted disturbance measurements at a telecommunication port using a CP (see also B.5)

### 5.5.1 Measurand for measurements using a CP

$I$  Asymmetric (common mode) current, in dB( $\mu$ A), measured on the cable connected to the telecommunication port of the EUT

### 5.5.2 Symbols of input quantities specific for measurements using a CP

$Y_T$  Transfer admittance of the CP, in dB(S)  
 $\delta Y_{Tf}$  Correction for the CP transfer admittance frequency interpolation error, in dB  
 $\delta D_{AE}$  Correction for the error caused by disturbances from the AE, in dB  
 $\delta I_{env}$  Correction for the effect of the environment, in dB  
 $\delta Z_{CP}$  Correction for the error caused by the CP insertion impedance, in dB  
 $\delta Z_{AE}$  Correction for imperfect termination of the telecommunication port by the AE, in dB

### 5.5.3 Input quantities to be considered for conducted disturbance measurements at a telecommunication port using a CP

- Receiver reading
- Attenuation of the connection between CP and receiver
- Transfer admittance of the CP
- CP transfer admittance frequency interpolation
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch effects between CP and receiver
- Effect of the CP insertion impedance
- Effect of disturbances from the AE
- Effect of the termination impedance of the telecommunication cable by the AE
- Effect of environment

## 5.6 Conducted disturbance measurements using a CDNE (see also B.7)

### 5.6.1 Measurand for measurements using a CDNE

$V$  Asymmetric (common-mode) disturbance voltage, in dB( $\mu$ V), measured on the connection lead of the EUT through a CDNE referred to reference ground

### 5.6.2 Symbols of input quantities specific to CDNE measurements

$F_{CDNE}$  Voltage division factor (VDF) of the CDNE, in dB  
 $\delta F_{CDNE}$  Correction for VDF frequency interpolation error, in dB

|                               |                                                                       |
|-------------------------------|-----------------------------------------------------------------------|
| $\delta Z_{\text{CDNE}}$      | Correction for the imperfect common mode impedance of the CDNE, in dB |
| $\delta D_{\text{amb}}$       | Correction for the effect of ambient disturbances, in dB              |
| $\delta V_{\text{grounding}}$ | Correction for the effect of imperfect grounding, in dB               |
| $\delta V_{\text{env}}$       | Correction for the effect of the environment, in dB                   |

### 5.6.3 Input quantities to be considered for conducted disturbance measurements at a mains port using a CDNE

- Receiver reading
- Cable attenuation between CDNE and receiver
- CDNE VDF
- CDNE VDF frequency interpolation
- CDNE impedance
- Receiver related input quantities
  - Receiver sine wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse repetition rate response
  - Receiver noise floor proximity
- Mismatch effects between CDNE receiver port and receiver
- Effect of ambient disturbances
- Effect of the grounding
- Effect of environment

## 5.7 Conducted disturbance measurements at AC mains and other power ports using a $\Delta$ -AN

### 5.7.1 Measurand for measurements using a $\Delta$ -AN

|     |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $V$ | Asymmetric voltage in dB( $\mu$ V), measured at the EUT port of the $\Delta$ -AN relative to the reference ground plane, and also symmetric voltage between two terminals at the EUT port of the $\Delta$ -AN not including reference ground; optionally also the unsymmetric voltage in dB( $\mu$ V), measured at the EUT port of the $\Delta$ -AN relative to the reference ground plane, if the $\Delta$ -AN is furnished with a respective port for connection of the measuring receiver |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

### 5.7.2 Symbols of input quantities specific to measurements using a $\Delta$ -AN

|                           |                                                                                        |
|---------------------------|----------------------------------------------------------------------------------------|
| $F_{\text{AN}}$           | Voltage division factor (asymmetric resp. symmetric) of the $\Delta$ -AN, in dB        |
| $\delta F_{\text{AN}f}$   | Correction for voltage division factor (VDF) frequency interpolation error, in dB      |
| $\delta D_{\text{mains}}$ | Correction for the error caused by AC mains and other power supply disturbances, in dB |
| $\delta V_{\text{env}}$   | Correction for the effect of the environment, in dB                                    |
| $\delta Z_{\text{AN}}$    | Correction for imperfect asymmetric or symmetric $\Delta$ -AN impedance, in dB         |

### 5.7.3 Input quantities to be considered for conducted disturbance measurements at AC mains and other power ports using a $\Delta$ -AN

- Receiver reading
- Attenuation of the connection between AN and receiver
- AN voltage division factor (asymmetric and symmetric)
- AN VDF frequency interpolation
- Receiver related input quantities:

- Receiver sine-wave voltage accuracy
- Receiver pulse amplitude response
- Receiver pulse response variation with repetition frequency
- Receiver noise floor
- Mismatch effects between the AN's receiver port and receiver
- AN impedance
- Effect of disturbances originating from the laboratory AC mains or other power supply
- Effect of environment

## 6 Disturbance power measurements (see also C.1)

### 6.1 Measurand for disturbance power measurements

$P$  Disturbance power, in dB(pW), measured on a power lead at the clamp position of maximum indication of emission

### 6.2 Symbols of input quantities specific for disturbance power measurements

$F_{AC}$  Clamp factor (original) of the absorbing clamp, in dB(pW/μV)

NOTE Clamp factor (original) is defined in CISPR 16-1-3.

$\delta F_{ACf}$  Correction for the clamp factor frequency interpolation error, in dB

$\delta D_{mains}$  Correction for the error caused by mains disturbances, in dB

$\delta P_{env}$  Correction for the effect of the environment, in dB

### 6.3 Input quantities to be considered for disturbance power measurements

- Receiver reading
- Attenuation of the connection between absorbing clamp and receiver
- Clamp factor (original) of the absorbing clamp (as defined in CISPR 16-1-3)
- Clamp factor frequency interpolation
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch effects between absorbing clamp receiver port and receiver
- Effect of mains disturbances
- Effect of environment

## 7 Radiated disturbance measurements in the frequency range 30 MHz to 1 000 MHz

### 7.1 Radiated disturbance measurements at an OATS or in a SAC (see also D.1)

#### 7.1.1 Measurand for radiated disturbance measurements at an OATS or in a SAC

$E$  Maximum electric field strength, in dB(μV/m), in horizontal and vertical polarizations measured 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

### 7.1.2 Symbols of input quantities specific for radiated disturbance measurements

|                   |                                                                                 |
|-------------------|---------------------------------------------------------------------------------|
| $F_a$             | Antenna factor, in dB(1/m)                                                      |
| $\delta F_{af}$   | Correction for antenna factor frequency interpolation error, in dB              |
| $\delta F_{ah}$   | Correction for antenna factor variation with height, in dB                      |
| $\delta F_{adir}$ | Correction for antenna directivity, in dB                                       |
| $\delta F_{aph}$  | Correction for antenna phase centre location, in dB                             |
| $\delta F_{acp}$  | Correction for antenna cross-polarization response, in dB                       |
| $\delta F_{abal}$ | Correction for antenna unbalance, in dB                                         |
| $\delta A_N$      | Correction for imperfect normalized site attenuation, in dB                     |
| $\delta A_{NT}$   | Correction for the effect of setup table material on measurement results, in dB |
| $\delta d$        | Correction for imperfect antenna distance, in dB                                |
| $\delta h$        | Correction for imperfect table height above ground plane, in dB                 |
| $\delta E_{amb}$  | Correction for the effect of ambient noise at an OATS, in dB                    |

### 7.1.3 Input quantities to be considered for radiated disturbance measurements at an OATS or in a SAC

- Receiver reading
- Attenuation of the connection between antenna and receiver
- Antenna factor
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch effects between antenna port and receiver
- Antenna factor frequency interpolation
- Antenna factor variation with height
- Antenna directivity
- Antenna phase centre location
- Antenna cross-polarization response
- Antenna balance
- Site attenuation of the test site
- Separation between EUT and measurement antenna
- Height of table supporting the EUT
- Effect of setup table material supporting the EUT
- Effect of ambient noise at an OATS

## 7.2 Radiated disturbance measurements in a FAR (see also D.2)

### 7.2.1 Measurand for radiated disturbance measurements in a FAR

|     |                                                                                                                                                                                          |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $E$ | Maximum electric field strength, in dB( $\mu$ V/m), measured in horizontal and vertical polarizations at the specified horizontal distance from the EUT which is rotated 360° in azimuth |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## 7.2.2 Symbols of input quantities specific for radiated disturbance measurements

|                   |                                                                                 |
|-------------------|---------------------------------------------------------------------------------|
| $F_a$             | Antenna factor, in dB(1/m)                                                      |
| $\delta F_{af}$   | Correction for antenna factor frequency interpolation error, in dB              |
| $\delta F_{ah}$   | Correction for antenna factor variation due to FAR influence, in dB             |
| $\delta F_{adir}$ | Correction for antenna directivity, in dB                                       |
| $\delta F_{aph}$  | Correction for antenna phase centre location, in dB                             |
| $\delta F_{acp}$  | Correction for antenna cross-polarization response, in dB                       |
| $\delta F_{abal}$ | Correction for antenna unbalance, in dB                                         |
| $\delta A_N$      | Correction for imperfect normalized site attenuation, in dB                     |
| $\delta A_{NT}$   | Correction for the effect of setup table material on measurement results, in dB |
| $\delta d$        | Correction for imperfect antenna distance, in dB                                |
| $\delta h$        | Correction for imperfect table height, in dB                                    |

## 7.2.3 Input quantities to be considered for radiated disturbance measurements in a FAR

- Receiver reading
- Attenuation of the connection between antenna and receiver
- Antenna factor
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch effects between antenna port and receiver
- Antenna factor frequency interpolation
- Antenna factor variation due to FAR influence
- Antenna directivity
- Antenna phase centre location
- Antenna cross-polarization response
- Antenna balance
- Site attenuation of the test site (FAR)
- Separation between EUT and measurement antenna
- Effect of setup table material supporting the EUT
- Effect of imperfect table height

## 8 Radiated disturbance measurements in the frequency range 1 GHz to 18 GHz (see also E.1)

### 8.1 Measurand for radiated disturbance measurements in a FAR (FSOATS)

NOTE 1 A FAR is a practical approximation of an FSOATS (see CISPR 16-1-4).

|     |                                                                                                                                                                                                                               |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $E$ | Maximum electric field strength, in dB( $\mu$ V/m), measured in horizontal and vertical polarizations at the applicable antenna height and at the specified horizontal distance from the EUT which is rotated 360° in azimuth |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

NOTE 2 Antenna height variation is applied if the EUT is not encompassed by the antenna vertical-plane beamwidth.

## 8.2 Symbols of input quantities specific for radiated disturbance measurements

|                   |                                                                                 |
|-------------------|---------------------------------------------------------------------------------|
| $G_p$             | Preamplifier gain                                                               |
| $\delta G_p$      | Correction for instability of preamplifier gain, in dB                          |
| $F_a$             | Antenna factor, in dB(1/m)                                                      |
| $\delta F_{af}$   | Correction for antenna factor interpolation error, in dB                        |
| $\delta F_{adir}$ | Correction for antenna directivity, in dB                                       |
| $\delta F_{aph}$  | Correction for antenna phase centre location, in dB                             |
| $\delta F_{acp}$  | Correction for antenna cross-polarization response, in dB                       |
| $\delta S_{VSWR}$ | Correction for imperfect site voltage standing wave ratio ( $S_{VSWR}$ ), in dB |
| $\delta A_{NT}$   | Correction for the effect of setup table material on measurement results, in dB |
| $\delta d$        | Correction for imperfect antenna distance, in dB                                |
| $\delta h$        | Correction for imperfect table height, in dB                                    |

## 8.3 Input quantities to be considered for radiated disturbance measurements in a FAR

- Receiver reading
- Attenuation of the connection between antenna port and preamplifier input
- Preamplifier gain
- Effect of preamplifier gain instability
- Attenuation of the connection between preamplifier output and receiver
- Antenna factor
- Receiver sine-wave voltage accuracy
- Receiver noise floor
- Mismatch effects between antenna port and preamplifier input
- Mismatch effects between preamplifier output and receiver
- Antenna factor frequency interpolation
- Antenna directivity
- Antenna phase centre
- Antenna cross-polarization response
- Site voltage standing wave ratio of the test site (FAR)
- Separation between EUT and measurement antenna
- Effect of setup table material supporting the EUT
- Effect of imperfect table height

## 9 Radiated disturbance measurements in the frequency range 9 kHz to 30 MHz

### 9.1 Magnetic field disturbance measurements using the LLAS in the frequency range 9 kHz to 30 MHz (see also Clause F.1)

#### 9.1.1 Measurand for LLAS measurements

$I$  Current in dB( $\mu$ A), measured in each of the three loops of the LLAS

#### 9.1.2 Symbols of input quantities specific for LLAS measurements

$\delta Z_{vf}$  Correction for validation factor deviation, in dB

$\delta Z_{fi}$  Correction for validation factor frequency interpolation, in dB

### **9.1.3 Input quantities to be considered for LLAS measurements**

- Receiver reading
- Attenuation of connecting cable between LLAS and receiver
- Validation factor deviation
- Validation factor frequency interpolation
- Receiver related input quantities:
  - Receiver sine-wave voltage accuracy
  - Receiver pulse amplitude response
  - Receiver pulse response variation with repetition frequency
  - Receiver noise floor
- Mismatch between LLAS and receiver

### **9.2 Magnetic field disturbance measurement in the frequency range 9 kHz to 30 MHz using a loop antenna at various distances from the EUT**

(Void)

## Annex A (informative)

### Basis for $U_{\text{CISPR}}$ values in Table 1, general information and rationale for input quantities common to all measurement methods

#### A.1 General

Annexes A through E outline the approach used to determine  $U_{\text{CISPR}}$  for the measurement methods specified in the CISPR 16-2 series.

Each annex first presents the model equation for the measurand – the basic equation summarizing the main sources of MIU (i.e. the input quantities) that are attributable to the measurement instrumentation chain. The model equation results from the measurement model and provides a mathematical definition of the measurand.

One or more tables are then presented that document the estimated value of each input quantity that is considered for the calculation of the values of  $U_{\text{CISPR}}$  in Table 1 of Clause 4. Note that values in tables in Annexes B through E are examples only, derived from requirements in the CISPR 16-1 series and do not constitute a requirement.

All assumptions made for the determination of the estimated values are documented. The assumptions are referenced via a superscript. Superscripts marked “A” refer to sources of MIU that are common to more than one measurement method. The assumptions of these sources of MIU are documented in A.2 hereafter. Superscripts marked “B” through “E” refer to sources of MIU that are specific to one measurement method. The assumptions on which the estimates are based are documented within a subclause of the corresponding annex that follows the table(s). A note following a comment is intended to provide additional guidance for test laboratories confronted with data or situations different from those assumed in this document.

The uncertainty associated with the estimate  $x_i$  of each input quantity in the tables of the Annexes B through E is the largest value considered likely within the frequency range covered by the table, provided that this uncertainty value is consistent with the measuring apparatus specifications in the CISPR 16-1 series standards.

Definitions of measurement uncertainty terms and information about the evaluation and expression of the uncertainty of measurement are available in references [2] to [5] of the bibliography and in ISO/IEC Guide 98-3.

The standard uncertainty  $u(x_i)$  is calculated by dividing the value of the uncertainty associated with  $x_i$  by a factor that depends on the probability distribution of the input quantity and on the level of confidence associated with the value. For a U-shaped, rectangular or triangular probability distribution, where  $X_i$  is estimated to lie between  $(x_i - a^-)$  and  $(x_i + a^+)$  with a level of confidence of 100 %,  $u(x_i)$  is taken as  $a/\sqrt{2}$ ,  $a/\sqrt{3}$  or  $a/\sqrt{6}$  respectively, where  $a = (a^+ + a^-)/2$  is the half-width of the probability distribution. For a normal probability distribution, the divisor is 2 if the value of the uncertainty associated with  $x_i$  has a level of confidence of 95 % (the value is twice the experimental standard deviation), or 1 if the value of the uncertainty associated with  $x_i$  has a level of confidence of 68 % (the value is the experimental standard deviation). In case of a non-symmetrical distribution, the value  $\delta x_i = c_i (a^+ - a^-)/2$ , if significant, should be considered to be applied for a correction of the measurement result. If it is insignificant, it is acceptable to use the average of the two limits.

A correction is 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 in the model equations preceding the tables. Every correction also serves as an input quantity having an associated uncertainty.

The assumptions leading to the values in the tables of Annexes B through E may not be appropriate for a particular test laboratory. When a test laboratory evaluates its expanded MIU  $U_{lab}$ , it shall consider the information available about its own particular measuring system, including equipment characteristics, actual validation data of the test sites, the quality of calibration data (within the defined calibration interval), the known or likely probability distributions and internal measurement procedures. A test laboratory may find it advantageous to evaluate its uncertainties over subranges of the frequency range of interest, particularly if a dominant input quantity varies significantly over the complete frequency range.

The frequency step size of a measuring receiver is not regarded as a source of uncertainty, as it can be minimized by reducing the step size and avoided altogether by a final frequency adjustment. Guidance to selecting the step size is given in CISPR 16-2-1, CISPR 16-2-2 and CISPR 16-2-3. Final frequency adjustments will normally be done at the critical frequencies with respect to the disturbance limit. If reduction of step size or final frequency adjustment is not used, it may have to be treated as an additional input quantity. This is similar to the antenna height and EUT azimuth stepped scanning in radiated emission measurements, where it is advisable to use final height and azimuth adjustment as well. Some of these effects are discussed in CISPR 16-4-1.

The sensitivity coefficients are partial derivatives of the model equation for the measurands (i.e. the left-hand sides of the model equations) with respect to the varying input quantity. Since all model equations are linear in logarithmic units, all sensitivity coefficients  $c_i$  become 1 ( $c_i = 1$ ) and are therefore not listed in the tables.

Repeatability of cable connections is considered negligibly small compared to the other sources of uncertainty. Therefore it is not included as a relevant input quantity.

In the uncertainty budgets a normal distribution function is used, unless otherwise identified in the tables.

## A.2 Rationale for the estimates of input quantities common to all disturbance measurements ("A" comments)

The following comments are applicable to the input quantities that are common to more than one measurement method, being those marked with the superscript "A" (e.g. <sup>A1</sup>).

- A1) Receiver readings will vary for reasons that include measuring system instability and meter scale interpolation errors.

The estimate of  $V_r$  is the mean of many readings (sample size larger than 10) of a stable signal, with a standard uncertainty given by the experimental standard deviation of the mean ( $k = 1$ ).

- A2) An estimate of the attenuation  $a_c$  of the connection between the receiver and the V-AMN, AAN, CDNE, CP, CVP, VP, LLAS, absorbing clamp or antenna is assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

NOTE 1 If the estimate of attenuation  $a_c$  is obtained from manufacturer's data for a cable or attenuator, a rectangular probability distribution having a half-width equal to the manufacturer's specified tolerance on the attenuation may be assumed. If the connection is a cable and attenuator in tandem, with manufacturer's data available on each,  $a_c$  has two components, each with its own rectangular probability distribution.

NOTE 2 This uncertainty contribution is not applicable if the absorbing clamp is calibrated together with the cable.

NOTE 3 In Tables B.1 through B.6, the estimate of the expanded uncertainty is 0,1 dB, in Table C.1 and D.1 through D.6 it is 0,2 dB, in Table E.1 it is 0,3 dB and in Table E.2 it is 0,6 dB with a coverage factor of 2. A lower estimate for this uncertainty contribution can be achieved using a vector network analyzer for the cable calibration.

- A3) An estimate of the correction  $\delta V_{sw}$  for receiver sine-wave voltage accuracy is assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

NOTE 4 If a calibration report states only that the receiver sine-wave voltage accuracy is within the CISPR 16-1-1 tolerance ( $\pm 2$  dB), then the estimate of the correction  $\delta V_{sw}$  should be taken as zero with a rectangular probability distribution having a half-width of 2 dB. If the calibration report states a value less than the CISPR 16-1-1 tolerance (e.g.  $\pm 1$  dB), then this value is to be used in the uncertainty calculation, not the stated uncertainty value of the calibration process. If the calibration report provides detailed deviations from reference values, then the reported deviations and the uncertainties of the calibration laboratory may be used to determine the uncertainties of the measuring receiver [12].

- A4) In general, it is impractical to correct for imperfect receiver pulse response characteristics.

A verification report stating that the receiver pulse amplitude response complies with the CISPR 16-1-1 tolerance of  $\pm 1,5$  dB for peak, quasi-peak, average or r.m.s.-average detection is assumed to be available. The correction  $\delta V_{pa}$  is estimated to be zero with a rectangular probability distribution having a half-width of 1,5 dB.

The CISPR 16-1-1 tolerance for pulse repetition rate response varies with repetition rate and detector type. A verification report stating that the receiver pulse repetition rate responses comply with the CISPR 16-1-1 tolerances is assumed to be available. The correction  $\delta V_{pr}$  is estimated to be zero with a rectangular probability distribution having a half-width of 1,5 dB, a value considered to be representative of the various CISPR 16-1-1 tolerances.

NOTE 5 If the pulse amplitude response or the pulse repetition rate response is verified to be within  $\pm \alpha$  dB of the CISPR specification ( $\alpha \leq 1,5$ ), the correction for that response may be estimated to be zero with a rectangular probability distribution having a half-width of  $\alpha$  dB.

NOTE 6 If a disturbance produces a continuous wave signal at the detector, pulse response corrections do not need to be considered.

- A5) The noise floor of a CISPR receiver is usually far below the disturbance voltage limit or the disturbance power limit that its effect on measurement results near those limits is negligible. However for radiated disturbances, the proximity of the receiver noise floor may influence measurement results near the radiated disturbance limit.

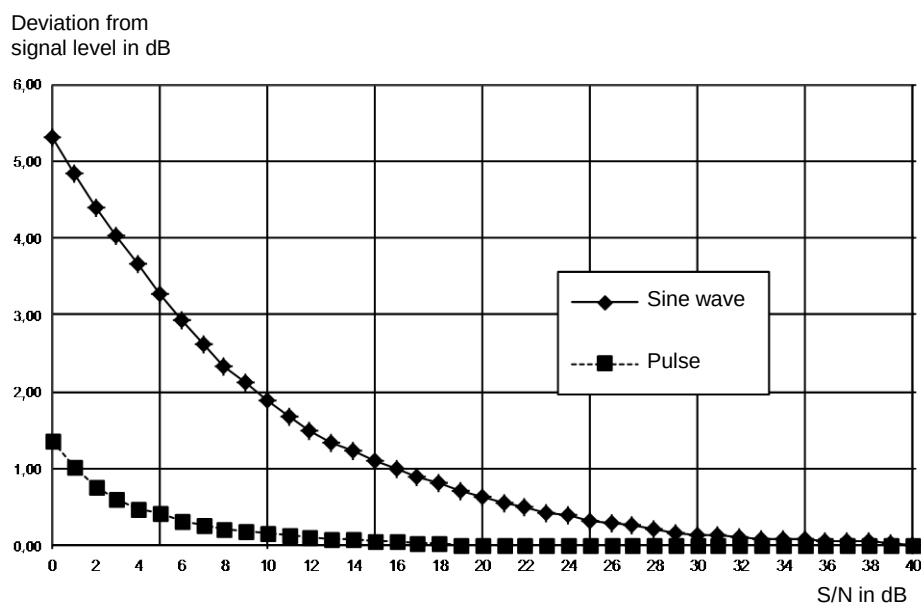
For radiated disturbance measurement below 1 GHz, the deviation  $\delta V_{nf}$  is estimated to be between zero and +1,1 dB. The correction is estimated to be zero as if the deviation would be symmetric around the value to be measured with a rectangular probability distribution having a half-width of 1,1 dB. Any correction for the effect of the noise floor would depend on the signal type (e.g. impulsive or unmodulated) and the signal to noise ratio and would change the noise level indication. The value of 1,1 dB is taken from Figure A.1 for a S/N = 14 dB. The S/N has been obtained for a noise figure of 6 dB, using

$$\begin{aligned} E_{NQP} &= V_{NQP} + F_a + a_c \\ E_{NQP} &= -67 + 10 \lg F_N + 10 \lg B_N + w_{NQP} + F_a + a_c \end{aligned} \quad (\text{A.1})$$

where

|                  |                                                                                                                                                                                                                                                                     |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $E_{\text{NQP}}$ | is the equivalent field strength of the quasi-peak noise floor, in dB( $\mu\text{V}/\text{m}$ );                                                                                                                                                                    |
| $V_{\text{NOP}}$ | is the receiver quasi-peak noise floor, in dB( $\mu\text{V}$ );                                                                                                                                                                                                     |
| $F_a$            | is the antenna factor at the receive frequency, in dB(1/m);                                                                                                                                                                                                         |
| $a_c$            | is the attenuation of the antenna connecting cable, in dB;                                                                                                                                                                                                          |
| $F_N$            | is the noise factor of the measuring receiver, i.e. a number;                                                                                                                                                                                                       |
| $10\lg F_N$      | is the noise figure of the measuring receiver, in dB;                                                                                                                                                                                                               |
| $B_N$            | is the noise bandwidth of the measuring receiver, in Hz;                                                                                                                                                                                                            |
| $w_{\text{NOP}}$ | is the quasi-peak weighting factor of noise, in dB;                                                                                                                                                                                                                 |
| -67              | is $10\lg(kT_0 \times 1\text{Hz} / P_{1\mu\text{V}})$ , the absolute noise level in dB( $\mu\text{V}$ ) in 1 Hz bandwidth, with $k$ = Boltzmann's Constant, $T_0 = 293,15$ K, and $P_{1\mu\text{V}}$ is the power generated by 1 $\mu\text{V}$ across 50 $\Omega$ . |

The worst case S/N is obtained near 1 000 MHz. With  $10\lg F_N = 6$ ,  $10\lg B_N = 50,8$  (for 120 kHz), the weighting factor  $w_{\text{NOP}}$  being 7 dB, the LPDA antenna factor of  $F_a = 24$  dB( $\text{m}^{-1}$ ) for 1 000 MHz and the cable attenuation  $a_c = 2$  dB, the quasi-peak noise indication in terms of field strength is  $E_{\text{NQP}} = 23$  dB( $\mu\text{V}/\text{m}$ ). This is compared to a disturbance level at the emission limit of 37 dB( $\mu\text{V}/\text{m}$ ) at 10 m distance to give a signal-to-noise ratio S/N of 14 dB. In the frequency range of 30 MHz to 200 MHz, the S/N is higher, hence an S/N > 20 dB is assumed. For a distance of 3 m, the emission electric field strength limit is higher, resulting in a higher S/N. For a distance of 30 m, Class A emission limits are assumed, resulting in the same S/N as for 10 m.



IEC 1158/11

**Figure A.1 – Deviation of the QP detector level indication from the signal level at receiver input for two cases, a sine-wave signal and an impulsive signal (PRF 100 Hz)**

For radiated disturbance measurements in a FAR, an emission limit of 42 dB( $\mu\text{V}/\text{m}$ ) is assumed, resulting in S/N = 19 dB at 1 000 MHz. The deviation  $\delta V_{\text{nf}}$  is then estimated at between zero and +0,7 dB.

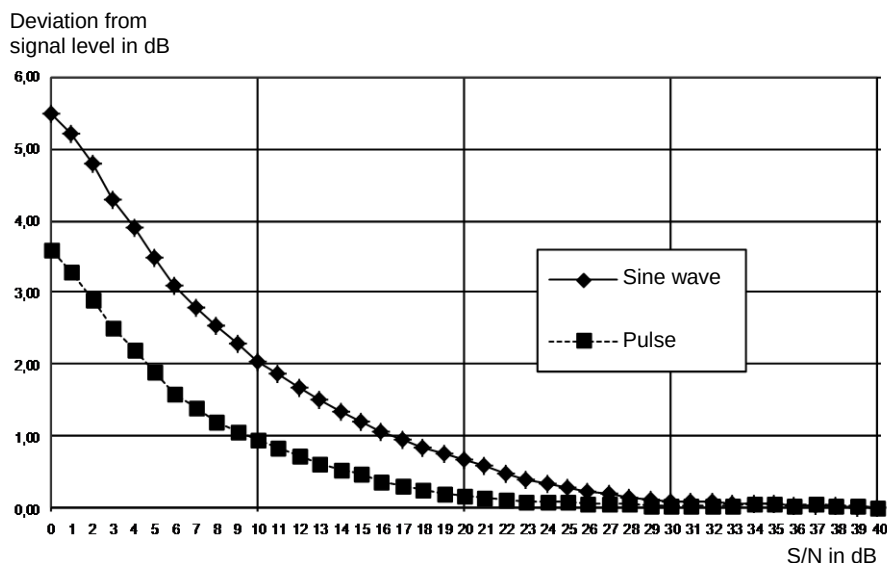
For radiated disturbance measurements from 1 GHz to 18 GHz, the frequency range is subdivided into:

- 1 GHz to 6 GHz, where the emission limits of CISPR 22 are taken into consideration, i.e. from 1 GHz to 3 GHz, an average limit of 50 dB( $\mu\text{V}/\text{m}$ ) and a peak limit of

70 dB(μV/m) applies and from 3 GHz to 6 GHz an average limit of 54 dB(μV/m) and a peak limit of 74 dB(μV/m) applies, and

- 6 GHz to 18 GHz, where an average limit of 54 dB(μV/m) and peak limit of 74 dB(μV/m) are the assumed emission limits.

A system noise figure  $10\lg F_N = 6$  dB is assumed up to 6 GHz. For the frequency range above 6 GHz, it is assumed that  $10\lg F_N = 4$  dB, i.e. a preamplifier is mounted to the antenna port. Using data from Figure A.2 with minimum values of S/N = 22 dB below 6 GHz and 19 dB above 6 GHz, this results in deviations of up to 0,5 dB (below 6 GHz) and up to 0,8 dB (above 6 GHz).

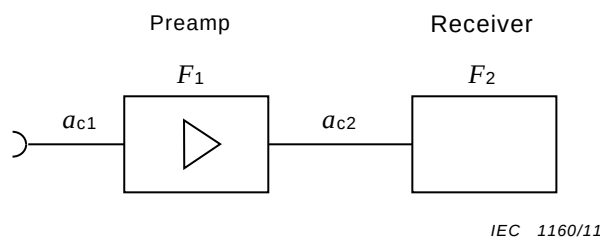


IEC 1159/11

**Figure A.2 – Deviation of the peak detector level indication from the signal level at receiver input for two cases, a sine-wave signal and an impulsive signal (PRF 100 Hz)**

NOTE 7 The system noise figure  $N_{fsyst}$  is the noise figure of the system consisting of measuring receiver, preamplifier and connecting cable(s) as seen from the antenna port. It determines the noise floor and the signal-to-noise ratio for a signal at the limit level.  $F_1$  and  $F_2$  are the noise factors of preamplifier and measuring receiver,  $a_{c1}$  and  $a_{c2}$  are the attenuations in dB of the two connecting cables.  $G_1 = 10\lg g_1$  is the preamplifier gain in dB minus the attenuation  $a_{c2}$  ( $G_1 = G_p - a_{c2}$ ). The noise figure  $N_{ftot}$  is the noise factor  $F_{tot}$  referenced to the preamplifier input in dB. In order to keep the system noise figure low, the attenuation  $A_{c1}$  of the connection between antenna port and preamplifier should be kept as low as possible. The system noise figure is illustrated with Equation (A.2) and Figure A.3.

$$F_{tot} = F_1 + \frac{F_2 - 1}{g_1}, \quad N_{ftot} = 10\lg F_{tot}, \quad N_{fsyst} = a_{c1} + N_{ftot} \quad (A.2)$$



**Key**

- $a_{c1}$  and  $a_{c2}$       attenuations of the connecting cable  
 $F_1$  and  $F_2$           noise factor of the preamplifier and the measuring receiver, respectively

**Figure A.3 – Illustration of system noise figure**

- A6) When a conversion factor (voltage division factor for an AMN, AN, AAN, VP and CVP, transfer admittance of a current probe, absorbing clamp factor, LLAS validation factor and antenna factor) is calculated by interpolation between frequencies at which calibration data is available, the uncertainty associated with that conversion factor depends on the frequency interval between calibration points and the variability of conversion factor with frequency. Plotting calibrated conversion factor versus frequency helps visualise the factor changes.

The estimate of the correction  $\delta F_{AMNf}$ ,  $\delta F_{ANf}$ ,  $\delta F_{VPf}$ ,  $\delta F_{AANf}$ ,  $\delta F_{CVPf}$ ,  $\delta Y_{Tf}$  for voltage division factor and transfer admittance interpolation error is zero, with a rectangular probability distribution having a half-width of 0,1 dB.

The estimate of the correction  $\delta F_{ACf}$  for absorbing clamp factor interpolation error is zero, with a rectangular probability distribution having a half-width of 0,2 dB.

The estimate of the correction  $\delta F_{af}$  for antenna factor interpolation error is zero, with a rectangular probability distribution having a half-width of 0,3 dB.

NOTE 8 At any frequency for which a calibrated conversion factor is available, the correction  $\delta F_{xf}$  does not need to be considered.

- A7) Mismatch uncertainty

a) General

In general, the receiver port of an ~~AMN~~ AN, absorbing clamp, antenna or other ancillary equipment will be connected to port 1 of a two-port network whose port 2 is terminated by a receiver of reflection coefficient  $\Gamma_r$ . The two-port network, which might be a cable, attenuator, attenuator and cable in tandem, or some other combination of components, can be represented by its S-parameters. The mismatch correction is then

$$\delta M = 20 \lg \left[ (1 - \Gamma_e S_{11})(1 - \Gamma_r S_{22}) - S_{21}^2 \Gamma_e \Gamma_r \right] \quad (\text{A.3})$$

where  $\Gamma_e$  is the reflection coefficient looking into the receiver port of the AMN or absorbing clamp with the EUT connected, or looking into the output port of the antenna when it is set up for disturbance measurement. All parameters are referenced to 50  $\Omega$ . Background is provided in [13].

When only the magnitudes, or extremes of magnitudes, of the parameters are known, it is not possible to calculate  $\delta M$ , but its extreme values  $\delta M^\pm$  are not greater than

$$\delta M^\pm = 20 \lg \left[ 1 \pm \left( |\Gamma_e| |S_{11}| + |\Gamma_r| |S_{22}| + |\Gamma_e| |\Gamma_r| |S_{11}| |S_{22}| + |\Gamma_e| |\Gamma_r| |S_{21}|^2 \right) \right] \quad (\text{A.4})$$

The probability distribution of  $\delta M$  is approximately U-shaped, with a width not greater than  $(\delta M^+ - \delta M^-)$  and standard deviation not greater than the half-width divided by  $\sqrt{2}$ .

b) Conducted disturbance and disturbance power

For disturbance voltage and disturbance power measurements,  $\Gamma_e$  is bound by the attenuators specified in CISPR 16-1-2 (10 dB) and CISPR 16-1-3 (6 dB) respectively.

Therefore, a worst-case reflection coefficient magnitude of  $|\Gamma_e| = 0,1$  is assumed for disturbance voltage and  $|\Gamma_e| = 0,25$  for disturbance power measurements. It is also assumed that the connection to the receiver is made using a well-matched cable ( $|S_{11}| \ll 1$ ,  $|S_{22}| \ll 1$ ) of negligible attenuation ( $|S_{21}| \approx 1$ ) and that the receiver RF attenuation is set to 10 dB or more, for which the CISPR 16-1-1 tolerance of voltage standing wave ratio  $s_{wr} \leq 1,2:1$  implies  $|\Gamma_r| \leq 0,09$ .

For disturbance voltage measurements with a voltage probe, a reflection coefficient of the voltage probe itself of  $|\Gamma_e| = 1$  (due to the high source impedance) should be assumed. Therefore the minimum receiver RF attenuation should be 10 dB, which implies  $|\Gamma_r| \leq 0,09$ .

For disturbance current measurements with a current probe, a reflection coefficient of the current probe itself of  $|\Gamma_e| = 1$  (due to the low source impedance) should be assumed. Therefore, the minimum receiver RF attenuation should be 10 dB, which implies  $|\Gamma_r| \leq 0,09$ .

c) Radiated disturbance

For radiated disturbance measurements below 1 GHz, an antenna specification of  $s_{wr} \leq 2,0:1$  is assumed, implying  $|\Gamma_e| \leq 0,33$ . It is also assumed that the connection to the receiver is made using a well-matched cable ( $|S_{11}| \ll 1$ ,  $|S_{22}| \ll 1$ ) of negligible attenuation ( $|S_{21}| \approx 1$ ) and that the receiver RF attenuation is 0 dB, for which the CISPR 16-1-1 tolerance of  $s_{wr} \leq 2,0:1$  implies  $|\Gamma_r| \leq 0,33$ .

For radiated disturbance measurements above 1 GHz, an antenna specification of  $s_{wr} \leq 2,0:1$  is assumed, implying  $|\Gamma_e| \leq 0,33$ . It is also assumed that the connection to the receiver is made using a well-matched cable ( $|S_{11}| \ll 1$ ,  $|S_{22}| \ll 1$ ) of minimum attenuation of 1 dB at 1 GHz ( $|S_{21}| \approx 0,9$ ) and that the receiver RF attenuation is 0 dB, for which the CISPR 16-1-1 tolerance of  $s_{wr} \leq 3,0:1$  implies  $|\Gamma_r| \leq 0,50$ .

If a preamplifier external to the receiver is used, then two mismatch uncertainties have to be considered, i.e. between antenna port and preamplifier input port and between preamplifier output port and receiver input port. For the preamplifier both input and output VSWR of  $s_{wr} \leq 2,0:1$  are assumed. The use of an external preamplifier is taken into consideration in Annex E for the frequency range above 1 GHz. Usually, external preamplifiers are not used below 1 GHz, but if used, Annex E may be used as a model for uncertainty calculation.

The estimate of the correction  $\delta M$  is zero with a U-shaped probability distribution having width equal to the difference  $(\delta M^+ - \delta M^-)$ . Background is provided in [10] and [11].

NOTE 9 The expressions for  $\delta M$  and  $\delta M^\pm$  show that mismatch error can be reduced by increasing the attenuation of the well-matched two-port network preceding the receiver. The penalty is a reduction in measurement sensitivity.

NOTE 10 For some antennas at some frequencies, the  $s_{wr}$  may be much greater than 2,0:1, e.g. 20:1 for biconical antennas at 30 MHz. Where this is the case, a 6-dB attenuator is recommended to limit the mismatch uncertainty and to take a lower S/N into account [see comment A5)].

NOTE 11 Precautions may be necessary to ensure that the impedance seen by the receiver complies with the CISPR 16-1-4 specification of  $s_{wr} \leq 2,0:1$  when a complex antenna is used.

NOTE 12 If an ~~AMN~~ AN or absorbing clamp is calibrated with an attenuator connected permanently to its output port, the effect of the EUT impedance on the mismatch error will be reduced as the value of the

attenuation increases, i.e.  $|\Gamma_e| \leq |\Gamma_a| + 0,5 \times 10^{a/20}$ , where  $|\Gamma_a|$  and  $a$  are the reflection coefficient and the attenuation of the attenuator respectively, in dB.

NOTE 13 Additional considerations related to Equation (A.3): a) Due to non-existing or only weak correlation of the addends (summands, or terms in the sum), the linear addition may be replaced by the root sum square rule. b) Due to the usually small magnitude of the addends, a further approximation (where  $\delta M^\pm$  is the half width of a U-shaped distribution) is applicable (see also [5] and [8]), yielding finally:

$$\delta M^\pm \approx 8,7 \sqrt{(\langle \Gamma_e \| S_{11} \rangle)^2 + (\langle \Gamma_r \| S_{22} \rangle)^2 + (\langle \Gamma_e \| \Gamma_r \| S_{21} \rangle)^2} \text{ dB}$$

## Annex B (informative)

### Basis for $U_{\text{CISPR}}$ values in Table 1, uncertainty budgets and rationale for conducted disturbance measurements

#### B.1 Uncertainty budget for conducted disturbance measurements at ~~a~~ AC mains port using ~~an artificial mains network (AMN)~~ a V-AMN

The measurand  $V$  is calculated using:

$$\cancel{V = V_r + a_c + F_{\text{AMN}} + \delta F_{\text{AMN}f} + \delta V_{\text{sw}} + \delta V_{\text{pa}} + \delta V_{\text{pr}} + \delta V_{\text{nf}} + \delta M + \delta Z_{\text{AMN}} + \delta D_{\text{mains}} + \delta V_{\text{env}}} \quad (\text{B.1})$$

$$V = V_r + A_c + F_{\text{AMN}} + \delta F_{\text{AMN}f} + \delta V_{\text{sw}} + \delta V_{\text{pa}} + \delta V_{\text{pr}} + \delta V_{\text{nf}} + \delta M + \delta Z_{\text{AMN}} + \delta D_{\text{mains}} + \delta E \quad (\text{B.1})$$

**Table B.1 – Conducted disturbance measurements from 9 kHz to 150 kHz using a 50  $\Omega$ /50  $\mu\text{H}$  + 5  $\Omega$  V-AMN**

| Input quantity <sup>a</sup>                                                                                        | $X_i$                     | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$ |
|--------------------------------------------------------------------------------------------------------------------|---------------------------|----------------------|-----------------------------------|----------------|
|                                                                                                                    |                           | dB                   | Probability distribution function | dB             |
| Receiver reading <sup>A1)</sup>                                                                                    | $V_r$                     | $\pm 0,1$            | $k = 1$                           | 0,10           |
| Attenuation: AMN-receiver <sup>A2)</sup>                                                                           | $a_c$                     | $\pm 0,1$            | $k = 2$                           | 0,05           |
| AMN voltage division factor <sup>B1)</sup>                                                                         | $F_{\text{AMN}}$          | $\pm 0,2$            | $k = 2$                           | 0,10           |
| Receiver corrections:                                                                                              |                           |                      |                                   |                |
| Sine wave voltage <sup>A3)</sup>                                                                                   | $\delta V_{\text{sw}}$    | $\pm 1,0$            | $k = 2$                           | 0,50           |
| Pulse amplitude response <sup>A4)</sup>                                                                            | $\delta V_{\text{pa}}$    | $\pm 1,5$            | Rectangular                       | 0,87           |
| Pulse repetition rate response <sup>A4)</sup>                                                                      | $\delta V_{\text{pr}}$    | $\pm 1,5$            | Rectangular                       | 0,87           |
| Noise floor proximity <sup>A5)</sup>                                                                               | $\delta V_{\text{nf}}$    | $\pm 0,0$            |                                   | 0,00           |
| AMN VDF frequency interpolation <sup>A6)</sup>                                                                     | $\delta F_{\text{AMN}f}$  | $\pm 0,1$            | Rectangular                       | 0,06           |
| Mismatch: AMN-receiver <sup>A7)</sup>                                                                              | $\delta M$                | $\pm 0,07$           | U-shaped                          | 0,05           |
| AMN impedance <sup>B2)</sup>                                                                                       | $\delta Z_{\text{AMN}}$   | +3,1/–3,6            | Triangular                        | 1,37           |
| Effect of mains disturbance <sup>B5)</sup>                                                                         | $\delta D_{\text{mains}}$ | $\pm 0,0$            |                                   | 0,00           |
| Effect of the environment <sup>B19)</sup>                                                                          | $\delta V_{\text{env}}$   | -                    | -                                 | -              |
| <sup>a</sup> Superscripts [e.g. <sup>A1)</sup> ] correspond to numbered comments in the annexes (see A.2 and B.6). |                           |                      |                                   |                |
| <sup>b</sup> All $c_i = 1$ (see A.1).                                                                              |                           |                      |                                   |                |

Hence, expanded uncertainty  $U(V) = 2 u_c(V) = 3,83$  dB

**Table B.2 – Conducted disturbance measurements from  
150 kHz to 30 MHz using a 50  $\Omega$ /50  $\mu$ H V-AMN**

| Input quantity <sup>a</sup>                                                                                        | $X_i$              | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$ |
|--------------------------------------------------------------------------------------------------------------------|--------------------|----------------------|-----------------------------------|----------------|
|                                                                                                                    |                    | dB                   | Probability distribution function | dB             |
| Receiver reading <sup>A1)</sup>                                                                                    | $V_r$              | $\pm 0,1$            | $k = 1$                           | 0,10           |
| Attenuation: AMN-receiver <sup>A2)</sup>                                                                           | $a_c$              | $\pm 0,1$            | $k = 2$                           | 0,05           |
| AMN voltage division factor <sup>B1)</sup>                                                                         | $F_{AMN}$          | $\pm 0,2$            | $k = 2$                           | 0,10           |
| Receiver corrections:                                                                                              |                    |                      |                                   |                |
| Sine wave voltage <sup>A3)</sup>                                                                                   | $\delta V_{sw}$    | $\pm 1,0$            | $k = 2$                           | 0,50           |
| Pulse amplitude response <sup>A4)</sup>                                                                            | $\delta V_{pa}$    | $\pm 1,5$            | Rectangular                       | 0,87           |
| Pulse repetition rate response <sup>A4)</sup>                                                                      | $\delta V_{pr}$    | $\pm 1,5$            | Rectangular                       | 0,87           |
| Noise floor proximity <sup>A5)</sup>                                                                               | $\delta V_{nf}$    | $\pm 0,0$            |                                   | 0,00           |
| AMN VDF frequency interpolation <sup>A6)</sup>                                                                     | $\delta F_{AMNf}$  | $\pm 0,1$            | Rectangular                       | 0,06           |
| Mismatch: AMN-receiver <sup>A7)</sup>                                                                              | $\delta M$         | $\pm 0,07$           | U-shaped                          | 0,05           |
| AMN impedance <sup>B2)</sup>                                                                                       | $\delta Z_{AMN}$   | $+2,6/-2,7$          | Triangular                        | 1,08           |
| Effect of mains disturbance <sup>B5)</sup>                                                                         | $\delta D_{mains}$ | $\pm 0,0$            |                                   | 0,00           |
| Effect of the environment <sup>B19)</sup>                                                                          | $\delta V_{env}$   | -                    | -                                 | -              |
| <sup>a</sup> Superscripts [e.g. <sup>A1)</sup> ] correspond to numbered comments in the annexes (see A.2 and B.6). |                    |                      |                                   |                |
| <sup>b</sup> All $c_i = 1$ (see A.1).                                                                              |                    |                      |                                   |                |

Hence, expanded uncertainty  $U(V) = 2u_c(V) = 3,44$  dB

## B.2 Uncertainty budget for conducted disturbance measurements at a mains port using a voltage probe (VP)

The measurand  $V$  is calculated using:

$$V = V_r + a_c + F_{VP} + \delta F_{VPf} + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta Z_{vp} + \delta D_{mains} + \delta Z_{mains} + \delta V_{env} \quad (B.2)$$

**Table B.3 – Conducted disturbance measurements from 9 kHz to 30 MHz using a VP**

| Input quantity <sup>a</sup>                                                                                        | $X_i$              | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$ |
|--------------------------------------------------------------------------------------------------------------------|--------------------|----------------------|-----------------------------------|----------------|
|                                                                                                                    |                    | dB                   | Probability distribution function | dB             |
| Receiver reading <sup>A1)</sup>                                                                                    | $V_r$              | $\pm 0,1$            | $k = 1$                           | 0,10           |
| Attenuation: VP-receiver <sup>A2)</sup>                                                                            | $a_c$              | $\pm 0,1$            | $k = 2$                           | 0,05           |
| VP voltage division factor (VDF) <sup>B3)</sup>                                                                    | $F_{VP}$           | $\pm 0,2$            | $k = 2$                           | 0,10           |
| Receiver corrections:                                                                                              |                    |                      |                                   |                |
| Sine wave voltage <sup>A3)</sup>                                                                                   | $\delta V_{sw}$    | $\pm 1,0$            | $k = 2$                           | 0,50           |
| Pulse amplitude response <sup>A4)</sup>                                                                            | $\delta V_{pa}$    | $\pm 1,5$            | Rectangular                       | 0,87           |
| Pulse repetition rate response <sup>A4)</sup>                                                                      | $\delta V_{pr}$    | $\pm 1,5$            | Rectangular                       | 0,87           |
| Noise floor proximity <sup>A5)</sup>                                                                               | $\delta V_{nf}$    | $\pm 0,0$            |                                   | 0,00           |
| VP VDF frequency interpolation <sup>A6)</sup>                                                                      | $\delta F_{VPf}$   | $\pm 0,1$            | Rectangular                       | 0,06           |
| Mismatch: VP - receiver <sup>A7)</sup>                                                                             | $\delta M$         | $+0,7/-0,8$          | U-shaped                          | 0,53           |
| VP impedance <sup>B4)</sup>                                                                                        | $\delta Z_{VP}$    | $\pm 0,5$            | Triangular                        | 0,20           |
| Effect of mains disturbances <sup>B5)</sup>                                                                        | $\delta D_{mains}$ | -                    | -                                 | -              |
| Effect of mains impedance when compared with AMN <sup>B5)</sup>                                                    | $\delta Z_{mains}$ | $\pm 30,0$           | Triangular                        | 12,24          |
| Effect of the environment <sup>B19)</sup>                                                                          | $\delta V_{env}$   | -                    | -                                 | -              |
| <sup>a</sup> Superscripts [e.g. <sup>A1)</sup> ] correspond to numbered comments in the annexes (see A.2 and B.6). |                    |                      |                                   |                |
| <sup>b</sup> All $c_i = 1$ (see A.1).                                                                              |                    |                      |                                   |                |

Hence, expanded uncertainty

$$U(V) = 2u_c(V) = \begin{cases} 2,91\text{dB} \\ 24,65\text{ dB, considering the effect of mains impedance when compared with AMN} \end{cases}$$

NOTE The expanded uncertainty with effect of mains impedance when compared to AMN (i.e. 24,65 dB) is recommended to be considered when the emission limits are defined for the AMN test method. For in-situ measurements the comparison with the AMN does not apply, i.e. only the uncertainty of the voltage probe measurement (2,9 dB) applies. For in-situ tests, other input quantities (e.g.  $\delta D_{mains}$ ,  $\delta V_{env}$ ) may have to be considered.

### B.3 Uncertainty budget for conducted disturbance measurements at a telecommunication port using an asymmetrical artificial network (AAN)

The measurand  $V$  is calculated using:

$$V = V_r + a_c + F_{\text{AAN}} + \delta F_{\text{AAN}f} + \delta V_{\text{sw}} + \delta V_{\text{pa}} + \delta V_{\text{pr}} + \delta V_{\text{nf}} + \delta M + \delta Z_{\text{AAN}} + \delta a_{\text{LCL}} + \delta D_{\text{AE}} + \delta V_{\text{env}} \quad (\text{B.3})$$

**Table B.4 – Conducted disturbance measurements from 150 kHz to 30 MHz using an AAN**

| Input quantity <sup>a</sup>                                                                                                                                                                                                                                                                                                                            | $X_i$                    | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$ |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|----------------------|-----------------------------------|----------------|
|                                                                                                                                                                                                                                                                                                                                                        |                          | dB                   | Probability distribution function | dB             |
| Receiver reading <sup>A1)</sup>                                                                                                                                                                                                                                                                                                                        | $V_r$                    | $\pm 0,1$            | $k = 1$                           | 0,10           |
| Attenuation: AAN-receiver <sup>A2)</sup>                                                                                                                                                                                                                                                                                                               | $a_c$                    | $\pm 0,1$            | $k = 2$                           | 0,05           |
| AAN voltage division factor (VDF) <sup>B6)</sup>                                                                                                                                                                                                                                                                                                       | $F_{\text{AAN}}$         | $\pm 0,2$            | $k = 2$                           | 0,10           |
| Receiver corrections:                                                                                                                                                                                                                                                                                                                                  |                          |                      |                                   |                |
| Sine wave voltage <sup>A3)</sup>                                                                                                                                                                                                                                                                                                                       | $\delta V_{\text{sw}}$   | $\pm 1,0$            | $k = 2$                           | 0,50           |
| Pulse amplitude response <sup>A4)</sup>                                                                                                                                                                                                                                                                                                                | $\delta V_{\text{pa}}$   | $\pm 1,5$            | Rectangular                       | 0,87           |
| Pulse repetition rate response <sup>A4)</sup>                                                                                                                                                                                                                                                                                                          | $\delta V_{\text{pr}}$   | $\pm 1,5$            | Rectangular                       | 0,87           |
| Noise floor proximity <sup>A5)</sup>                                                                                                                                                                                                                                                                                                                   | $\delta V_{\text{nf}}$   | $\pm 0,0$            |                                   | 0,00           |
| AAN VDF frequency interpolation <sup>A6)</sup>                                                                                                                                                                                                                                                                                                         | $\delta F_{\text{AAN}f}$ | $\pm 0,1$            | Rectangular                       | 0,06           |
| Mismatch: AAN - receiver <sup>A7)</sup>                                                                                                                                                                                                                                                                                                                | $\delta M$               | $+0,7/-0,8$          | U-shaped                          | 0,53           |
| AAN asymmetric impedance <sup>B7)</sup>                                                                                                                                                                                                                                                                                                                | $\delta Z_{\text{AAN}}$  | $+2,5/-2,0$          | Triangular                        | 0,92           |
| AAN longitudinal conversion loss <sup>B8)</sup>                                                                                                                                                                                                                                                                                                        |                          |                      |                                   |                |
| AAN with $a_{\text{LCL}} = 55 \dots 40$ dB <sup>c</sup>                                                                                                                                                                                                                                                                                                | $\delta a_{\text{LCL}}$  | $+3,0/-3,0$          | Triangular                        | 1,22           |
| AAN with $a_{\text{LCL}} = 65 \dots 50$ dB <sup>c</sup>                                                                                                                                                                                                                                                                                                | $\delta a_{\text{LCL}}$  | $+3,0/-4,5$          | Triangular                        | 1,53           |
| AAN with $a_{\text{LCL}} = 75 \dots 60$ dB <sup>c</sup>                                                                                                                                                                                                                                                                                                | $\delta a_{\text{LCL}}$  | $+3,0/-6,0$          | Triangular                        | 1,84           |
| Effect of AE disturbances <sup>B9)</sup>                                                                                                                                                                                                                                                                                                               | $\delta D_{\text{AE}}$   | $\pm 0,2$            | Rectangular                       | 0,12           |
| Effect of the environment <sup>B19)</sup>                                                                                                                                                                                                                                                                                                              | $\delta V_{\text{env}}$  | -                    | -                                 | -              |
| <sup>a</sup> Superscripts [e.g. <sup>A1)</sup> ] correspond to comments in the annexes (see A.2 and B.6).<br><sup>b</sup> All $c_i = 1$ (see A.1).<br><sup>c</sup> $a_{\text{LCL}}$ starts at 150 kHz with a value of 55 dB (respectively 65 dB or 75 dB), varies with frequency and reaches a value of 40 dB (respectively 50 dB or 60 dB) at 30 MHz. |                          |                      |                                   |                |

Hence, expanded uncertainty

$$U(V) = 2u_c(V) = \begin{cases} 4,20 \text{ dB, for AAN with } a_{\text{LCL}} = 55\dots40 \text{ dB} \\ 4,59 \text{ dB, for AAN with } a_{\text{LCL}} = 65\dots50 \text{ dB} \\ 5,03 \text{ dB, for AAN with } a_{\text{LCL}} = 75\dots60 \text{ dB} \end{cases}$$

## B.4 Uncertainty budget for conducted disturbance measurements at a telecommunication port using a capacitive voltage probe (CVP)

The measurand  $V$  is calculated using:

$$V = V_r + a_c + F_{CVP} + \delta F_{CVPf} + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta Z_{CVP} + \delta F_{cpos} + \delta F_{crad} + \delta D_{AE} + \delta Z_{AE} + \delta V_{env} \quad (B.4)$$

**Table B.5 – Conducted disturbance measurements from 150 kHz to 30 MHz using a capacitive voltage probe (CVP)**

| Input quantity <sup>a</sup>                                                                                        | $X_i$             | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$ |
|--------------------------------------------------------------------------------------------------------------------|-------------------|----------------------|-----------------------------------|----------------|
|                                                                                                                    |                   | dB                   | Probability distribution function | dB             |
| Receiver reading <sup>A1)</sup>                                                                                    | $V_r$             | $\pm 0,1$            | $k = 1$                           | 0,10           |
| Attenuation: CVP-receiver <sup>A2)</sup>                                                                           | $a_c$             | $\pm 0,1$            | $k = 2$                           | 0,05           |
| CVP voltage division factor (VDF) <sup>B10)</sup>                                                                  | $F_{CVP}$         | $\pm 0,5$            | $k = 2$                           | 0,25           |
| Receiver corrections:                                                                                              |                   |                      |                                   |                |
| Sine wave voltage <sup>A3)</sup>                                                                                   | $\delta V_{sw}$   | $\pm 1,0$            | $k = 2$                           | 0,50           |
| Pulse amplitude response <sup>A4)</sup>                                                                            | $\delta V_{pa}$   | $\pm 1,5$            | Rectangular                       | 0,87           |
| Pulse repetition rate response <sup>A4)</sup>                                                                      | $\delta V_{pr}$   | $\pm 1,5$            | Rectangular                       | 0,87           |
| Noise floor proximity <sup>A5)</sup>                                                                               | $\delta V_{nf}$   | $\pm 0,0$            |                                   | 0,00           |
| CVP VDF frequency interpolation <sup>A6)</sup>                                                                     | $\delta F_{CVPf}$ | $\pm 0,1$            | Rectangular                       | 0,06           |
| Mismatch: CVP to receiver <sup>A7)</sup>                                                                           | $\delta M$        | $+0,7/-0,8$          | U-shaped                          | 0,53           |
| CVP impedance <sup>B11)</sup>                                                                                      | $\delta Z_{CVP}$  | $+1/-2$              | Rectangular                       | 0,87           |
| Effect of cable position on $F_{CVP}$ <sup>B12)</sup>                                                              | $\delta F_{cpos}$ | 0,5                  | $k = 1$                           | 0,5            |
| Effect of cable radius on $F_{CVP}$ <sup>B13)</sup>                                                                | $\delta F_{crad}$ | 0,76                 | $k = 1$                           | 0,76           |
| Effect of AE disturbances <sup>B14)</sup>                                                                          | $\delta D_{AE}$   | -                    | -                                 | -              |
| Effect of AE impedance <sup>B14)</sup>                                                                             | $\delta Z_{AE}$   | $\pm 30$             | Triangular                        | 12,24          |
| Effect of the environment <sup>B19)</sup>                                                                          | $\delta V_{env}$  | -                    | -                                 | -              |
| <sup>a</sup> Superscripts (e.g. <sup>A1)</sup> ) correspond to numbered comments in the annexes (see A.2 and B.6). |                   |                      |                                   |                |
| <sup>b</sup> All $c_i = 1$ (see A.1).                                                                              |                   |                      |                                   |                |

Hence, expanded uncertainty

$$U(V) = 2u_c(V) = \begin{cases} 3,85 \text{ dB} \\ 24,78 \text{ dB, considering the effect of AE impedance when compared with AAN} \end{cases}$$

NOTE 1 Adjustments of capacitive voltage probe measurements using current probe measurements may have to be considered [see comment B18)].

NOTE 2 The expanded uncertainty with effect of AE impedance when compared to AAN (i.e. 24,78 dB) is recommended to be considered when the emission limits are defined for the AAN test method.

## B.5 Uncertainty budget for conducted disturbance measurements at a telecommunication port using a current probe (CP)

The measurand  $I$  is calculated using:

$$I = V_r + a_c + Y_T + \delta Y_{Tf} + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta Z_{cp} + \delta D_{AE} + \delta Z_{AE} + \delta I_{env} \quad (B.5)$$

**Table B.6 – Conducted disturbance measurements from 9 kHz to 30 MHz using a CP**

| Input quantity <sup>a</sup>                                                                                        | $X_i$            | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$ |
|--------------------------------------------------------------------------------------------------------------------|------------------|----------------------|-----------------------------------|----------------|
|                                                                                                                    |                  | dB                   | Probability distribution function |                |
| Receiver reading <sup>A1)</sup>                                                                                    | $V_r$            | $\pm 0,1$            | $k = 1$                           | 0,10           |
| Attenuation: current probe-receiver <sup>A2)</sup>                                                                 | $a_c$            | $\pm 0,1$            | $k = 2$                           | 0,05           |
| Current probe transfer admittance <sup>B15)</sup>                                                                  | $Y_T$            | $\pm 0,3$            | $k = 2$                           | 0,15           |
| Receiver corrections:                                                                                              |                  |                      |                                   |                |
| Sine wave voltage <sup>A3)</sup>                                                                                   | $\delta V_{sw}$  | $\pm 1,0$            | $k = 2$                           | 0,50           |
| Pulse amplitude response <sup>A4)</sup>                                                                            | $\delta V_{pa}$  | $\pm 1,5$            | Rectangular                       | 0,87           |
| Pulse repetition rate response <sup>A4)</sup>                                                                      | $\delta V_{pr}$  | $\pm 1,5$            | Rectangular                       | 0,87           |
| Noise floor proximity <sup>A5)</sup>                                                                               | $\delta V_{nf}$  | $\pm 0,0$            |                                   | 0,00           |
| Transfer admittance frequency interpolation <sup>A6)</sup>                                                         | $\delta Y_{Tf}$  | $\pm 0,1$            | Rectangular                       | 0,06           |
| Mismatch: current probe-receiver <sup>A7)</sup>                                                                    | $\delta M$       | $+0,7/-0,8$          | U-shaped                          | 0,53           |
| Current probe insertion impedance <sup>B16)</sup>                                                                  | $\delta Z_{CP}$  | $+0,1$               | Rectangular                       | 0,06           |
| Effect of AE disturbances <sup>B17)</sup>                                                                          | $\delta D_{AE}$  | -                    | -                                 | -              |
| Effect of AE impedance <sup>B17)</sup>                                                                             | $\delta Z_{AE}$  | $\pm 30$             | Triangular                        | 12,24          |
| Effect of the environment <sup>B19)</sup>                                                                          | $\delta I_{env}$ | -                    | -                                 | -              |
| <sup>a</sup> Superscripts [e.g. <sup>A1)</sup> ] correspond to numbered comments in the annexes (see A.2 and B.6). |                  |                      |                                   |                |
| <sup>b</sup> All $c_i = 1$ (see A.1).                                                                              |                  |                      |                                   |                |

Hence, expanded uncertainty

$$U(I) = 2u_c(I) = \begin{cases} 2,89 \text{ dB} \\ 24,65 \text{ dB, considering the effect of AE} \\ \text{impedance when compared with AAN} \end{cases}$$

NOTE The expanded uncertainty with effect of AE impedance when compared with AAN (i.e. 24,65 dB) is recommended to be considered when the emission limits are defined for the AAN test method.

## B.6 Rationale for the estimates of input quantities specific to conducted disturbance measurement methods

- B1) An estimate of the AMN voltage division factor  $F_{AMN}$  is assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.
- B2) The impedance tolerance in CISPR 16-1-2 for a  $50\ \Omega/50\ \mu\text{H} + 5\ \Omega$  AMN or a  $50\ \Omega/50\ \mu\text{H}$  AMN requires the impedance magnitude to be within 20 % of the magnitude of the nominal impedance and within  $\pm 11,5^\circ$  of the nominal phase angle when the receiver port is terminated in  $50\ \Omega$ .

It is assumed that the impedance presented by the AMN EUT port when the receiver port is terminated in  $50\ \Omega$  lies within a circle centred on the nominal impedance on the complex-impedance plane, that circle having a radius of 20 % of the nominal impedance magnitude. This places a tolerance on the impedance phase commensurate with that on the impedance magnitude. The estimate of the correction  $\delta Z_{AMN}$  is zero with a probability distribution bounded by the extremes of all combinations of the constrained AMN impedance and unconstrained EUT impedance over the defined frequency range (see [9] for background information). A triangular probability distribution is assumed because there is only a small chance of encountering the particular combinations of frequency, AMN impedance and EUT impedance needed to produce those extremes.

NOTE If an adapter is used at the AMN EUT port to match the actual EUT power cord plug, then the impedance requirements called out in CISPR 16-1-2 are to be met at the EUT connection point (i.e. the adapter).

- B3) An estimate of the voltage probe voltage division factor  $F_{vp}$  is assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.
- B4) CISPR 16-1-2 defines the impedance of the voltage probe as  $1\ 500\ \Omega$  with no tolerance. Available resistors have maximum tolerances of 5 %. In addition, a coupling capacitance of 10 nF should be taken into consideration which causes the voltage division factor to be frequency dependent. Furthermore, typical voltage probes have an input capacitance of up to 10 pF, appearing as a shunt capacitance.
- B5) For measurements using an AMN, mains disturbances are assumed to be suppressed by the AMN itself or by additional filters, if necessary.

Voltage probes are applied without decoupling between EUT and the mains network. This is a large source of uncertainty (e.g. in in-situ tests). Both the impedance of the mains side and the disturbances from the mains side are unknown. It is not possible to provide estimates of the uncertainty due to the effects from the mains side. The user's experience and judgement is needed in actual measurements. Therefore an estimate of this input quantity is not provided.

If measurements with voltage probes are compared with measurements using an AMN, then the mains impedance  $Z_{\text{mains}}$  in comparison with the probe impedance  $Z_{vp}$  and the AMN impedance  $Z_{AMN}$  largely determines the result. Assuming a high EUT impedance, if  $Z_{\text{mains}} \gg Z_{vp}$  then the measurement result may be up to 30 times (approximately 30 dB) higher than the result using an AMN. Also, if  $Z_{\text{mains}} \ll Z_{AMN}$ , then the measured disturbance voltage is proportional to the factor  $Z_{\text{mains}}/Z_{AMN}$ . Factors as low as 1/30 (approximately -30 dB) may be possible, so, the impedance  $Z_{\text{mains}}$  becomes part of the instrumentation and the instrumentation uncertainty increases to  $\pm 30$  dB. Thus, a lower value of  $U_{\text{CISPR}}$  for the measurement with a voltage probe in Table 1 does not justify a replacement of the AMN by the voltage probe.

- B6) An estimate of the AAN voltage division factor  $F_{AAN}$  is assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.

- B7) CISPR 16-1-2 defines the impedance of the AAN as  $150\ \Omega$  with a magnitude tolerance of  $\pm 20\ \Omega$  and a phase tolerance of  $\pm 20^\circ$ .
- B8) CISPR 16-1-2 provides examples of LCL requirements and CISPR 22 defines the frequency dependent LCLs with corner frequencies of 5 MHz and tolerances for the following cables:

|       |                                   |                                                                                          |
|-------|-----------------------------------|------------------------------------------------------------------------------------------|
| Cat 3 | 55 dB falling to 40 dB at 30 MHz, | with a tolerance of $\pm 3$ dB up to 30 MHz,                                             |
| Cat 5 | 65 dB falling to 50 dB at 30 MHz, | $\leq 2$ MHz, the tolerance is $\pm 3$ dB,<br>> 2 MHz, the tolerance is $-3$ dB/+4,5 dB, |
| Cat 6 | 75 dB falling to 60 dB at 30 MHz, | $\leq 2$ MHz, the tolerance is $\pm 3$ dB,<br>> 2 MHz, the tolerance is $-3$ dB/+6 dB.   |

The AAN with 65 dB LCL is the most important AAN and its tolerance is therefore used for the definition of  $U_{\text{CISPR}}$ . A calibration certificate with a lower deviation from the nominal LCL value together with a sufficiently low uncertainty will reduce the uncertainty contribution of the LCL.

- B9) For the effect of AE disturbances, the lowest decoupling attenuation of 35 dB is assumed, together with an AE disturbance level equal to the EUT disturbance level.
- B10) An estimate of the CVP voltage division factor  $F_{\text{CVP}}$  is assumed to be available from a calibration report for the cable type to be measured, along with an expanded uncertainty and a coverage factor. The uncertainty includes the calibration setup.
- B11) The impedance includes the shunt capacitance that is specified as  $< 10$  pF in CISPR 16-1-2. For an EUT source and load impedance equal to  $50\ \Omega$ , the effect of the shunt capacitance is included in the voltage division factor. For  $150\ \Omega$ , there is a loading effect of approximately -2 dB at 30 MHz.
- B12) The effect of the cable position on the voltage division factor is shown in CISPR 16-1-2.
- B13) The effect of the cable radius on the voltage division factor is shown in CISPR 16-1-2. In order to reduce the uncertainty, the voltage division factor could be calibrated as a function of cable radius or a table of corrections  $\delta F_{\text{crad}}$  may be supplied.
- B14) CVPs are applied without decoupling between EUT and AE. This is a large source of uncertainty. Both the impedance of the AE side and disturbances from the AE side are unknown. It is not possible to provide estimates of the uncertainty due to effects on the AE side. The user's experience and judgement are needed in actual measurements. Therefore an estimate of this input quantity is not provided.

If measurements with CVPs are compared with measurements using an AAN, then the AE impedance  $Z_{\text{AE}}$  in comparison with the probe impedance  $Z_{\text{CVP}}$  and the AAN impedance  $Z_{\text{AAN}}$  largely determines the result. Assuming a high EUT impedance, if  $Z_{\text{AE}} \gg Z_{\text{CVP}}$  then the measurement result up to 30 times (approximately 30 dB) higher than the result using an AAN can be assumed. Also, if  $Z_{\text{AE}} \ll Z_{\text{AAN}}$ , then the measured disturbance voltage is proportional to the factor  $Z_{\text{AE}}/Z_{\text{AAN}}$ . Factors of as low as 1/30 (approximately -30 dB) are possible, so the impedance  $Z_{\text{AE}}$  becomes part of the instrumentation, and the instrumentation uncertainty increases to  $\pm 30$  dB. Thus, a lower value of  $U_{\text{CISPR}}$  for the measurement with a capacitive voltage probe in Table 1 does not justify a replacement of the AAN by the capacitive voltage probe.

- B15) The current probe correction factor is the logarithm of the transfer admittance  $20\lg(Y_T) = 20\lg(1/Z_T)$  which is added to the voltage level to give the current level  $I$  in dB( $\mu$ A). An estimate of the current probe correction factor  $Y_T$  is assumed to be

available from a calibration report, along with an expanded uncertainty and a coverage factor.

- B16) CISPR 16-1-2 requires that the current probe insertion impedance be below 1  $\Omega$ .
- B17) Current probes are applied without decoupling between EUT and AE. This is a large source of uncertainty. Both the impedance of the AE side as well as disturbances from the AE side are unknown. It is not possible to provide estimates of the uncertainty due to effects on the AE side. The user's experience and judgement are needed in actual measurements. Therefore an estimate of this input quantity is not provided.

If measurements with current probes are compared with measurements using an AMN, then the mains impedance  $Z_{\text{mains}}$  in comparison with the AMN impedance  $Z_{\text{AMN}}$  largely determines the result. Assuming a high EUT impedance, if  $Z_{\text{mains}} \ll Z_{\text{AMN}}$ , then a measurement result up to 30 times (approximately 30 dB) higher than the result using an AMN is possible. Also, if  $Z_{\text{mains}} \gg Z_{\text{AMN}}$ , then the measured disturbance current is proportional to the factor  $Z_{\text{mains}}/Z_{\text{AMN}}$ . Factors of as low as 1/30 (approximately -30 dB) are possible. The impedance  $Z_{\text{mains}}$  then becomes part of the instrumentation, and the instrumentation uncertainty increases to  $\pm 30$  dB. A lower value of  $U_{\text{CISPR}}$  for the measurement with a current probe in Table 1 therefore does not justify a replacement of the AMN by the current probe.

Similar considerations apply for a comparison of current probe measurements with measurements using an AAN. In this case  $Z_{\text{mains}}$  is to be replaced by  $Z_{\text{tn}}$  (impedance of the telecommunication network) and  $Z_{\text{AMN}}$  is to be replaced by  $Z_{\text{AAN}}$ .

- B18) When the disturbance voltage measured with a capacitive voltage probe is adjusted by the current margin which includes measurement results of the disturbance current as required in C.1.3 of CISPR 22:2008 and in C.4.1.6.4 of CISPR 32:2015 [19], then the uncertainty of the adjusted voltage is slightly increased by those input quantities of the disturbance current uncertainty, that are not common to the uncertainty for the capacitive voltage probe measurement. The following additional input quantities may have to be considered: Uncertainty of the CP transfer admittance  $Y_T$  and mismatch uncertainty CP-receiver  $\delta M$ . Assuming that the same measuring receiver is used for both measurements and taking the values for  $Y_T$  (0,15 dB) and  $\delta M$  (0,53 dB) from Table B.6,  $U_{\text{CISPR}}$  becomes 4,0 instead of 3,85.
- B19) The effect of the environment (test site, ground loops, effect of magnetic fields, imperfect grounding of the ancillary equipment etc.) is to some extent included in CISPR 16-2-1 and CISPR 16-4-1. It cannot be generally quantified. A reference source can be used to determine the magnitude of this input quantity for a single EUT, but not for a system consisting of multiple units.

## B.7 Uncertainty budget for conducted disturbance measurements at a mains port using a CDNE

The measurand  $V$  is calculated using:

$$V = V_r + a_c + F_{\text{CDNE}} + \delta Z_{\text{CDNE}} + \delta V_{\text{sw}} + \delta V_{\text{pa}} + \delta V_{\text{pr}} + \delta V_{\text{nf}} + \delta F_{\text{CDNE}} + \delta M + \delta D_{\text{amb}} + \delta V_{\text{grounding}} + \delta V_{\text{env}} \quad (\text{B.6})$$

**Table B.7 – Uncertainty budget for conducted disturbance measurements  
from 30 MHz to 300 MHz**

| Input quantity <sup>a</sup>                                                             | $X_i$                  | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$<br>dB |
|-----------------------------------------------------------------------------------------|------------------------|----------------------|-----------------------------------|----------------------|
|                                                                                         |                        | dB                   | Probability distribution function |                      |
| Receiver reading <sup>A1)</sup>                                                         | $V_r$                  | $\pm 0,1$            | $k = 1$                           | 0,10                 |
| Attenuation: CDNE-receiver <sup>A2)</sup>                                               | $a_c$                  | $\pm 0,1$            | $k = 2$                           | 0,05                 |
| CDNE VDF <sup>B20)</sup>                                                                | $F_{CDNE}$             | $\pm 0,4$            | $k = 2$                           | 0,20                 |
| CDNE impedance tolerances <sup>B21)</sup>                                               | $\delta Z_{CDNE}$      | +2,69/–2,25          | Triangular                        | 1,01                 |
| Receiver corrections:                                                                   |                        |                      |                                   |                      |
| Sine wave voltage <sup>A3)</sup>                                                        | $\delta V_{sw}$        | $\pm 1,0$            | $k = 2$<br>Rectangular            | 0,50                 |
| Pulse amplitude response <sup>A4)</sup>                                                 | $\delta V_{pa}$        | $\pm 1,5$            |                                   | 0,87                 |
| Pulse repetition rate response <sup>A4)</sup>                                           | $\delta V_{pr}$        | $\pm 1,5$            | Rectangular                       | 0,87                 |
| Noise floor proximity <sup>A5)</sup>                                                    | $\delta V_{nf}$        | $\pm 0,0$            | Rectangular                       | 0,00                 |
| CDNE VDF frequency interpolation <sup>A6)</sup>                                         | $\delta F_{CDNE}$      | $\pm 0,1$            | Rectangular                       | 0,06                 |
| Mismatch: CDNE-receiver <sup>A7)</sup>                                                  | $\delta M$             | +0,19/–0,20          | U-shaped                          | 0,14                 |
| Effect of ambient disturbances <sup>B22)</sup>                                          | $\delta D_{amb}$       | $\pm 0,0$            | –                                 | 0,00                 |
| Grounding related factors <sup>B23)</sup>                                               | $\delta V_{grounding}$ | $\pm 1,5$            | Triangular                        | 0,61                 |
| Effect of the environment <sup>B24)</sup>                                               | $\delta V_{env}$       | $\pm 1,5$            | Triangular                        | 0,61                 |
| <sup>a</sup> Superscripts (e.g. <sup>A1)</sup> ) correspond to comments in A.2 and B.8. |                        |                      |                                   |                      |
| <sup>b</sup> All $c_i = 1$ (see A.1).                                                   |                        |                      |                                   |                      |

NOTE The influence of differential-mode emission from the EUT is negligible under the conditions specified in CISPR 16-1-2 and/or CISPR 16-2-1.

Hence, expanded uncertainty  $U(V) = 2u_c(V) = 3,79$  dB–

## B.8 Rationale for the estimates of input quantities specific to the measurement method using a CDNE

B20) The uncertainty associated with the calibration of the CDNE voltage division factor. This quantity includes the uncertainty of the internal attenuator of the CDNE.

B21) CISPR 16-1-2 defines the common-mode impedance of the CDNE as 150  $\Omega$  with a magnitude tolerance of +10  $\Omega$ /–20  $\Omega$  and a phase tolerance of  $0^\circ \pm 25^\circ$ . Taking the extremes of all combinations of the constrained CDNE common-mode impedance and the unconstrained EUT impedance, the estimate of the correction  $\delta Z_{CDNE}$  is zero with a deviation of +2,69/–2,25 dB. A triangular probability distribution is assumed, because there is only a small chance of encountering the particular combinations of CDNE impedance and EUT impedance needed to produce those extremes.

The estimation of the uncertainty is caused by the tolerance of the common-mode (CM) impedance. The tolerances of the differential-mode impedance and phase of the CDNE-M2 and CDNE-M3 are not taken into account.

B22) This factor includes the uncertainty from all radiated and conducted disturbances from the ambient and can be neglected. This can be guaranteed only if the measurement

takes place in a shielded room. Therefore the estimate of the correction  $\delta D_{\text{amb}}$  is zero with an uncertainty of zero. If conducted disturbances are not negligible, and their effect on the receiver reading has not been reduced adequately by appropriate suppression measures, a non-zero estimate of the correction and its uncertainty should be included.

- B23) The uncertainty associated with imperfect grounding related factors is generalized with  $\delta V_{\text{grounding}}$ . The influence is due mainly to the variation of the capacitive coupling between the EUT and the reference ground. The influence of imperfect grounding related factors has been estimated as a correction  $\delta V_{\text{grounding}}$  of zero and a deviation of 1,5 dB. A triangular probability distribution is assumed, because there is only a small chance of reaching maximum deviation.

NOTE 1 The conductive floor of a shielded room is an adequate way of implementing the reference ground plane.

NOTE 2 Grounding related factors include the effect of the variability of position of EUT, CDNE and cables:

- electrical properties of non-conducting blocks;
- variation of dimension of the reference ground plane;
- different ways of earthing the reference ground plane;
- electrical bonding of the CDNE with the reference ground plane;
- tolerance of height of EUT above reference ground plane.

- B24) The uncertainty given in Table B.7 can be applied if the distance between the EUT and any conductive obstacle is greater than 0,8 m. If the distance is reduced to 0,4 m, an uncertainty of 0,2 dB should be applied, as explained in CISPR 16-2-1. The influence is due mainly to the capacitive coupling between the EUT and the conductive obstacles or wall in question.

NOTE 3 A reference source can generally be used to determine the magnitude of this input quantity for a single port EUT.

## **B.9 Basis for $U_{\text{CISPR}}$ values in Table 1, uncertainty budgets and rationale for conducted disturbance measurements at mains and other ports using a $\Delta$ -AN**

The measurand  $V$  is calculated using:

$$V = V_r + a_c + F_{\text{AN}} + \delta F_{\text{ANf}} + \delta V_{\text{sw}} + \delta V_{\text{pa}} + \delta V_{\text{pr}} + \delta V_{\text{nf}} + \delta Z_{\text{AN}} + \delta M + \delta D_{\text{mains}} + \delta V_{\text{env}} \quad (\text{B.7})$$

**Table B.8 – Conducted disturbances measurements from  
150 kHz to 30 MHz using a 150 Ω Δ-AN**

| Input quantity <sup>a</sup>                                                            | $X_i$              | Uncertainty of $x_i$ |                                   | $c_i u(x_i)$ <sup>b</sup> |
|----------------------------------------------------------------------------------------|--------------------|----------------------|-----------------------------------|---------------------------|
|                                                                                        |                    | dB                   | Probability distribution function |                           |
| Receiver reading <sup>A1)</sup>                                                        | $V_r$              | $\pm 0,1$            | $k = 1$                           | 0,10                      |
| Cable attenuation: AN-receiver <sup>A2)</sup>                                          | $a_c$              | $\pm 0,1$            | $k = 2$                           | 0,05                      |
| AN voltage division factor <sup>B25)</sup>                                             | $F_{AN}$           | $\pm 0,2$            | $k = 2$                           | 0,10                      |
| Receiver corrections:                                                                  |                    |                      |                                   |                           |
| Sine wave voltage <sup>A3)</sup>                                                       | $\delta V_{sw}$    | $\pm 1,0$            | $k = 2$                           | 0,50                      |
| Pulse amplitude response <sup>A4)</sup>                                                | $\delta V_{pa}$    | $\pm 1,5$            | Rectangular                       | 0,87                      |
| Pulse repetition rate response <sup>A4)</sup>                                          | $\delta V_{pr}$    | $\pm 1,5$            | Rectangular                       | 0,87                      |
| Noise floor proximity <sup>A5)</sup>                                                   | $\delta V_{nf}$    | $\pm 0,0$            | Rectangular                       | 0,00                      |
| AN VDF frequency interpolation <sup>A6)</sup>                                          | $\delta F_{ANf}$   | $\pm 0,1$            | Rectangular                       | 0,06                      |
| Mismatch AN-receiver <sup>A7)</sup>                                                    | $\delta M$         | $\pm 0,07$           | U-shaped                          | 0,05                      |
| AN Impedance (CM) tolerances <sup>B26)</sup>                                           | $\delta Z_{AN-CM}$ | +5,37/–1,94          | Triangular                        | 1,49                      |
| AN Impedance (DM) tolerances <sup>B26)</sup>                                           | $\delta Z_{AN-DM}$ | +5,37/–1,94          | Triangular                        | 1,49                      |
| Effect of mains disturbances <sup>B27)</sup>                                           | $\delta D_{mains}$ | $\pm 0,0$            |                                   | 0,00                      |
| Effect of the environment <sup>B19)</sup>                                              | $\delta V_{env}$   |                      |                                   |                           |
| <sup>a</sup> Superscripts refer to numbered comments in A.2 and in this annex.         |                    |                      |                                   |                           |
| <sup>b</sup> All sensitivity coefficients $c_i$ are assumed to be equal to 1, see A.2. |                    |                      |                                   |                           |
| Combined standard uncertainty                                                          | $u_C$              |                      |                                   | 2,50                      |
| Expanded uncertainty ( $U_{CISPR}$ )                                                   | $2 u_C$            |                      |                                   | 4,99                      |

## B.10 Rationale for the estimates of input quantities specific to the measurement method using a Δ-AN

B25) Estimates of the Δ-AN voltage division factors  $F_{AN}$  ( $F_{AN\_asymmetric}$  and  $F_{AN\_symmetric}$ ) are assumed to be available from a calibration report, along with their expanded uncertainties and coverage factors.

B26) CISPR 16-1-2 defines the CM impedance of the 150 Ω Δ-AN as 150 Ω with a magnitude tolerance of  $\pm 30$  Ω and a phase tolerance of  $\pm 40^\circ$ . Taking the extremes of all combinations of the constrained AN CM impedance and the unconstrained EUT impedance the estimate of the correction  $\delta Z_{AN-CM}$  is zero with a deviation of +5,37/–1,94 dB. A triangular probability distribution is assumed because there is only a small chance of encountering the particular combinations of AN impedance and EUT impedance needed to produce those extremes. The triangular distribution is assumed to be symmetric.

The actual uncertainty will be reduced if the actual CM impedance does not reach the tolerance limits.

CISPR 16-1-2 defines the DM impedance of the 150 Ω Δ-AN as 150 Ω with a magnitude tolerance of  $\pm 30$  Ω and a phase tolerance of  $\pm 40^\circ$ . Taking the extremes of all combinations of the constrained AN differential mode impedance and the unconstrained EUT impedance the estimate of the correction  $\delta Z_{AN-DM}$  is zero with a deviation of +5,37/–1,94 dB. A triangular probability distribution is assumed because there is only a small chance of encountering the particular combinations of AN

impedance and EUT impedance needed to produce those extremes. The triangular distribution is assumed to be symmetric.

The actual uncertainty will be reduced if the actual DM impedance does not reach the tolerance limits.

- B27) For measurements using a  $\Delta$ -AN, disturbances from the AC mains, other kind of power supply or from an external load are assumed to be suppressed by the  $\Delta$ -AN itself or by additional filters inserted in the power supply line – if necessary.

## Annex C (informative)

### Basis for $U_{\text{cispr}}$ values in Table 1 – Disturbance power measurements

#### C.1 Uncertainty budget for disturbance power measurements

The measurand  $P$  is calculated using:

$$P = V_r + a_c + F_{AC} + \delta F_{ACf} + \delta V_{sw} + \delta V_{pa} + \delta V_{pr} + \delta V_{nf} + \delta M + \delta D_{\text{mains}} + \delta P_{\text{env}} \quad (\text{C.1})$$

**Table C.1 – Disturbance power from 30 MHz to 300 MHz**

| Input quantity <sup>a</sup>                                                                                        | $X_i$                     | Uncertainty of $x_i$ |                                   | $c_i u(x_i)^b$ |
|--------------------------------------------------------------------------------------------------------------------|---------------------------|----------------------|-----------------------------------|----------------|
|                                                                                                                    |                           | dB                   | Probability distribution function |                |
| Receiver reading <sup>A1)</sup>                                                                                    | $V_r$                     | $\pm 0,1$            | $k = 1$                           | 0,10           |
| Attenuation: absorbing clamp-receiver <sup>A2)</sup>                                                               | $a_c$                     | $\pm 0,2$            | $k = 2$                           | 0,10           |
| Clamp factor of absorbing clamp <sup>C1)</sup>                                                                     | $F_{AC}$                  | $\pm 3,0$            | $k = 2$                           | 1,50           |
| Receiver corrections:                                                                                              |                           |                      |                                   |                |
| Sine wave voltage <sup>A3)</sup>                                                                                   | $\delta V_{sw}$           | $\pm 1,0$            | $k = 2$                           | 0,50           |
| Pulse amplitude response <sup>A4)</sup>                                                                            | $\delta V_{pa}$           | $\pm 1,5$            | Rectangular                       | 0,87           |
| Pulse repetition rate response <sup>A4)</sup>                                                                      | $\delta V_{pr}$           | $\pm 1,5$            | Rectangular                       | 0,87           |
| Noise floor proximity <sup>A5)</sup>                                                                               | $\delta V_{nf}$           | $\pm 0,0$            |                                   | 0,00           |
| Clamp factor frequency interpolation <sup>A6)</sup>                                                                | $\delta F_{ACf}$          | $\pm 0,2$            | Rectangular                       | 0,12           |
| Mismatch: Absorbing clamp-receiver <sup>A7)</sup>                                                                  | $\delta M$                | $+0,19/-0,20$        | U-shaped                          | 0,14           |
| Effect of mains disturbances <sup>C2)</sup>                                                                        | $\delta D_{\text{mains}}$ | $\pm 0,0$            |                                   | 0,00           |
| Effect of environment <sup>C3)</sup>                                                                               | $\delta P_{\text{env}}$   | $\pm 2,5$            | Triangular                        | 1,02           |
| <sup>a</sup> Superscripts [e.g. <sup>A1)</sup> ] correspond to numbered comments in the annexes (see A.2 and C.2). |                           |                      |                                   |                |
| <sup>b</sup> All $c_i = 1$ (see A.1).                                                                              |                           |                      |                                   |                |

Hence, expanded uncertainty  $U(P) = 2u_c(P) = 4,52$  dB

#### C.2 Rationale for the estimates of input quantities specific to the disturbance power measurement method

- C1) An estimate of the clamp factor (original)  $F_{AC}$  of the absorbing clamp (see CISPR 16-1-3) is assumed to be available from a calibration report, along with an expanded uncertainty and a coverage factor.
- C2) Mains disturbances that are inadequately isolated from the absorbing clamp current transformer may affect the receiver reading. Fixing ferrite absorber along the mains cord near the mains supply, or using an AMN to provide a filtered mains supply, may be necessary to reduce the effect of mains disturbances.