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## Specification for radio disturbance and immunity measuring apparatus and methods:Part 4-1: Uncertainties, statistics and limit modelling - Uncertainties in standardized EMC tests (CISPR 16-4-1:2003/A1:2004,IDT)

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# TECHNICAL REPORT

# CISPR 16-4-1

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AMENDMENT 1
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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

Amendment 1

**Specification for radio disturbance and immunity measuring apparatus and methods –**

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



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# FOREWORD

This amendment has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

The text of this amendment is based on the following documents:

| DTR | Report on voting |
|---|---|
| CISPR/A/496/DTR | CISPR/A/516/RVC |

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

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

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- withdrawn,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

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## 6 Voltage measurements

*Renumber Figures 6-1 to 6-8 as Figures 10 to 17.*

*Renumber the existing references to Figures 6-1 to 6-8 in Clause 6 accordingly.*

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## 7 Absorbing clamp measurements

*Replace the existing text by the following subclauses:*

### 7.1 General

#### 7.1.1 Objective

The primary goal of this clause is to provide information and guidance for the determination of uncertainties associated with the absorbing clamp measurement and calibration methods. This clause gives rationale for the various uncertainty aspects described in several parts of CISPR 16 related to the absorbing clamp, i.e.:

- the absorbing clamp calibration method (see Clause 4 of CISPR 16-1-3);.
- the absorbing clamp measurement method (see Clause 7 of CISPR 16-2-2).

The rationale given in this clause is background information for the above-mentioned parts of CISPR 16 related to the absorbing clamp and it may be useful in the future when modifying these parts. In addition, this clause provides useful information for those who apply the absorbing clamp measurement and calibration method and who have to establish their own uncertainty estimates.

### 7.1.2 Introduction

This clause provides information on the uncertainties associated with the absorbing clamp test method (ACTM) described in CISPR 16-2-2, and with the absorbing clamp calibration methods described in CISPR 16-1-3. The uncertainty budgets on the ACTM as described in CISPR 16-4-2 or in LAB 34 [15] are not suitable for actual compliance tests in accordance with the CISPR specification given in CISPR 16-2-2. The reason is that this uncertainty budget is limited to the measurement instrumentation uncertainties (MIUs). Uncertainties due to the set up of the equipment under test (EUT) including the lead under test (LUT), and due to the measurement procedure are not taken into account. In this clause however, for the uncertainty considerations of the absorbing clamp measurement method, all the uncertainty sources that are relevant for the compliance test in accordance with the standard (the standards compliance uncertainty (SCU)) are considered. For these uncertainty calculations it is assumed that the EUT is the same. In other words, we consider the uncertainty of an ACTM using the same EUT that is measured by different test laboratories, using different measurement instrumentation, a different test site, different measurement procedures and different operators. Consequently, the reproducibility of this 'same' EUT may become a significant uncertainty source. Also the length of the LUT and the type of the cable can be slightly different if a test laboratory has to extend the lead by a cable of the 'same' type.

The uncertainty assessment described in this clause is performed in accordance with the basic considerations on uncertainties in emission measurements given in Clause 4.

Subclause 7.2 gives the uncertainty considerations related to the calibration of the absorbing clamp, while 7.3 gives the uncertainty considerations related to the absorbing clamp measurement method.

## 7.2 Uncertainties related to the calibration of the absorbing clamp

CISPR 16-1-3 specifies three different calibration methods for the absorbing clamp, i.e., the original method, the jig method and the reference device method.

This section describes the determination of the uncertainty budgets for the original clamp calibration method. The budgets for the jig and reference calibration methods will be included at a later stage.

For convenience a schematic overview of the original clamp calibration method is given in Figure 18.

### 7.2.1 The measurand

For a clamp calibration using the original (org) method, the measurand is the clamp factor $CF_{\text{org}}$ in dB(pW/$\mu$V).

The original clamp calibration method is in fact an insertion loss measurement (see Clause 4 of CISPR 16-1-3,):

$$CF_{\text{org}} = A_{\text{org}} - 17 \text{ in dB(pW/}\mu\text{V)} \quad (20)$$

where

$A_{\text{org}}$ = the measured insertion loss in dB

### 7.2.2 Uncertainty sources

This subclause gives the uncertainty sources associated with the clamp factor measurement.

The uncertainty of the clamp factor is equal to the uncertainty of the measured insertion loss (see Equation 20).

The uncertainty sources for the insertion loss are given by the uncertainty sources of the measurement chain. The measurement chain-related uncertainty sources are the EUT (=clamp under test in this case), the measurement instrumentation, the set-up, the measurement procedure and the environmental conditions. Figure 19 gives a schematic overview of all relevant uncertainty sources using a fish-bone diagram. The fish-bone diagram indicates the categories of uncertainty sources that contribute to the overall uncertainty of the clamp factor.

### 7.2.3 Influence quantities

For most of the qualitative uncertainty sources given in Figure 19, one or more influence quantities can be used ‘to translate’ the uncertainty source in question. Table 7 gives the relation between the uncertainty source and the influence quantity. If no influence quantity can be given, then in the uncertainty budget, the original uncertainty source will be used.

For each of the uncertainty sources/influence quantities some explanation is now given.

#### 7.2.3.1 EUT-related

- Stability clamp

The absorbing clamp is a mechanically rigid device that typically is quite stable over time. Nonetheless, aging effects may lead to poor contact between the ferrite cores which degrades the functions of the current probe and the decoupling. This may result in a ‘degradation’ of the clamp factor and may also cause a degradation of the decoupling factor. This is especially important if the test laboratory for quality assurance reasons repeats the clamp calibration. If the manufacturer calibrates new clamps, aging is not an issue. If the manufacturer performs a type test, then the manufacturer may repeat the calibration using different samples of the same type of clamp. Depending on the number of samples used, this Type-A uncertainty must be entered in the uncertainty budget. If the manufacturer performs a unit-specific calibration, then the calibration result is valid for that specific unit only, and consequently no uncertainty due to type testing shall be incorporated.

#### 7.2.3.2 Set-up related

a) Cross section lead under test

   For calibration of the clamp, a 4 mm diameter wire shall be used. The tolerance of the wire diameter is not specified. The resulting uncertainty is however considered negligible.

b) Length of lead under test

   The length of the lead under test shall be 7 m, of which 6 m runs over the clamp slide and 1 m is routed downwards to the CDN on the reference plane. Due to the application of the secondary absorbing device, the uncertainty due to variation in length and routing of the lead under test is considered to be low.

c) Height of lead under test above reference plane

   The LUT is running at a height of 0,8 m above the reference on top of the clamp slide with a tolerance of 5 cm. At the end of the clamp slide the LUT is routed to the CDN. The uncertainty due to residual routing variations is considered to be minor.

d) Displacement tolerance of lead under test in clamp

For the calibration procedure, a centering guide shall be used to control the position of the LUT within ±1 mm of the centre position at the location of the clamp reference point (CRP). The uncertainty figures reported in [16] are used.

e) Start and stop position tolerance

The start position of the CRP is 100 mm from the vertical reference plane (= equal to the SRP). The stop position of the CRP is 5,1 m from the vertical reference plane (SRP). The tolerance of the start position determines the uncertainty. A tolerance of ±5 mm is assumed. The resulting uncertainty is considered to be minor.

f) Guidance and routing of the measurement cable

The guidance and routing of the measurement cable to the receiver is specified. Still some degree of freedom remains which contributes to uncertainty.

#### 7.2.3.3 Measurement procedure related

Clamp scanning step size

The scanning speed and the frequency step size is specified. Still a residual uncertainty is expected due to the limited scanning step size.

#### 7.2.3.4 Environment related

a) Temperature and humidity tolerances

These environmental influence quantities are considered to have a negligible impact on the result of the measurement if the calibration is performed using an indoor test site. For outdoor test sites, the influence of temperature and humidity on the uncertainty shall be incorporated.

b) Signal to ambient ratio

For calibration, the measured signal levels shall be 40 dB above ambient levels. In this situation, the resulting uncertainty may be neglected. For lower signal to noise ratios, an additional uncertainty shall be taken into account.

c) Distance between operator and set-up

It is assumed that the scanning of the clamp is automated by some means (e.g., by a rope and pulley arrangement), and that the operator is not in the vicinity of the set-up. However, if an operator is needed to scan the clamp by hand, then the consequent uncertainty may be significant, especially below 100 MHz [16]. Such an operator-induced uncertainty can be investigated experimentally by measuring the clamp output signal at certain fixed position of the clamp, while the operator is approaching and touching the clamp from different sides (e.g., from the left and right side of the clamp slide). This can be repeated for a number of positions of the clamp. The maximum variation due to presence of the operator and touching the clamp can be determined for instance by using the maximum-hold and minimum-hold functions of a spectrum analyzer. This maximum variation can be used as a type-B input for the uncertainty budget.

#### 7.2.3.5 Measurement instrumentation related

a) Generator stability

The stability of the generator of the spectrum or network analyzer system is of importance for the uncertainty of the measured site attenuation.

b) Receiver/analyzer linearity

This uncertainty is obtained from information on the calibration of the measuring system. The uncertainty depends on the sweep mode or stepped mode of the analyzer.

c) Mismatch at the input

The attenuator in the input cable shall be at least 10 dB. Resulting mismatch uncertainties are taken from [16].

d) Mismatch at the output

The attenuator in the measuring cable shall be at least 6 dB. Resulting mismatch uncertainties are taken from [16].

e) Attenuator (optional)

If a separate generator is used for the clamp factor measurement, then during the direct measurement of the generator output, an additional attenuator may be used to avoid overload and consequent non-linear effects in the receiver. In this case, the absolute value of the attenuator and its uncertainty shall be taken into account in Equation 20 and in the uncertainty budget respectively.

f) Measuring system reading

Receiver reading uncertainties depend on receiver noise, meter scale interpolation errors. The latter should be a relatively insignificant contribution to the uncertainty for measuring systems with electronic displays (least significant digit fluctuation). For classical analogue meter displays this uncertainty contribution needs to be considered.

g) Signal to noise ratio

For clamp calibrations, the noise floor is usually sufficiently below the measured signal levels for calibration. The impact of the noise depends on the type of measuring system used (network analyzer versus spectrum analyzer).

h) Absorbing clamp test site deviation

The clamp calibration result is sensitive to the surrounding environment. The test site performance depends on the floor material and nearby obstacles.

The test site that is used for the calibration shall be validated in accordance with the specified validation procedure. Consequently, the pass/fail criterion for the deviation between the test site attenuation and the reference site attenuation given in CISPR 16-1-3 can be used in the uncertainty budget.

i) Clamp slide material

Typically the same clamp slide is used for clamp site validation and for clamp calibration procedure. If the clamp slide material is not RF-transparent, then the possible perturbing effects of the clamp slide material shall be taken into account.

j) SAD decoupling factor

The decoupling performance of the SAD specifies the decoupling of the far end of the LUT from the near end of the LUT. A minimum requirement for the SAD decoupling factor is given.

k) CDN impedance tolerance

For the clamp calibration, a CDN is specified to terminate the LUT near the reference plane. In the lower frequency range (30 MHz – 230 MHz) this gives a common-mode termination impedance of approximately 150 Ω. Beyond 230 MHz, the common-mode termination impedance of CDNs is not specified. The tolerance of the common-mode impedance of the CDN will affect the common-mode current in the LUT. However this effect will also depend on the common-mode impedance contributions from the EUT, LUT and the SAD. Quantitative information on the resulting uncertainty is not available. It is estimated that the effect due to the CDN common-mode impedance tolerance is minor.

#### 7.2.3.6 Repeatability of measurement

'Measurement system repeatability' is an influence quantity that is often a generic part of uncertainty budgets.

The repeatability of the calibration is determined by deriving the standard deviation of a series of repeated calibration measurements using the same set up and measurement equipment. In this way statistical information is gained about a number of influence quantities together, i.e., stability of the clamp, stability of the analyzer generator, measuring system reading, start/stop position tolerance, clamp scanning. Consequently, if 'repeatability of measurement' is included as a generic item of the uncertainty budget, then it is important to be sure that certain influence quantities that are part of this 'repeatability of measurement' category, are not included twice.

### 7.2.4 Application of the uncertainty budget

In general, the expanded uncertainty figure of the clamp factor is used by a test laboratory as an input to derive the expanded uncertainty of its clamp measurement method. Note that for this purpose, the standard uncertainty has to be derived from the expanded uncertainty. If we assume that the uncertainty of the clamp factor has a normal distribution, then the expanded uncertainty value of the clamp factor has to be divided by a factor $k = 2$. Consequently, the clamp manufacturer may also directly provide the standard uncertainty instead of the expanded uncertainty.

As already discussed in the previous section, the uncertainty figure of the clamp factor may be a unit-specific figure or it may be a figure that is applicable to that type of clamp. The uncertainty that is related to a type calibration is generally larger than the unit specific uncertainty. The reason is that for type testing a limited number of samples of the same type of clamp is used and the average of the individual clamp sources is taken as clamp factor of that particular type. Consequently the uncertainty due to the spread of this average clamp factor will result in an increased uncertainty.

### 7.2.5 Typical examples of an uncertainty budget

Tables C.1 and C.2 of Annex C give a typical uncertainty budget for the original clamp calibration method in the two frequency bands 30 MHz – 300 MHz and 300 MHz – 1 000 MHz respectively. The uncertainty budgets for the jig calibration method and the reference device calibration method are still under consideration.

The uncertainty budgets are calculated in accordance with the procedure given in Clause 4. Each budget contribution can be determined by using the Type A and Type B methods of evaluation. Type A evaluations of uncertainty are done by using statistical analysis of repeated measurement, and Type B evaluations of uncertainty are done by other than statistical analysis.

In practice, EMC compliance measurements are typically executed once for a certain type of EUT. Repeated measurements using the same EUT are not common practice. Therefore, the uncertainty budget contributions are mostly determined using the Type B method of evaluation.

This is also the case for the budgets presented in Annex E, i.e., most of the budget contributions are Type B evaluations and use data from calibration certificates, instrumentation manuals, manufacturers' specifications, previous measurements or from models or generic understanding of the measurement method. The probability distributions and uncertainty values for the various uncertainty sources/influence quantities that are given in Annex C are derived from various sources of information [16][17][20].

Unfortunately no model is available for the relation between the measurand and the various influence quantities. All that can be said is that the measurand is a function of the influence quantities given in Table 7. Most standard uncertainty values of each influence quantity must be derived from specifications or from experimental data. Further, it is assumed that all sensitivity coefficients are equal to one. However, due to the absence of a realistic model, the true value of the sensitivity coefficients is unknown.

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