CISPR TR 16-4-5

Edition 1.0 2014-07

TECHNICAL REPORT

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

AMENDMENT 1

Specification for radio disturbance and immunity measuring apparatus and methods –
Part 4-5: Uncertainties, statistics and limit modelling – Conditions for the use of alternative test methods

CISPR TR 16-4-5:2006-10/AMD1:2014-07(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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FOREWORD

This amendment has been prepared by subcommittee CISPR A: Radio-interference measurements and statistical methods, of IEC technical committee CISPR: International special committee on radio interference.

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

DTR	Report on voting
CISPR/A/1050/DTR	CISPR/A/1069/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 stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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

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2 Normative references

Replace, in the existing reference to IEC 60050-161, "IEC 60050-161" *by* "IEC 60050-161:1990".

Delete the existing publication date from reference CISPR 16-4-1.

3.1
established test method

Replace the existing note in this definition by the following new note:

NOTE The following test methods have been considered to be established test methods in CISPR:

– conducted disturbance measurements at mains ports using an AMN in the frequency range 9 kHz to 30 MHz; this method is defined in CISPR 16-2-1;
– radiated disturbance measurements in the frequency range 30 MHz to 1 GHz at 10 m distance on an OATS or in a SAC; this method is defined in CISPR 16-2-3;
– radiated disturbance measurements in the frequency range 1 GHz to 18 GHz at 3 m distance on an FSOATS; this method is defined in CISPR 16-2-3.

3.8
intrinsic uncertainty of the measurand

Delete, in the existing source of this definition, the words ", definition 3.6".

Add, after the existing definition 3.9, the following new term and definition as follows:

3.10
standards compliance uncertainty
SCU
parameter, associated with the result of a compliance measurement as described in a standard, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[IEC 60050-161:1990, 311-01-02, modified, deletion of the notes]

4 Symbols and abbreviated terms

*Replace, in the existing symbol "i", the text by "*index number of an individual EUT*".*

Add, to the existing list, the following new symbols and abbreviated terms:

j	index number of an individual test lab
f	index number of an individual measured frequency
T	number of test labs
F	number of measured frequencies in the considered frequency range
RRT	round robin test
OATS	open-area test site
SAC	semi-anechoic chamber

Table 2 – Overview of quantities and defining equations for conversion process

Add, at the bottom of the existing table, the following new lines.

$U_{\mathrm{SC,XTM}}$	standards compliance uncertainty for the test method X, where X is either “E” for established test method or “A” for alternative test method	(26)
D_{K}	deviation of the single calculated conversion factor $K_i(f,j)$ from the average conversion factor $\overline{K}(f)$	(20), (21)
D_{XTM}	deviation of the single measured value $M_{\mathrm{XTM},i}(f,j)$ from the average for the measured values $\overline{M}_{\mathrm{XTM},i}$	(24), (25)
$M_{\mathrm{XTM},i(f,j)}$	measured value depending on EUT, lab, and frequency	(18), (23)

Add, after the existing 6.10, the following new clause:

7 Measurement-based procedure to derive limits for an alternative test method based on measurement results

7.1 General

As presented in Clause 6, the conversion factor $\overline{K}$ of alternative disturbance measurement methods is based on the concept of the availability of models of the measurement methods under consideration, the considered EUTs, and the application of an independent reference quantity *X*. In this way, the inherent uncertainties of the two methods under comparison are determined, and these uncertainties plus the intrinsic uncertainties of the measurand and the measurement instrumentation uncertainties (MIUs) are taken into account in determining the limit for the ATM [see Equations (7), (9) and (16)].

Because the independent reference quantity is not always available, the conversion factor $\overline{K}$ can be estimated by direct comparison of the measurement results [see Equation (14)]. The uncertainty of each measurement procedures is estimated by the standards compliance uncertainty (SCU). The uncertainty of the conversion factor is determined by the SCUs of the ETM and ATM, as well as by the different characteristics of the EUTs. The limit L_{ATM} is determined according to Equation (15) using the conversion factor $\overline{K}$. The limit $L_{\mathrm{ATM,U}}$ takes into account the difference between the SCUs of the ATM and ETM, as well as the uncertainty caused by the different characteristics of the EUTs.

The condition for the estimation of the conversion factor by measurements is that at least five independent sets of data for each EUT are obtained through a round robin test (RRT), and *N* representative EUTs are used for the RRT. To assure statistical independence of the sets of data, the RRT involves at least five test houses. For simplicity, it is assumed here that each set of data is provided by a different test house. Outliers are identified and removed from the sets of data if no correction is possible.

7.2 Application of practical measurement results to determine the conversion factors

7.2.1 The conversion factor

The conversion factor K_i in the considered frequency range can be calculated for each of the *F* measured frequencies, for each of the *N* EUTs and for each of *T* labs.

$$K_i(f,j) = M_{\mathrm{ATM},i}(f,j) - M_{\mathrm{ETM},i}(f,j) \quad \text{in dB} \tag{18}$$

The average conversion factor $\overline{K}(f)$ is calculated using Equation (19).

$$\overline{K}(f)=\frac{1}{NT}\sum_{i=1}^{N}\sum_{j=1}^{T}K_i(f,j) \quad \text{in dB} \tag{19}$$

The uncertainty of the average conversion factor $\overline{K}(f)$ can be estimated by the deviation $D_{K,i}(f,j)$ of each calculated conversion factor $K_i(f,j)$ from the average conversion factor $\overline{K}(f)$ and the standard deviation s_K of $D_{K,i}(f,j)$.

$$D_{K,i}(f,j)=\overline{K}(f)-K_i(f,j) \quad \text{in dB} \tag{20}$$

The experimental standard deviation can be calculated by

$$s_K=\sqrt{\frac{1}{(NTF)-1}\sum_{i=1}^{N}\sum_{j=1}^{T}\sum_{f=1}^{F}[\overline{D}_K-D_{K,i}(f,j)]^2} \quad \text{in dB} \tag{21}$$

where $\overline{D}_K$ is the average of all $D_{K,i}(f,j)$.

The resulting expanded uncertainty U_K of the conversion factor is

$$U_K=2s_K \quad \text{in dB} \tag{22}$$

7.2.2 Estimation of SCU by measurement

For the estimation of the SCU, the average for the measured values of all T test labs for each EUT i is calculated using Equation (23).

$$\overline{M}_{\text{XTM},i}(f)=\frac{1}{T}\sum_{j=1}^{T}M_{\text{XTM},i}(f,j) \quad \text{in dB} \tag{23}$$

where XTM is either ETM or ATM.

For each frequency f and for each EUT i, the deviation $D_{\text{XTM},i}(f,j)$ between the measured values' average $\overline{M}_{\text{XTM},i}(f)$ and each measured value $M_{\text{XTM},i}(f,j)$ is calculated using Equation (24).

$$D_{\text{XTM},i}(f,j)=\overline{M}_{\text{XTM},i}(f)-M_{\text{XTM},i}(f,j) \quad \text{in dB} \tag{24}$$

The experimental standard deviation of all these deviations $D_{\text{XTM},i}(f,j)$ can be calculated by

$$s=\sqrt{\frac{1}{(NTF)-1}\sum_{i=1}^{N}\sum_{j=1}^{T}\sum_{f=1}^{F}[\overline{D}_{\text{XTM}}(f)-D_{\text{XTM},i}(f,j)]^2} \quad \text{in dB} \tag{25}$$

where $\overline{D}_{\text{XTM}}(f)$ is the average of all $D_{\text{XTM},i}(f,j)$.

The uncertainty that causes this deviation depends on the measurement equipment and the measurement procedure. This uncertainty is the SCU, and it is estimated by

$$U_{SC,XTM} = 2s \text{ in dB} \tag{26}$$

7.2.3 Applying the conversion factor

The limit of an established test method can be converted into limit conditions for an alternative test method using the average conversion factor [see Equation (15)] and the measurement uncertainties of ETM and ATM [see Equations (16) and (17)].

Equations (16) and (17) take into account the instrumentation uncertainty. The inherent and intrinsic uncertainty of the measurand is considered by using a reference quantity X in estimating the conversion factor $\overline{K}(f)$. If $\overline{K}(f)$ is estimated by measuring the influence of all uncertainties, then the instrumentation uncertainty, the uncertainty of the measurement procedure, and the uncertainty caused by the different radiation characteristics of the EUTs are all taken into account. Therefore the difference Δ_{meas} of the uncertainties of the ATM and ETM is:

$$\Delta_{meas} = U_{ATM} - U_{SC,ETM} \text{ in dB} \tag{27}$$

For the estimation of the uncertainty U_{ATM} [see Equation (32)], the uncertainty of the conversion factor U_K is investigated. The amount of the uncertainty U_K of the conversion factor can be estimated by:

$$U_K^2 = U_{SC,ETM}^2 + U_{SC,ATM}^2 + U_{EUT}^2 \tag{28}$$

where

$U_{SC,ETM}$ is the SCU of the ETM,

$U_{SC,ATM}$ is the SCU of the ATM, and

U_{EUT} is the uncertainty that is caused by the different radiation characteristics of the EUTs, which is estimated by Equations (29) to (31).

The different characteristics cause a unique conversion factor for each EUT. The difference between the conversion factors is estimated by the deviation $D_{K,EUT}$ between the average conversion factor $\overline{K}(f)$ and the average conversion factor for each EUT $\overline{K}_i(f)$.

$$D_{K,EUT}(f) = \overline{K}(f) - \overline{K}_i(f) \tag{29}$$

$D_{K,EUT}$ has standard deviation

$$s_{EUT} = \sqrt{\frac{1}{(NF)-1}\sum_{i=1}^{N}\sum_{f=1}^{F}[\overline{D}_{K,i} - D_{K,EUT}(f)]^2} \tag{30}$$

where $\overline{D}_{K,i}$ is the average of all $D_{K,EUT}(f)$.

The uncertainty U_{EUT} is estimated by

$$U_{EUT} = 2s_{EUT} \text{ in dB.} \tag{31}$$

The uncertainty U_{ATM} is determined by the uncertainty $U_{SC,ATM}$ of the ATM and the uncertainty U_{EUT} caused by the EUTs. Therefore U_{ATM} can be estimated by

$$U_{ATM} = \sqrt{U_{EUT}^2 + U_{SC,ATM}^2} \, . \quad (32)$$

Therefore, using Equation (27) the application of Equation (17) becomes

$$L_{ATM,U} = L_{ATM} - \Delta_{meas} \text{ if } \Delta_{meas} > 0\text{, and} \quad (33)$$

$$L_{ATM,U} = L_{ATM} \text{ if } \Delta_{meas} \leq 0 \quad (34)$$

It should be considered that $U_{SC,ETM}$ in Equation (27) is estimated in accordance with CISPR 16-4-1, which estimates generally the U_{SC} for 3 m test site results in the frequency range 30 MHz to 300 MHz to be 15,5 dB; for the conditions of the RRT and the terminated cables, U_{SC} may be reduced to 11 dB. CISPR 16-4-1 gives no value for the $U_{SC,ETM}$ of the 10 m test site results, but the value can be expected to be in the order of about 10 dB.

B.1.1.5 Estimate the standard uncertainties of the test methods (see 6.6)

Replace, in the existing text for intrinsic uncertainty, "CISPR 16-4-1:2003" *by* "CISPR 16-4-1".

B.2.1.5 Estimate the standard uncertainties of the test methods (see 6.6)

Replace, in the existing text for intrinsic uncertainty, "CISPR 16-4-1 ed.1.1" *by* "CISPR 16-4-1".

Add, at the end of the existing B.3, the following new annex.

Annex C
(informative)

Example of the application of the test method comparison procedure based on measurement results

NOTE 1 The example described in this annex uses the results of a RRT with a CDNE. The correction of measurement results and missing data sets are deemed acceptable for the purposes of this demonstration.

NOTE 2 A CDNE is defined in CISPR 16-1-2 as a coupling/decoupling network for emission measurement in the frequency range 30 MHz to 300 MHz.

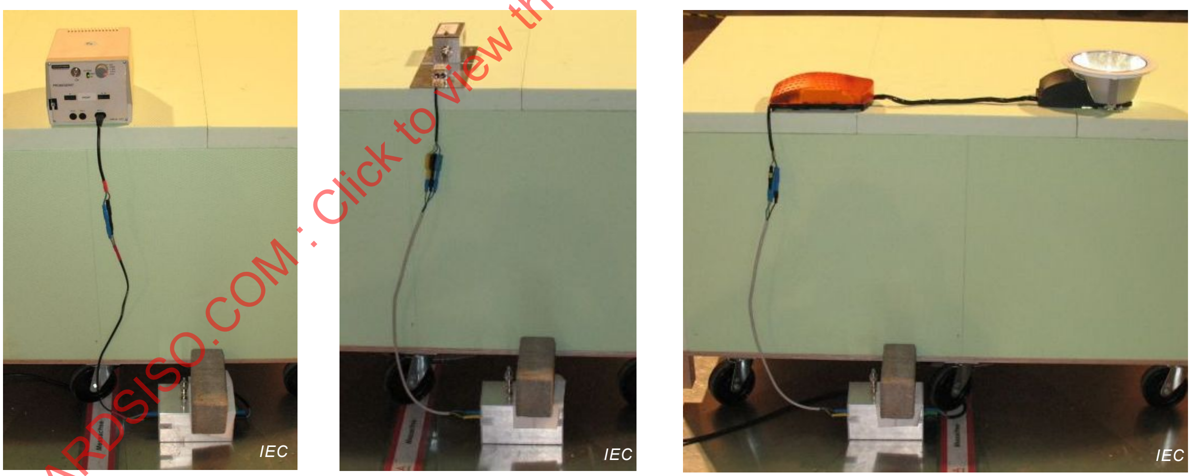
C.1 General

A RRT was carried out by CISPR/A participants for estimating the conversion factor for the ATM “measurement of the disturbance voltage in the frequency range 30 MHz to 300 MHz with a CDNE.” Six international test labs participated.

Three different representative EUTs were used. Figure C.1 a) shows comb generator 1 radiating via the connected cable as well as via its case. Figure C.1 b) shows comb generator 2 radiating via the connected cable that was fed via a typical EMI-mitigation filter. Figure C.1 c) shows a luminaire downlight.

The field strength measurement (i.e. ETM) was carried out using a CDNE as a CMAD. Where available for a given test lab, two different CDNEs from different manufacturers were utilized.

NOTE A CMAD is defined in CISPR 16-1-4 as a common mode absorption device that can be applied on cables leaving the test volume in radiated emission measurements to reduce the compliance uncertainty.



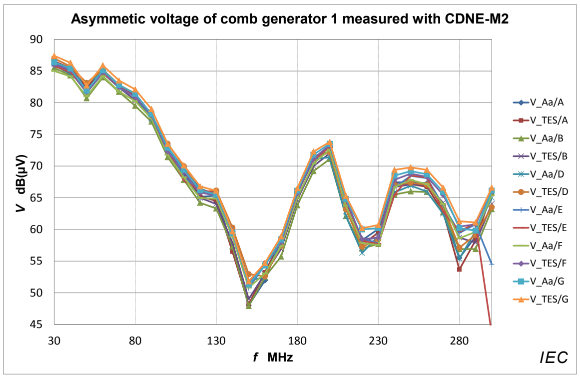
a) Comb generator 1 b) Comb generator 2 c) Luminaire downlight

Figure C.1 – EUTs used during RRT

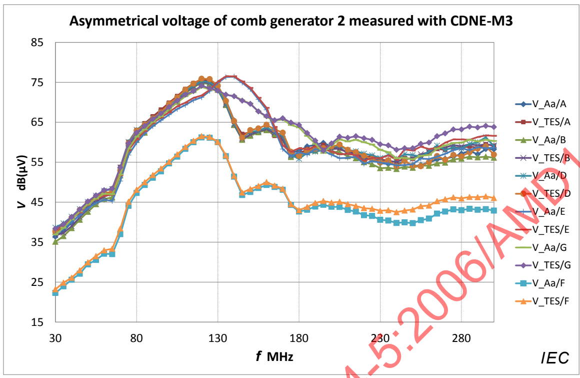
C.2 Measurement of conducted disturbance using CDNEs

Figure C.2 shows the results of measurements of the asymmetric voltage using both CDNEs. An approximately constant deviation of 10 dB for lab “F” in Figure C.2 b) can be seen. This measurement is not taken into account for further consideration of the standards compliance uncertainty.

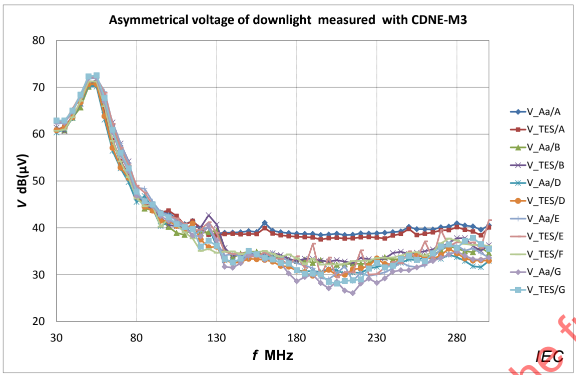
For the downlight results, one test lab used a measurement bandwidth of 10 kHz. A correction of 10,8 dB is made, which allows inclusion of the measurement results. Further it should be noted that above about 130 MHz there are no EUT emissions. Therefore only measurement results up to 130 MHz are considered.



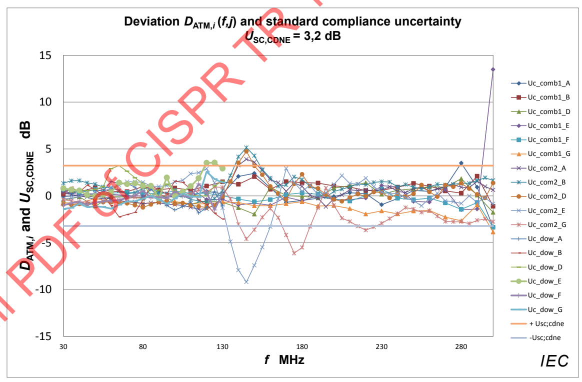
a) Comb generator 1



b) Comb generator 2



c) Downlight



d) Deviations and SCU

Figure C.2 – Measurement results of the asymmetrical voltage using both CDNEs

For estimating the SCU, the average of all T = 6 test labs for EUT i is calculated using Equation (23).

For each frequency f and for each EUT i, the deviation $D_{ATM,i}(f,j)$ between the measured values' average $\overline{M}_{XTM,i}(f)$ and each measured value $M_{ATM,i}(f,j)$ is calculated using Equation (24).

The experimental standard deviation of all these deviations $D_{ATM,i}(f,j)$ is calculated to be 1,6 dB, using Equation (25).

The uncertainty that causes this deviation depends on the measurement equipment and the measurement procedure. This uncertainty is the SCU, which is estimated by Equation (26).

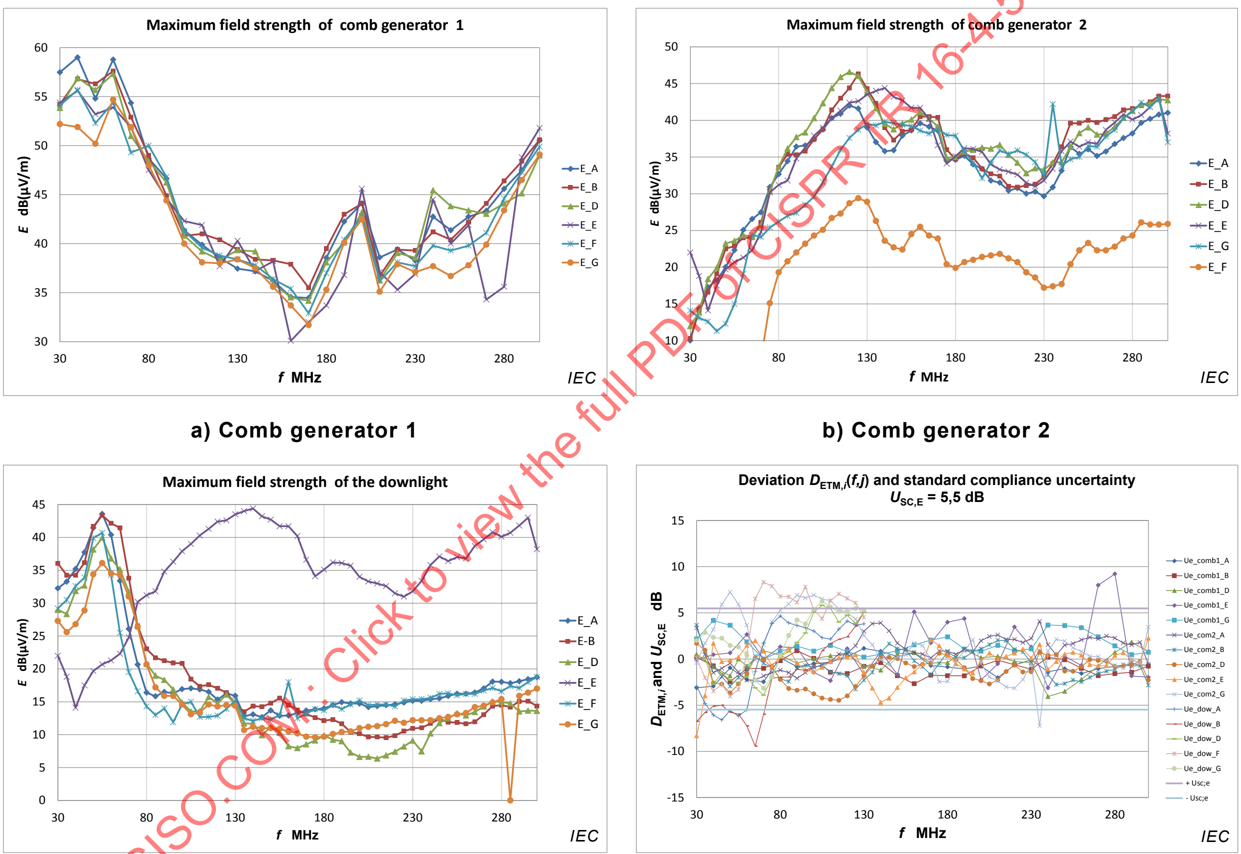
The calculated deviations $D_{ATM,i}(f,j)$, and the SCU of 3,2 dB, are shown in Figure C.2 d).

C.3 Measured disturbance field strength

The disturbance field strength of the EUTs was measured in a 10 m SAC or on a 10 m OATS. This measurement procedure is the established measurement procedure (ETM), with the exception that then CDNE was used as a CMAD.

Figure C.3 shows the measured disturbance field strength. It can be seen in Figure C.3 b) that lab “F” again has a systematic deviation of 10 dB. This measurement result of lab “F” is not taken into account for the SCU calculation. The measurement result of the downlight [Figure C.3 c)] for lab “F” again contains a correction for a systematic deviation of 10 dB. This measurement result was corrected to enable calculating the correction factor. The correction was taken because half of all measurement results from this lab show the systematic deviation of 10 dB from the average. Figure C.3 c) also shows a large deviation for lab “E.” This measurement result is not considered.

Equations (23) to (26) were used to calculate the SCU of the field strength measurement. The calculated SCU of 5,5 dB is very low for the field strength measurement with a connected cable. This low value is the result of the exact termination of the cables with a CDNE, and it shows that a CDNE can be used as a CMAD for field strength measurements.



a) Comb generator 1

b) Comb generator 2

c) Downlight

d) Deviation and SCU

Figure C.3 – Measured disturbance field strength

C.4 Conversion factor for the measurement with a CDNE

C.4.1 The conversion factor

For each of the measured frequencies, for each of the N EUTs, and for each of the T labs, the conversion factor $K_i(f,j)$ can be calculated using Equation (18).

Figure C.4 shows the frequency dependent results of $K_i(f,j)$. Figure C.5 shows the mean value of the conversion factor for each i^{th} EUT, as well as the mean value of the frequency dependent conversion factors $\overline{K}(f)$ and its correlation function trend line, which uses a polynomial of 2nd order. A commonly used electronic spreadsheet program indicates this trend line as "poly(mean value *K*(*f*))", as seen in Figure C.5. This choice of a polynomial of 2nd order avoids a strong gradient in the lower frequency range. The conversion factor $\overline{K}(f)$ is calculated using Equation (19).

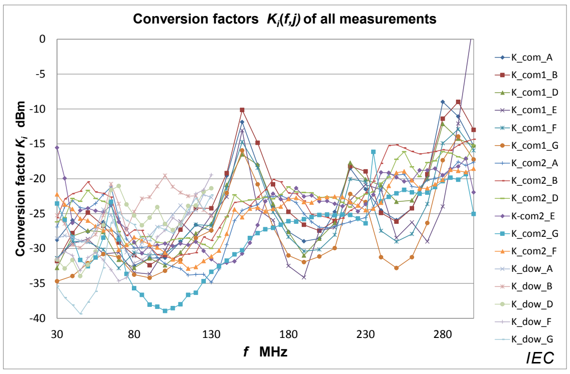


Figure C.4 – Conversion factors of all measurements

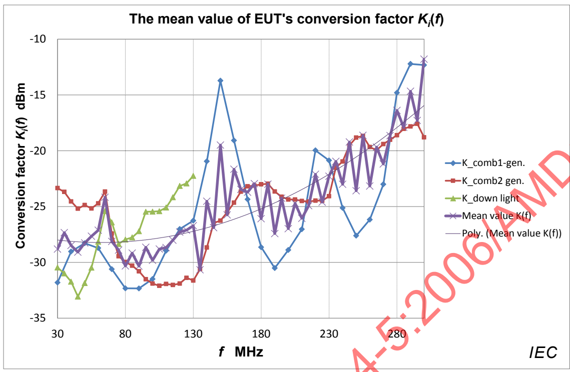


Figure C.5 – Mean conversion factors for each EUT

The conversion factor $\overline{K}(f)$ differs from that used in CISPR 15:2013 [12]; the conversion factor from CISPR 15:2013 is -24 dB at 300 MHz (see Figure C.7). The lower calculated value of about -17 dB may be caused by the radiation characteristics of the EUTs. The precondition for the ATM is that the main radiation from the EUT is via the connected cable, and therefore a vertical polarization should be expected with the arrangement according to Figure C.1. A check of the polarization of the measured maximum field strength shows that the vertical as well as the horizontal polarization show the maximum reading.

Figure C.6 shows the polarization's mean value of the measured maximum field strength of all labs for each EUT. The mean value indicates the changes from vertical to horizontal polarization and vice versa for the measurement in *n* test houses. When all labs measured the maximum field strength for the EUT with the vertical polarization, the indication in Figure C.6 is on the level "vertical". If one lab measured the maximum field strength with horizontal polarization, the indication goes down one step. If all labs measured the maximum field strength with horizontal polarization, the indication is on the level "horizontal." Figure C.6 illustrates that a larger EUT radiates at lower frequencies with horizontal polarization, and the precondition for the ATM may be questionable.

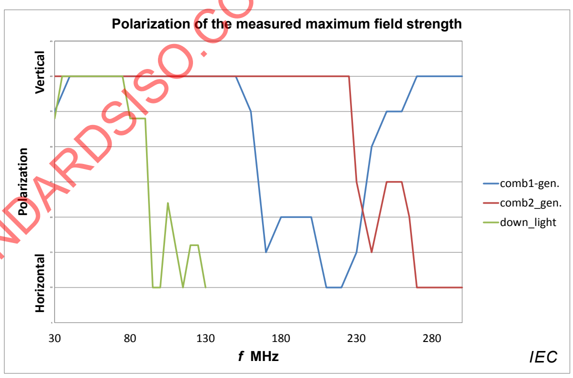


Figure C.6 – Measured polarization

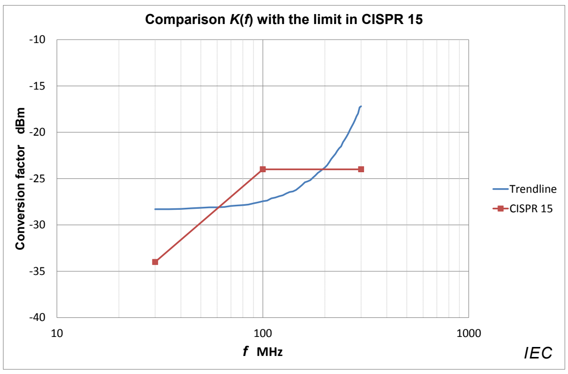


Figure C.7 – Comparison with CISPR 15:2013

C.4.2 Uncertainty of the conversion factor

The uncertainty of the average conversion factor $\overline{K}(f)$ can be estimated by the deviations $D_{K,i}(f,j)$ of each calculated conversion factor $K_i(f,j)$ from the average conversion factor $\overline{K}(f)$, and the standard deviation s_K of $D_{K,i}(f,j)$.

The experimental standard deviation has been calculated to be 2,65 dB using Equation (21).

The resulting expanded uncertainty U_K of the conversion factor is calculated by Equation (22).

Figure C.8 shows the deviations $D_{K,i}(f,j)$ of each conversion factor from the mean value of the EUT. That means in Equation (19) $\overline{K}(f)$ is replaced by $\overline{K}_i(f)$, i.e. the conversion factor for each EUT. The uncertainty of the conversion factor due to the SCU is 5,3 dB.

Because the conversion factor of each EUT is different, the limit for the ATM should be in line with the average of all $K_i(f,j)$, or the correlation function poly (mean value) shown in Figure C.5. Figure C.9 shows that the distribution of the deviation $D_{K,i}(f,j)$ of each individual EUT increases if the trend line [poly (mean value $K(f)$)] is used as the reference for the calculation of $D_{K,i}(f,j)$. Therefore the uncertainty of the conversion factor U_K increases to 8,4 dB.

The results of the RRT are in line with the presentation [11] that has shown that the conversion factor of different modelled large EUTs deviates mostly less than 10 dB from the selected conversion factor.

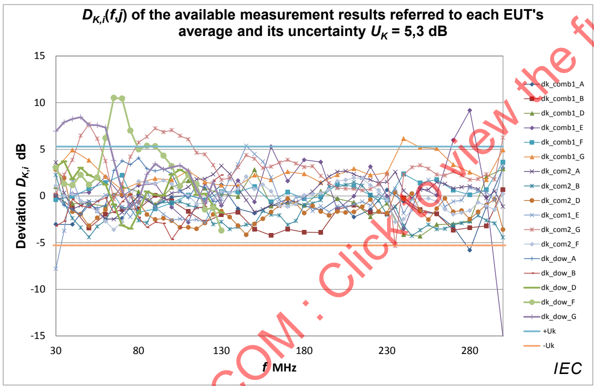


Figure C.8 – Deviation of the conversion factors from the average conversion factor of each EUT

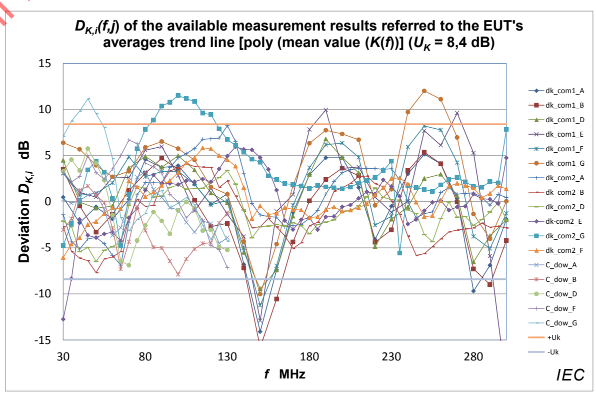


Figure C.9 – Deviation of the conversion factors from the trend line [poly (mean value *K*(*f*))]

C.4.3 Applying the conversion factor

The limit of an established test method can be converted into limit conditions for an alternative test method using the average conversion factor and consideration of Δ_{meas}, i.e. the difference of U_{ATM} and $U_{\text{SC,ETM}}$ according to Equation (27).

U_{ATM} is determined according to Equation (32). The uncertainty U_{EUT} is calculated by Equations (29), (30), and (31) to be 5,6 dB. Consequently U_{ATM} becomes

$$U_{\text{ATM}} = \sqrt{5{,}6^2 + 3{,}2^2} = 6{,}4 \text{ in dB.}$$