EURAMET Project 1064: Spectrum of Pulse Generators in Accordance with CISPR-16-1-1 v03

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Abstract

This report represents the results of an interlaboratory measurement comparison of a pulse generator spectrum in accordance with CISPR 16-1-1. Two national metrology institutes and four commercial laboratories participated in this exercise. The measurand of interest was the spectral voltage amplitude density in different frequency bands up to 1 GHz as defined in CISPR 16-1-1. To our knowledge no comparisons have been conducted so far for this quantity. The device under calibration was a EMI Calibration Pulse Generator.

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1 Introduction

Pulse generators, as the one employed in this comparison, are used worldwide as measurement standards for the calibration of EMI measuring receivers. The requirements to the pulse spectrum of these generators are defined in the normative IEC document CISPR 16-1-1 [1]. This first comparison offers the participants the possibility to verify their measurement procedures and it provides a possibility to find and fix errors.

2 Participants and Schedule

Table 1 lists the participants in this interlaboratory comparison. Pilot duties were shared among the two national metrology institutes, PTB and METAS. PTB provided the travelling standard, organized the measurement loop and performed regular control measurements to monitor the stability of the device, whereas METAS acted as coordinator of the Euramet project, analyzed the data and wrote this report. The other four participating laboratories were commercial laboratories.

Shortcut	Laboratory
PTB	Physikalisch-Technische Bundesanstalt Braunschweig, Germany contact: Meinhard Spitzer e-mail: Meinhard.Spitzer@ptb.de
METAS	Federal Office of Metrology Bern-Wabern, Switzerland contact: Markus Zeier e-mail: Markus.Zeier@metas.ch
RhSC	DKD laboratory K-00201 Rohde & Schwarz Cologne, Germany contact: Bernhard Kistinger e-mail: Bernhard.Kistinger@rohde-schwarz.com
Schwb	Schwarzbeck Mess-Elektronik Schoenau, Germany contact: Dieter Schwarzbeck e-mail: support@schwarzbeck.de
RhSM	DKD laboratory K-16101 Rohde & Schwarz Memmingen, Germany contact: Wilfried Schmidt e-mail: Wilfried.Schmidt@rohde-schwarz.com
ICMET	National Institute for Electrical Engineering Craiova, Romania contact: Andrei Marinescu e-mail: marinesu@icmetro.ro

Table 1: Participants and contacts of the comparisons

Table 2 shows the sequence of measurements done by the participants. The third column is the date of measurement in days with respect to the first measurement done by PTB. PTB indicated their first measurement (18.06.2008) to be the official PTB result, which will be used in the analysis. ICMET did not provide a date of measurement. The entry for ICMET in table 2 is thus an estimate.

Laboratory	Date of measurement	Time line (days)
PTB	18.06.2008	0
METAS	30.07.2008	42
PTB	05.08.2008	48
RhSC	14.08.2008	57
PTB	01.09.2008	75
Schwb	26.09.2008	100
PTB	06.10.2008	110
RhSM	30.10.2008	134
PTB	06.11.2008	141
ICMET	30.11.2008	165
PTB	05.01.2009	201

Table 2: Sequence of measurements done by participants.

3 Travelling Standard and Measurements

The travelling standard was an EMI Calibration Pulse Generator type IGUU 2916 manufactured by Schwarzbeck Mess-Elektronik with the serial number 111. The measurand of this comparison was the spectral voltage amplitude density of this pulse generator in the frequency range from 9 kHz to 1 GHz for the three bands defined in CISPR 16-1-1. The exact settings are shown in table 3.

CISPR Band	Frequency Range	Generator Amplitude	Repetition Frequency	Pulse Polarity	Nominal Value
A	9 kHz - 150 kHz	60 dBμV	25 Hz	positive	6.75 μVs
B	150 kHz - 30 MHz	60 dBμV	100 Hz	positive	0.158 μVs
C/D	30 MHz - 1 GHz	60 dBμV	100 Hz	positive	0.022 μVs

Table 3: Measurement settings

Only the main generators were measured and the reference plane was the N-output connector of the respective generator. The comparison protocol defined a list of frequencies for each band (the comparison frequencies, see section 4) and the participants were asked to provide for each frequency a CISPR correction factor with respect to the nominal value in dB:

Correction factor (dB) = nominal value (dB) - measured value (dB)

The participants were further asked to provide an expanded uncertainty (k=2) for each measured value together with a GUM [2] compliant uncertainty budget. Results should be reported in the form of a calibration certificate but also made available electronically for the purpose of data analysis.

Tables and figures of the electronic data submitted by the participants can be found in appendix A. Additional information of the participants, as uncertainty budgets, is shown in appendix C.

4 Data Analysis

The analysis of the data of this comparison aims at evaluating the consistency among the results of the participants. In analogy to the international comparisons at the BIPM level (key comparisons[1]) a comparison reference value (CRV) is determined from the data of the participants as an estimate of the measurand and degrees of equivalence (DoE) are calculated for each participant as a measure of the deviation from the CRV, as e.g. described in [3]. Beforehand it is however necessary to evaluate the control measurements of PTB and apply drift corrections to the data. Drift correction and analysis of the data were only done for the frequencies defined in the comparison protocol, but neglecting the highest frequency in each band. Measurements at these frequencies are outside the CISPR specifications and should be considered as supplementary. Any measurements taken at other frequencies than those defined in the comparison protocol have been excluded from further processing.

4.1 Drift correction

Figures 1, 2 and 3 show PTB data for the different bands. The top graph displays the control measurements as a function of frequency. Each line corresponds to a measurement at a particular time. The bottom graph shows the drift of the measurements at each frequency over time. Each line corresponds a particular frequency and each point is a measurement of that frequency at a point in time indicated by the horizontal axis.

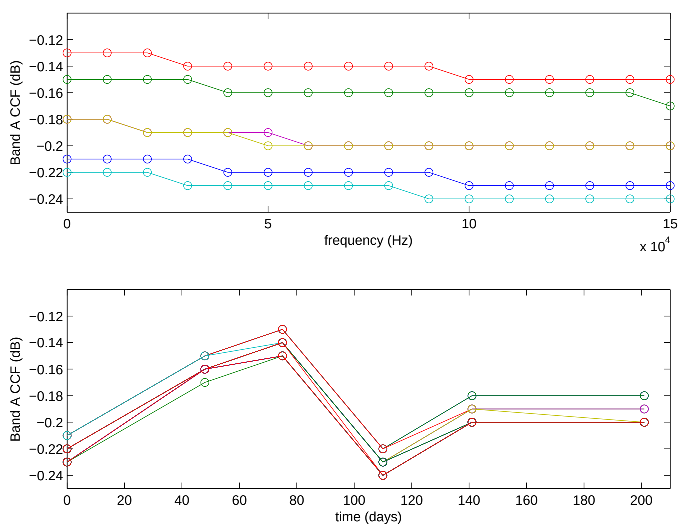

Figure 1: PTB control measurements for CISPR band A

The figures indicate that band B shows a small drift over time while band A and band C/D remain constant. To quantify the effect a simple linear dependence of the form $f(t) = p_1 + p_2 t$,

[1] http://kcdb.bipm.org/appendixB/KCDB_ApB_search.asp

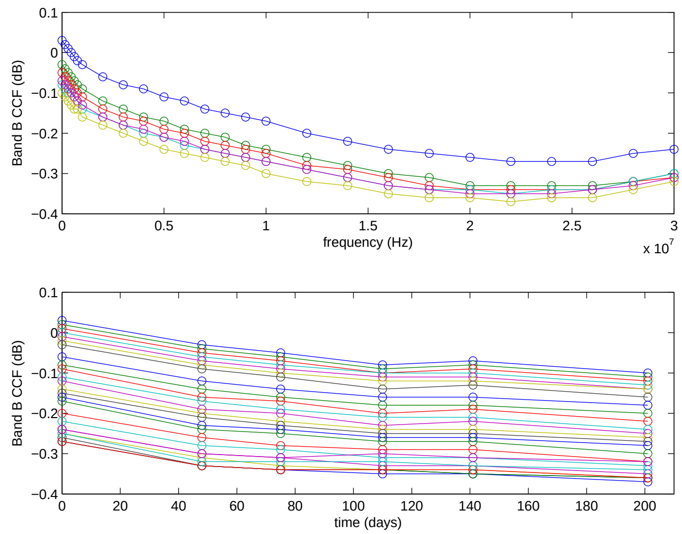

Figure 2: PTB control measurements for CISPR band B

t indicating the time of the measurement, is fitted to the PTB control measurements at each frequency using least square optimization. The results for the fit parameters p_1 and p_2 are shown in tables in appendix B. The uncertainties of the fit parameters are determined rather conservatively from the fit residuals such that the resulting reduced chi square is approximately 0.5.

Figure 4 shows as an example the fit at $f = 0$ for each band. The blue points indicate the control measurements of PTB over time and the straight black line indicates the result of the fit bounded by the red standard uncertainty region.

Finally the data of the participants are corrected for each frequency point in each CISPR band using the expression

$$CCF\,(t) = CCF_{raw}\,(t) - p_2 t$$

t is the time of measurement as indicated in the last column of table 2. Thus all results are corrected back to $t = 0$.

Tables 4, 5 and 6 show the corrected CCF for each band at the comparison frequencies. Quoted are expanded (k=2) uncertainties which include the uncertainties of the drift correction. NaN indicates that the laboratory did not submit a result at this frequency. Comparison with the raw data in appendix A shows that the changes in values and the changes in uncertainties due to the drift corrections are indeed small.

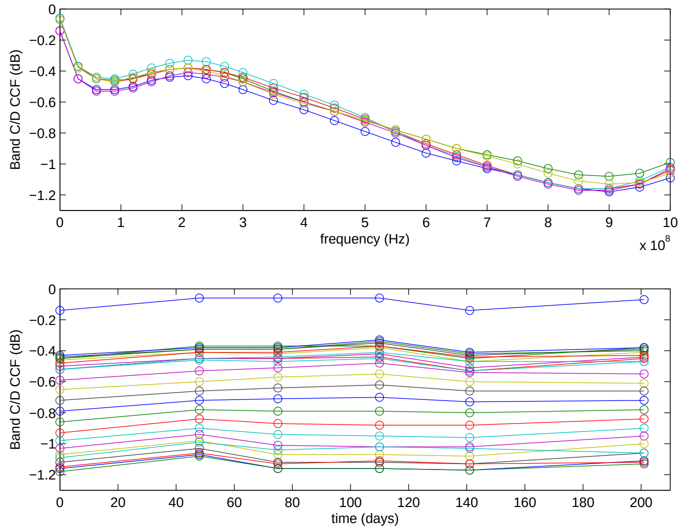

Figure 3: PTB control measurements for CISPR band C/D

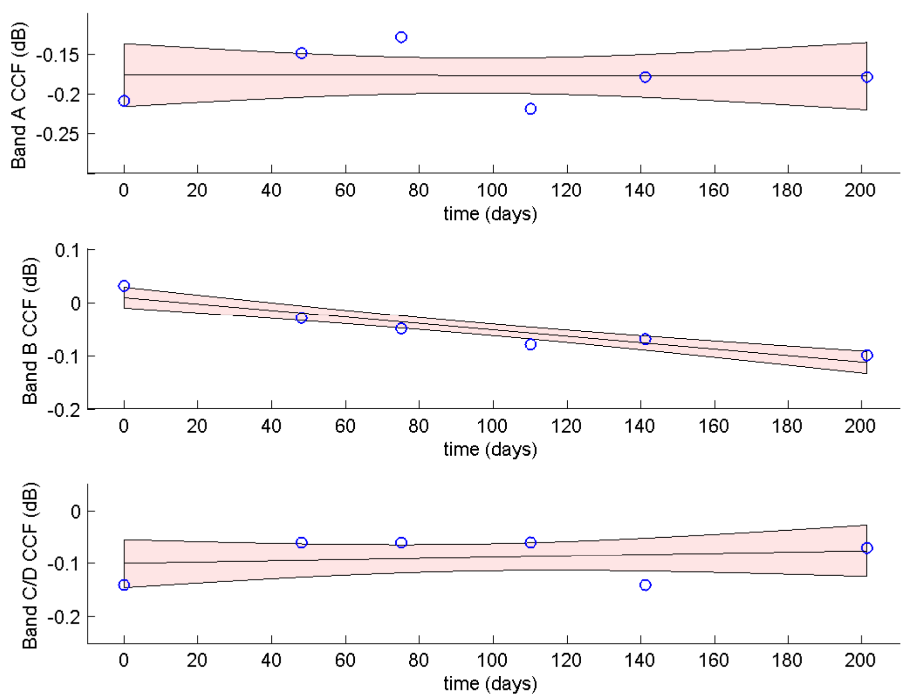

Figure 4: Examples of the drift evaluation at a single selected frequency in each CISPR band

	PTB		METAS		RhSC		Schwb		RhSM		ICMET	
Frequency (Hz)	CCF (dB)	$U(CCF)$ (dB)	CCF (dB)	$U(CCF)$ (dB)	CCF (dB))	$U(CCF)$ (dB))	CCF (dB))	$U(CCF)$ (dB))	CCF (dB))	$U(CCF)$ (dB))	CCF (dB))	$U(CCF)$ (dB)
0.0E+000	-0.21	0.25	-0.03	0.29	NaN	NaN	-0.43	0.47	NaN	NaN	NaN	NaN
1.0E+004	-0.21	0.25	0.07	0.30	-0.15	0.20	-0.32	0.47	NaN	NaN	0.19	0.33
2.0E+004	-0.21	0.25	0.05	0.29	-0.14	0.20	-0.44	0.47	0.20	0.23	0.14	0.32
3.0E+004	-0.21	0.25	0.02	0.30	-0.15	0.20	-0.43	0.47	NaN	NaN	0.15	0.32
4.0E+004	-0.22	0.25	0.04	0.29	-0.15	0.20	-0.44	0.47	NaN	NaN	0.16	0.32
5.0E+004	-0.22	0.25	0.06	0.30	-0.15	0.20	-0.43	0.47	0.21	0.23	0.19	0.33
6.0E+004	-0.22	0.25	0.05	0.29	-0.15	0.20	-0.42	0.47	NaN	NaN	0.15	0.32
7.0E+004	-0.22	0.25	0.05	0.29	-0.15	0.20	-0.42	0.47	NaN	NaN	0.16	0.32
8.0E+004	-0.22	0.25	0.05	0.29	-0.14	0.20	-0.42	0.47	0.22	0.23	0.14	0.32
9.0E+004	-0.22	0.25	0.06	0.29	-0.15	0.20	-0.42	0.47	NaN	NaN	0.14	0.32
1.0E+005	-0.23	0.25	0.06	0.31	-0.14	0.20	-0.43	0.47	0.21	0.23	0.14	0.32
1.1E+005	-0.23	0.25	0.06	0.31	-0.15	0.20	-0.43	0.47	NaN	NaN	0.16	0.32
1.2E+005	-0.23	0.25	0.06	0.31	-0.15	0.20	-0.43	0.47	NaN	NaN	0.18	0.33
1.3E+005	-0.23	0.25	0.06	0.30	-0.15	0.20	-0.43	0.47	NaN	NaN	0.21	0.33
1.4E+005	-0.23	0.25	0.06	0.30	-0.15	0.20	-0.42	0.47	NaN	NaN	0.22	0.34
1.5E+005	-0.23	0.25	0.06	0.30	-0.15	0.20	-0.42	0.47	0.20	0.25	0.26	0.35

Table 4: Drift corrected data for CISPR band A.

Frequency (Hz)	PTB *CCF* (dB)	PTB *U (CCF)* (dB)	METAS *CCF* (dB)	METAS *U (CCF)* (dB)	RhSC *CCF* (dB))	RhSC *U (CCF)* (dB))	Schwb *CCF* (dB))	Schwb *U (CCF)* (dB))	RhSM *CCF* (dB))	RhSM *U (CCF)* (dB))	ICMET *CCF* (dB))	ICMET *U (CCF)* (dB)
0.0E+000	0.03	0.25	0.21	0.28	NaN	NaN	-0.01	0.32	NaN	NaN	NaN	NaN
1.5E+005	0.02	0.25	0.30	0.30	-0.18	0.20	0.01	0.32	0.08	0.23	-0.25	0.35
3.0E+005	0.01	0.25	0.29	0.30	-0.18	0.20	0.01	0.32	NaN	NaN	-0.21	0.34
4.5E+005	0.00	0.25	0.30	0.30	-0.18	0.20	0.01	0.32	NaN	NaN	-0.21	0.34
6.0E+005	-0.01	0.25	0.30	0.30	-0.18	0.20	-0.00	0.32	NaN	NaN	-0.28	0.36
7.5E+005	-0.02	0.25	0.29	0.30	-0.18	0.20	-0.00	0.32	NaN	NaN	-0.28	0.36
1.0E+006	-0.03	0.25	0.30	0.29	-0.17	0.20	-0.01	0.32	0.30	0.23	-0.13	0.32
2.0E+006	-0.06	0.25	0.27	0.30	-0.17	0.20	-0.03	0.32	0.33	0.23	-0.15	0.32
3.0E+006	-0.08	0.25	0.26	0.30	-0.18	0.20	-0.04	0.32	NaN	NaN	-0.16	0.32
4.0E+006	-0.09	0.25	0.27	0.30	-0.18	0.20	-0.05	0.32	NaN	NaN	-0.14	0.33
5.0E+006	-0.11	0.25	0.28	0.30	-0.17	0.20	-0.06	0.32	0.45	0.23	-0.14	0.32
6.0E+006	-0.12	0.25	0.26	0.30	-0.17	0.20	-0.07	0.32	NaN	NaN	-0.11	0.32
7.0E+006	-0.14	0.25	0.24	0.30	-0.17	0.20	-0.07	0.32	NaN	NaN	-0.03	0.30
8.0E+006	-0.15	0.25	0.23	0.30	-0.17	0.20	-0.07	0.32	0.47	0.23	0.06	0.29
9.0E+006	-0.16	0.25	0.22	0.30	-0.16	0.20	-0.08	0.32	NaN	NaN	0.09	0.30
1.0E+007	-0.17	0.25	0.21	0.30	-0.14	0.20	-0.07	0.32	0.39	0.23	0.18	0.30
1.2E+007	-0.20	0.25	0.21	0.30	-0.15	0.20	-0.07	0.32	NaN	NaN	0.25	0.30
1.4E+007	-0.22	0.25	0.21	0.30	-0.15	0.20	-0.06	0.32	NaN	NaN	0.23	0.30
1.6E+007	-0.24	0.25	0.22	0.30	-0.13	0.20	-0.04	0.32	NaN	NaN	0.21	0.30
1.8E+007	-0.25	0.25	0.23	0.29	-0.14	0.20	-0.02	0.32	NaN	NaN	0.27	0.31
2.0E+007	-0.26	0.25	0.24	0.29	-0.10	0.20	-0.01	0.32	0.36	0.24	0.32	0.33
2.2E+007	-0.27	0.25	0.25	0.29	-0.10	0.20	0.02	0.32	NaN	NaN	0.28	0.31
2.4E+007	-0.27	0.25	0.27	0.29	-0.11	0.20	0.04	0.32	NaN	NaN	0.29	0.32
2.6E+007	-0.27	0.25	0.28	0.30	-0.09	0.20	0.07	0.32	NaN	NaN	0.35	0.33
2.8E+007	-0.25	0.25	0.28	0.30	-0.07	0.20	0.08	0.32	NaN	NaN	0.50	0.39
3.0E+007	-0.24	0.25	0.27	0.30	-0.02	0.20	0.09	0.32	0.47	0.23	0.55	0.41

Table 5: Drift corrected data for CISPR band B.

Frequency (Hz)	PTB CCF (dB)	PTB $U(CCF)$ (dB)	METAS CCF (dB)	METAS $U(CCF)$ (dB)	RhSC CCF (dB))	RhSC $U(CCF)$ (dB))	Schwb CCF (dB))	Schwb $U(CCF)$ (dB))	RhSM CCF (dB))	RhSM $U(CCF)$ (dB))	ICMET CCF (dB))	ICMET $U(CCF)$ (dB)
0.0E+000	-0.14	0.27	0.18	0.18	NaN	NaN	0.10	0.31	NaN	NaN	NaN	NaN
3.0E+007	-0.45	0.27	0.02	0.22	-0.27	0.25	0.14	0.31	-0.13	0.28	0.21	0.35
6.0E+007	-0.52	0.28	-0.03	0.22	-0.28	0.25	0.08	0.31	NaN	NaN	0.16	0.34
9.0E+007	-0.52	0.30	-0.08	0.22	-0.26	0.25	0.11	0.30	NaN	NaN	0.35	0.38
1.2E+008	-0.50	0.31	-0.13	0.22	-0.25	0.25	0.11	0.30	NaN	NaN	0.17	0.33
1.5E+008	-0.46	0.32	-0.13	0.21	-0.25	0.25	0.19	0.30	NaN	NaN	0.33	0.37
1.8E+008	-0.44	0.32	-0.14	0.21	-0.26	0.25	0.17	0.30	NaN	NaN	0.28	0.35
2.1E+008	-0.43	0.33	-0.14	0.21	-0.31	0.25	0.16	0.30	NaN	NaN	0.20	0.34
2.4E+008	-0.45	0.33	-0.14	0.21	-0.29	0.25	0.18	0.30	NaN	NaN	0.26	0.35
2.7E+008	-0.48	0.33	-0.17	0.22	-0.30	0.25	0.11	0.30	NaN	NaN	0.24	0.35
3.0E+008	-0.52	0.34	-0.21	0.22	-0.33	0.25	0.12	0.30	-0.44	0.28	0.21	0.34
3.5E+008	-0.59	0.35	-0.22	0.22	-0.42	0.25	0.07	0.30	NaN	NaN	0.16	0.33
4.0E+008	-0.65	0.36	-0.23	0.22	-0.48	0.25	0.01	0.30	-0.57	0.27	0.15	0.33
4.5E+008	-0.72	0.36	-0.26	0.23	-0.57	0.25	-0.01	0.30	NaN	NaN	0.11	0.31
5.0E+008	-0.79	0.35	-0.29	0.23	-0.66	0.25	-0.08	0.30	-0.59	0.27	0.21	0.33
5.5E+008	-0.86	0.35	-0.34	0.23	-0.72	0.25	-0.15	0.30	NaN	NaN	-0.07	0.30
6.0E+008	-0.93	0.35	-0.40	0.23	-0.82	0.25	-0.22	0.40	-0.83	0.27	-0.16	0.31
6.5E+008	-0.98	0.35	-0.48	0.23	-0.90	0.25	-0.21	0.40	NaN	NaN	-0.23	0.32
7.0E+008	-1.03	0.35	-0.56	0.23	-0.96	0.25	-0.26	0.41	-0.88	0.28	-0.08	0.32
7.5E+008	-1.07	0.34	-0.64	0.23	-1.07	0.25	-0.32	0.41	NaN	NaN	-0.14	0.33
8.0E+008	-1.12	0.34	-0.71	0.23	-1.10	0.25	-0.29	0.41	-0.94	0.28	-0.18	0.34
8.5E+008	-1.16	0.34	-0.77	0.24	-1.21	0.25	-0.28	0.41	NaN	NaN	-0.07	0.32
9.0E+008	-1.18	0.33	-0.79	0.25	-1.25	0.25	-0.25	0.41	-0.74	0.28	0.00	0.31
9.5E+008	-1.15	0.33	-0.78	0.25	-1.23	0.25	-0.26	0.40	NaN	NaN	-0.13	0.32
1.0E+009	-1.09	0.32	-0.71	0.26	-1.23	0.25	-0.17	0.40	-0.63	0.28	-0.24	0.34

Table 6: Drift corrected data for CISPR band C/D.

4.2 Comparison Reference Value and Degrees of Equivalence

The comparison reference value (CRV) is calculated at each frequency as the weighted mean of the drift corrected CISPR Correction Factor (CCF).

$$CRV\left(f\right) = \sum_i w_i\left(f\right) CCF_i\left(f\right) \tag{1}$$

with i indicating the laboratory and weights w_i as the normalized inverse of the squared standard uncertainties

$$w_i = \left(\sum_i \frac{1}{\left[u\left(CCF_i\right)\right]^2}\right)^{-1} \frac{1}{\left[u\left(CCF_i\right)\right]^2} \tag{2}$$

The uncertainty of the (CRV) can be calculated using linear uncertainty propagation of the individual uncertainties of the laboratories. This is a reasonable estimate if the data is statistically consistent, i.e. if the spread of the data is reflected in the uncertainties of the data points. A measure of statistical consistence is the so-called Birge ratio [4], which is basically a weighted variance. In our case it can be written as

$$BR\left(f\right) = \sqrt{\frac{1}{n-1} \sum_i w_i\left(f\right)\left(CCF_i\left(f\right) - CRV\left(f\right)\right)^2} \tag{3}$$

with n the number of measurements contributing to the calculation of the CRV. A Birge ratio significantly larger than one indicates that the spread is too large to be statistically consistent. In these cases it is recommended to increase the uncertainty of the weighted mean by a factor given as the Birge ratio.

Calculation of the Birge ratio at each frequency and for each band in this comparison confirms the visual finding that the spread of the data points is in most cases indeed too large to be statistically consistent. The following approach is therefore taken: The uncertainty of the CRV is calculated for each frequency and band with linear uncertainty propagation. The Birge ratio is calculated for each frequency and band according to equation 3. If $BR > 1$ the uncertainty of CRV is multiplied by the value of BR.

The degrees of equivalence (DoE) are calculated for each frequency and each participant i as the deviation from the CRV

$$DoE_i\left(f\right) = CCF_i\left(f\right) - CRV\left(f\right) \tag{4}$$

Uncertainties of $u\left(DoE\right)$ are calculated using linear uncertainty propagation.

Comparison reference values, Birge ratio and degrees of equivalence determined according to equations 1, 3 and 4, respectively, are shown in tables 7, 8 and 9 together with expanded (k=2) uncertainties. Figures 5, 6 and 7 show the comparison reference values determined according to equation 1 together with the drift corrected data of the participants.

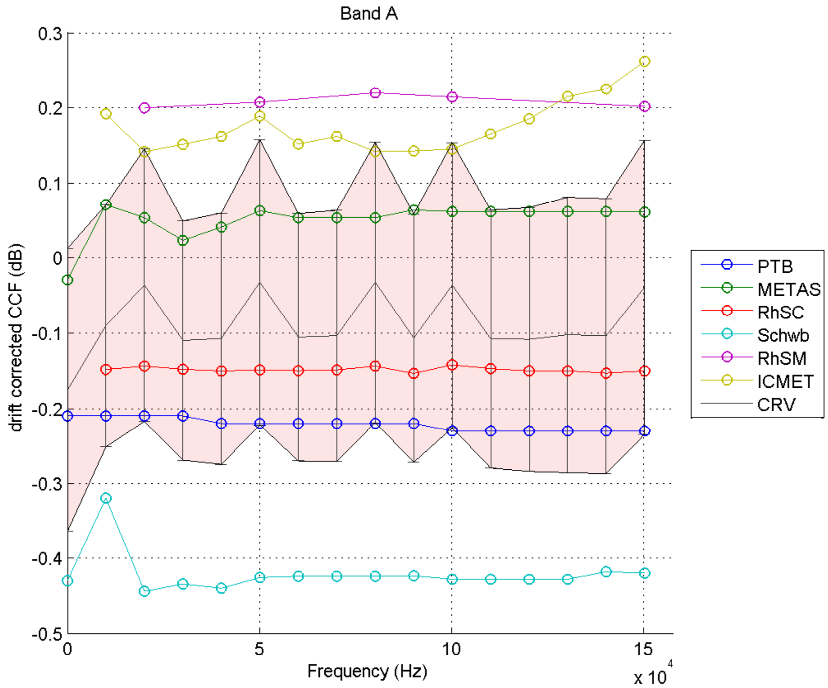

Figure 5: Comparison reference values with expanded (k=2) uncertainty region in red and drift corrected data of the participants for CISPR band A.

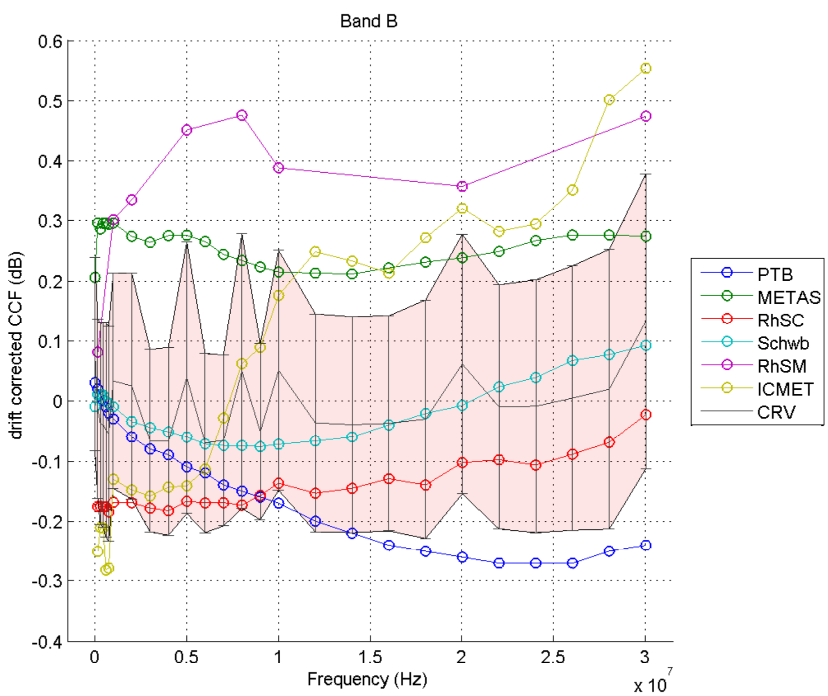

Figure 6: Comparison reference values with expanded (k=2) uncertainty region in red and drift corrected data of the participants for CISPR band B.

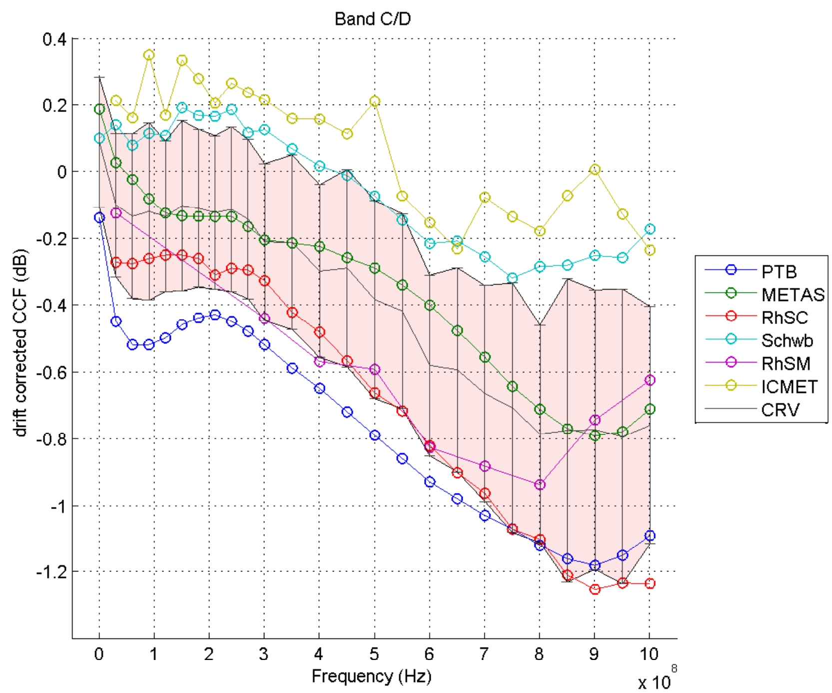

Figure 7: Comparison reference values with expanded (k=2) uncertainty region in red and drift corrected data of the participants for CISPR band C/D.

Frequency (Hz)	CRV (dB)	$U\,(CRV)$ (dB)	BR	PTB		METAS		RhSC		Schwb		RhSM		ICMET	
				DoE	$U\,(DoE)$	DoE	$U\,(DoE)$	DoE	$U\,(DoE)$	DoE	$U\,(DoE)$	DoE	$U\,(DoE)$	DoE	$U\,(DoE)$
0.0E+000	-0.18	0.19	1.07	-0.03	0.19	0.15	0.24	NaN	NaN	-0.25	0.43	NaN	NaN	NaN	0.00
1.0E+004	-0.09	0.16	1.25	-0.12	0.24	0.16	0.29	-0.06	0.19	-0.23	0.45	NaN	NaN	0.28	0.31
2.0E+004	-0.04	0.18	1.54	-0.17	0.27	0.09	0.30	-0.11	0.22	-0.41	0.47	0.24	0.24	0.18	0.32
3.0E+004	-0.11	0.16	1.24	-0.10	0.24	0.13	0.29	-0.04	0.18	-0.32	0.45	NaN	NaN	0.26	0.30
4.0E+004	-0.11	0.17	1.31	-0.11	0.25	0.15	0.28	-0.04	0.19	-0.33	0.46	NaN	NaN	0.27	0.31
5.0E+004	-0.03	0.19	1.61	-0.19	0.27	0.09	0.32	-0.12	0.22	-0.39	0.47	0.24	0.24	0.22	0.33
6.0E+004	-0.11	0.16	1.29	-0.11	0.24	0.16	0.28	-0.04	0.19	-0.32	0.46	NaN	NaN	0.26	0.31
7.0E+004	-0.10	0.17	1.31	-0.12	0.25	0.16	0.28	-0.05	0.19	-0.32	0.46	NaN	NaN	0.26	0.31
8.0E+004	-0.03	0.19	1.59	-0.19	0.27	0.09	0.31	-0.11	0.22	-0.39	0.47	0.25	0.24	0.17	0.32
9.0E+004	-0.11	0.16	1.28	-0.11	0.24	0.17	0.28	-0.05	0.19	-0.32	0.46	NaN	NaN	0.25	0.31
1.0E+005	-0.04	0.19	1.59	-0.19	0.27	0.10	0.33	-0.11	0.22	-0.39	0.47	0.25	0.24	0.18	0.33
1.1E+005	-0.11	0.17	1.32	-0.12	0.25	0.17	0.31	-0.04	0.19	-0.32	0.46	NaN	NaN	0.27	0.31
1.2E+005	-0.11	0.18	1.35	-0.12	0.25	0.17	0.31	-0.04	0.20	-0.32	0.46	NaN	NaN	0.29	0.32
1.3E+005	-0.10	0.18	1.42	-0.13	0.26	0.16	0.30	-0.05	0.20	-0.32	0.46	NaN	NaN	0.32	0.33
1.4E+005	-0.10	0.18	1.41	-0.13	0.25	0.17	0.30	-0.05	0.20	-0.31	0.46	NaN	NaN	0.33	0.34
1.5E+005	-0.04	0.20	1.63	-0.19	0.28	0.10	0.32	-0.11	0.23	-0.38	0.47	0.24	0.26	0.30	0.36

Table 7: Comparison reference values, birge ratio and degrees of equivalence for CISPR band A

Frequency (Hz)	CRV (dB)	$U(CRV)$ (dB)	BR	PTB		METAS		RhSC		Schwb		RhSM		ICMET	
				DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$
0.0E+000	0.08	0.16	0.80	-0.05	0.19	0.13	0.23	NaN	NaN	-0.09	0.27	NaN	NaN	NaN	0.00
1.5E+005	-0.01	0.15	1.37	0.03	0.25	0.31	0.30	-0.16	0.20	0.02	0.31	0.09	0.23	-0.24	0.35
3.0E+005	-0.04	0.17	1.39	0.05	0.25	0.32	0.30	-0.14	0.20	0.05	0.31	NaN	NaN	-0.17	0.34
4.5E+005	-0.04	0.17	1.42	0.04	0.25	0.33	0.30	-0.14	0.20	0.05	0.32	NaN	NaN	-0.17	0.34
6.0E+005	-0.05	0.18	1.47	0.04	0.26	0.34	0.30	-0.13	0.21	0.05	0.32	NaN	NaN	-0.23	0.37
7.5E+005	-0.05	0.18	1.48	0.03	0.26	0.35	0.30	-0.13	0.21	0.05	0.32	NaN	NaN	-0.22	0.37
1.0E+006	0.03	0.18	1.66	-0.06	0.27	0.26	0.31	-0.20	0.22	-0.04	0.33	0.27	0.25	-0.16	0.34
2.0E+006	0.02	0.19	1.74	-0.08	0.27	0.25	0.32	-0.19	0.23	-0.06	0.33	0.31	0.26	-0.17	0.34
3.0E+006	-0.07	0.15	1.27	-0.01	0.24	0.33	0.29	-0.11	0.19	0.02	0.31	NaN	NaN	-0.09	0.31
4.0E+006	-0.07	0.16	1.30	-0.02	0.24	0.34	0.29	-0.12	0.19	0.02	0.31	NaN	NaN	-0.08	0.32
5.0E+006	0.04	0.23	2.11	-0.15	0.30	0.24	0.34	-0.21	0.26	-0.10	0.36	0.41	0.29	-0.18	0.36
6.0E+006	-0.07	0.15	1.24	-0.05	0.24	0.33	0.29	-0.10	0.18	-0.00	0.31	NaN	NaN	-0.04	0.30
7.0E+006	-0.07	0.14	1.20	-0.07	0.23	0.31	0.29	-0.10	0.18	-0.01	0.30	NaN	NaN	0.04	0.29
8.0E+006	0.05	0.23	2.13	-0.20	0.30	0.18	0.35	-0.22	0.26	-0.12	0.36	0.43	0.29	0.01	0.34
9.0E+006	-0.05	0.15	1.24	-0.11	0.24	0.27	0.29	-0.11	0.18	-0.03	0.31	NaN	NaN	0.14	0.28
1.0E+007	0.05	0.20	1.87	-0.22	0.28	0.16	0.33	-0.19	0.24	-0.12	0.34	0.34	0.27	0.12	0.32
1.2E+007	-0.04	0.18	1.53	-0.16	0.26	0.25	0.31	-0.12	0.21	-0.03	0.32	NaN	NaN	0.28	0.31
1.4E+007	-0.04	0.18	1.52	-0.18	0.26	0.25	0.31	-0.11	0.21	-0.02	0.32	NaN	NaN	0.27	0.31
1.6E+007	-0.04	0.18	1.51	-0.20	0.26	0.26	0.31	-0.09	0.21	-0.00	0.32	NaN	NaN	0.25	0.31
1.8E+007	-0.03	0.20	1.67	-0.22	0.27	0.26	0.31	-0.11	0.23	0.01	0.33	NaN	NaN	0.30	0.33
2.0E+007	0.06	0.22	1.99	-0.32	0.29	0.18	0.33	-0.16	0.25	-0.07	0.35	0.30	0.28	0.26	0.36
2.2E+007	-0.01	0.20	1.71	-0.26	0.28	0.26	0.31	-0.09	0.23	0.03	0.34	NaN	NaN	0.29	0.33
2.4E+007	-0.01	0.21	1.77	-0.26	0.28	0.28	0.32	-0.10	0.24	0.05	0.34	NaN	NaN	0.30	0.35
2.6E+007	0.00	0.22	1.83	-0.27	0.29	0.27	0.33	-0.09	0.24	0.06	0.35	NaN	NaN	0.35	0.36
2.8E+007	0.02	0.23	1.90	-0.27	0.30	0.26	0.34	-0.09	0.25	0.06	0.35	NaN	NaN	0.48	0.42
3.0E+007	0.13	0.25	2.23	-0.37	0.32	0.14	0.36	-0.16	0.28	-0.04	0.37	0.34	0.30	0.42	0.45

Table 8: Comparison reference values, birge ratio and degrees of equivalence for CISPR band B

Frequency (Hz)	CRV (dB)	$U(CRV)$ (dB)	BR	PTB		METAS		RhSC		Schwb		RhSM		ICMET	
				DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$	DoE	$U(DoE)$
0.0E+000	0.09	0.19	1.41	-0.23	0.27	0.10	0.18	NaN	NaN	0.01	0.30	NaN	NaN	NaN	0.00
3.0E+007	-0.10	0.21	1.76	-0.35	0.31	0.13	0.26	-0.17	0.29	0.24	0.33	-0.02	0.30	0.31	0.36
6.0E+007	-0.14	0.25	1.92	-0.38	0.33	0.11	0.28	-0.14	0.30	0.21	0.35	NaN	NaN	0.29	0.37
9.0E+007	-0.12	0.27	2.06	-0.40	0.36	0.04	0.30	-0.14	0.32	0.23	0.36	NaN	NaN	0.47	0.42
1.2E+008	-0.14	0.23	1.75	-0.36	0.34	0.01	0.26	-0.12	0.29	0.24	0.33	NaN	NaN	0.30	0.35
1.5E+008	-0.10	0.25	1.99	-0.36	0.37	-0.03	0.28	-0.15	0.31	0.29	0.35	NaN	NaN	0.44	0.40
1.8E+008	-0.11	0.24	1.86	-0.33	0.36	-0.02	0.26	-0.15	0.30	0.28	0.34	NaN	NaN	0.39	0.38
2.1E+008	-0.12	0.23	1.81	-0.31	0.36	-0.01	0.26	-0.19	0.29	0.29	0.33	NaN	NaN	0.33	0.36
2.4E+008	-0.11	0.25	1.92	-0.34	0.37	-0.02	0.27	-0.18	0.30	0.30	0.34	NaN	NaN	0.38	0.38
2.7E+008	-0.14	0.24	1.82	-0.34	0.37	-0.02	0.27	-0.15	0.29	0.26	0.34	NaN	NaN	0.38	0.38
3.0E+008	-0.21	0.23	1.90	-0.31	0.38	0.01	0.28	-0.12	0.30	0.34	0.34	-0.23	0.31	0.43	0.37
3.5E+008	-0.21	0.26	1.98	-0.38	0.40	-0.00	0.29	-0.21	0.31	0.28	0.35	NaN	NaN	0.37	0.37
4.0E+008	-0.30	0.26	2.11	-0.35	0.41	0.07	0.30	-0.18	0.32	0.31	0.36	-0.27	0.33	0.46	0.37
4.5E+008	-0.29	0.30	2.26	-0.43	0.43	0.03	0.33	-0.28	0.34	0.28	0.38	NaN	NaN	0.40	0.39
5.0E+008	-0.38	0.30	2.46	-0.41	0.43	0.09	0.34	-0.28	0.35	0.31	0.39	-0.21	0.36	0.59	0.41
5.5E+008	-0.42	0.29	2.29	-0.44	0.42	0.08	0.33	-0.30	0.34	0.27	0.38	NaN	NaN	0.34	0.38
6.0E+008	-0.58	0.27	2.19	-0.35	0.41	0.18	0.31	-0.24	0.33	0.36	0.45	-0.24	0.34	0.43	0.37
6.5E+008	-0.59	0.31	2.26	-0.39	0.43	0.12	0.33	-0.31	0.35	0.38	0.47	NaN	NaN	0.36	0.40
7.0E+008	-0.67	0.32	2.50	-0.36	0.45	0.11	0.36	-0.30	0.37	0.41	0.48	-0.22	0.38	0.59	0.41
7.5E+008	-0.71	0.37	2.67	-0.36	0.47	0.06	0.39	-0.36	0.41	0.39	0.51	NaN	NaN	0.57	0.45
8.0E+008	-0.79	0.33	2.47	-0.33	0.44	0.07	0.36	-0.32	0.37	0.50	0.48	-0.15	0.38	0.61	0.42
8.5E+008	-0.78	0.45	3.25	-0.38	0.53	0.01	0.48	-0.43	0.48	0.49	0.57	NaN	NaN	0.70	0.51
9.0E+008	-0.77	0.42	3.21	-0.41	0.50	-0.02	0.45	-0.48	0.45	0.52	0.55	0.03	0.46	0.78	0.48
9.5E+008	-0.79	0.44	3.22	-0.36	0.52	0.01	0.47	-0.44	0.47	0.53	0.56	NaN	NaN	0.66	0.50
1.0E+009	-0.76	0.35	2.73	-0.33	0.45	0.05	0.40	-0.47	0.40	0.59	0.50	0.13	0.41	0.52	0.45

Table 9: Comparison reference values, birge ratio and degrees of equivalence for CISPR band C/D

4.3 Summarizing Results

A degree of equivalence at each frequency point is not very suitable to judge the overall performance of a participant. It is desirable to have a single summarizing quantity at least for each CISPR band. A possible choice is the mean of the degrees of equivalence for the frequencies of each CISPR band. In case of an oscillating deviation from the comparison reference value it is however possible that positive and negative degrees of equivalence cancel each other, leading to an untruly positive result. A more suitable choice is therefore the average absolute degree of equivalence $\widehat{DoE}$ given as

$$\widehat{DoE_i} = \frac{1}{n}\sum_f |DoE_i(f)| \tag{5}$$

with n indicating the number of frequency points f. $\widehat{DoE}$ is calculated for each participant in each CISPR band. The uncertainty $u\left(\widehat{DoE}\right)$ is calculated as the average of all $u(DoE)$

$$u\left(\widehat{DoE_i}\right) = \frac{1}{n}\sum_f u(DoE_i(f)) \tag{6}$$

Using linear uncertainty calculation in this case leads to an uncertainty, which is too small, unless correlations are taken into account properly. This requires that all participants quote the correlations between their measurements at different frequencies. This information however is not available. It is sound to assume that the correlations involved are significant and using equation 6 is a conservative approach, assuming that the correlation is indeed close to 1. Results of this analysis are listed in table 10 and shown in figures 8, 9 and 10. The average absolute degrees of equivalence are by definition positive-valued. One-sided expanded (k=2) uncertainty bars have been drawn in figures 8, 9 and 10 to emphasize this fact. Any of the results with an uncertainty bar crossing the zeroline can be considered as in agreement with the comparison reference value at a level better than 95%.

Laboratory	Band A		Band B		Band C/D	
	$\widehat{DoE}$	$U\left(\widehat{DoE}\right)$	$\widehat{DoE}$	$U\left(\widehat{DoE}\right)$	$\widehat{DoE}$	$U\left(\widehat{DoE}\right)$
PTB	0.13	0.25	0.14	0.26	0.36	0.40
METAS	0.14	0.30	0.26	0.31	0.06	0.32
RhSC	0.07	0.20	0.13	0.22	0.25	0.34
Schwb	0.33	0.46	0.05	0.33	0.33	0.41
RhSM	0.24	0.24	0.31	0.27	0.17	0.36
ICMET	0.26	0.32	0.21	0.34	0.46	0.40

Table 10: Averaged absolute degrees of equivalence with expanded (k=2) uncertainties calculated according to equations 5 and 6, respectively.

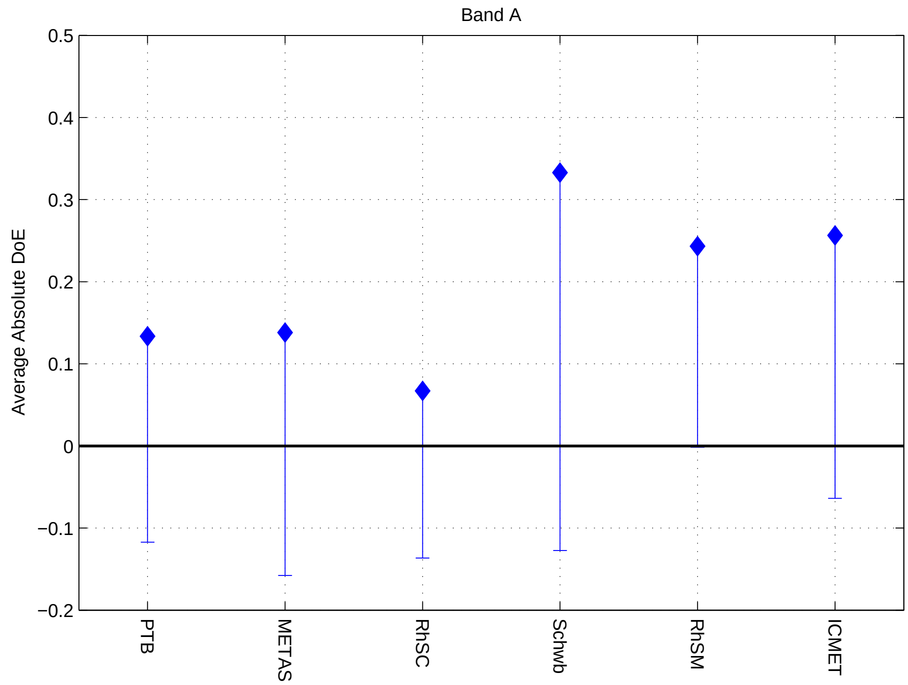

Figure 8: Averaged absolute degrees of equivalence with expanded (k=2) uncertainties calculated according to equations 5 and 6, respectively, for CISPR band A.

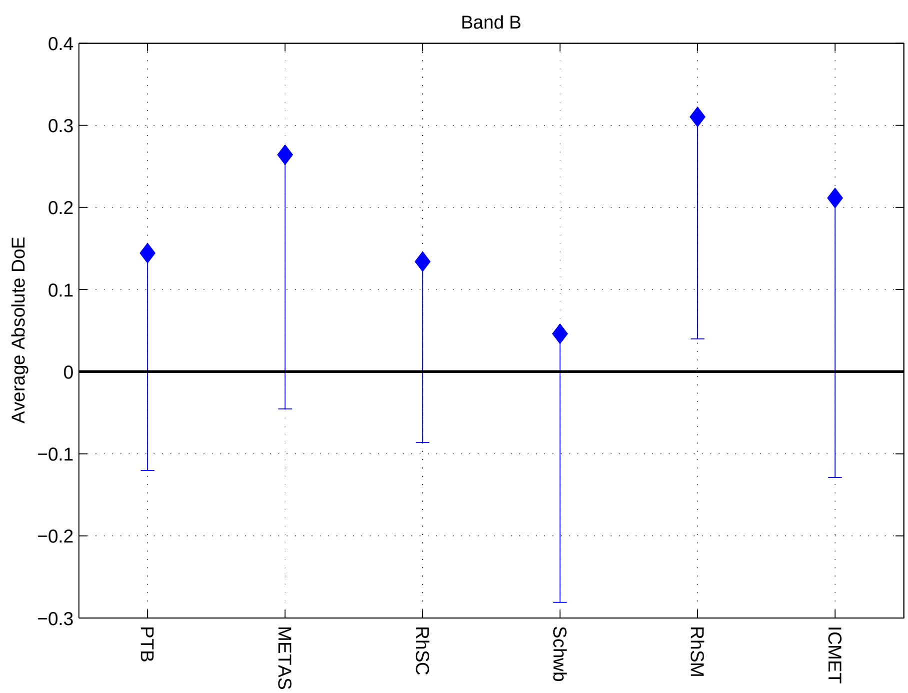

Figure 9: Averaged absolute degrees of equivalence with expanded (k=2) uncertainties calculated according to equations 5 and 6, respectively, for CISPR band B.

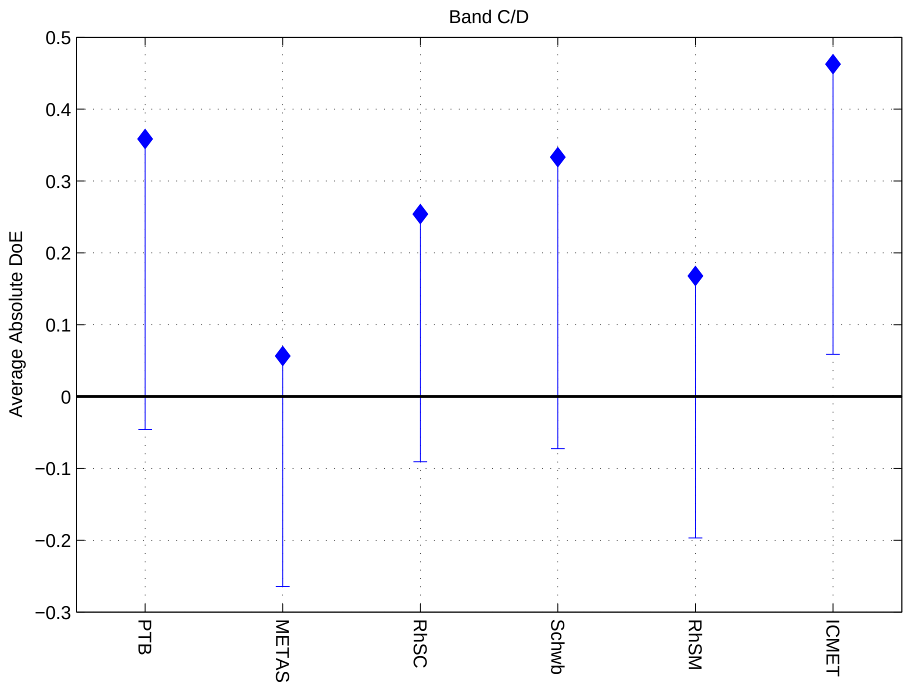

Figure 10: Averaged absolute degrees of equivalence with expanded (k=2) uncertainties calculated according to equations 5 and 6, respectively, for CISPR band C/D.

5 Conclusions

CISPR 16-1-1 requires an accuracy of ±0.5 dB for the determination of the spectral density of the pulse. The above results show that this requirement is indeed satisfied by the participants. The expanded uncertainties quoted by the participants are however typically in the order of 0.2 to 0.3 dB and the analysis in paragraph 4.2 indicates that the spread of the data is too large to be explained by the quoted uncertainties. Due to this larger spread it is necessary to increase the uncertainty of the reference value, which then results in a deceptively good agreement of most participants with the reference value. Nevertheless it is obvious that there must be unrecognized systematic effects which cause the additional spread. The deviations are primarily due to offset whereas the agreement in the frequency dependence is satisfactory with some exceptions in CISPR band B. This indicates that the deviations are caused by scaling effects which are not entirely under control.

6 Aknowledgement

METAS and PTB would like to thank the other participating laboratories for the cooperative spirit in this comparison. Most of the participants performed their measurements on schedule and provided their data and information in a timely and complete fashion. Also most of the participants were very responsive when outstanding questions needed to be clarified.

A Data submitted by participants

The figures and tables below show the CISPR correction factor (CCF) as a function of frequency submitted by the participants for the threes CISPR bands A, B and C/D, respectively. The tables list expanded (k=2) uncertainties $U(CCF)$, which are not shown in the figures for the sake of clarity.

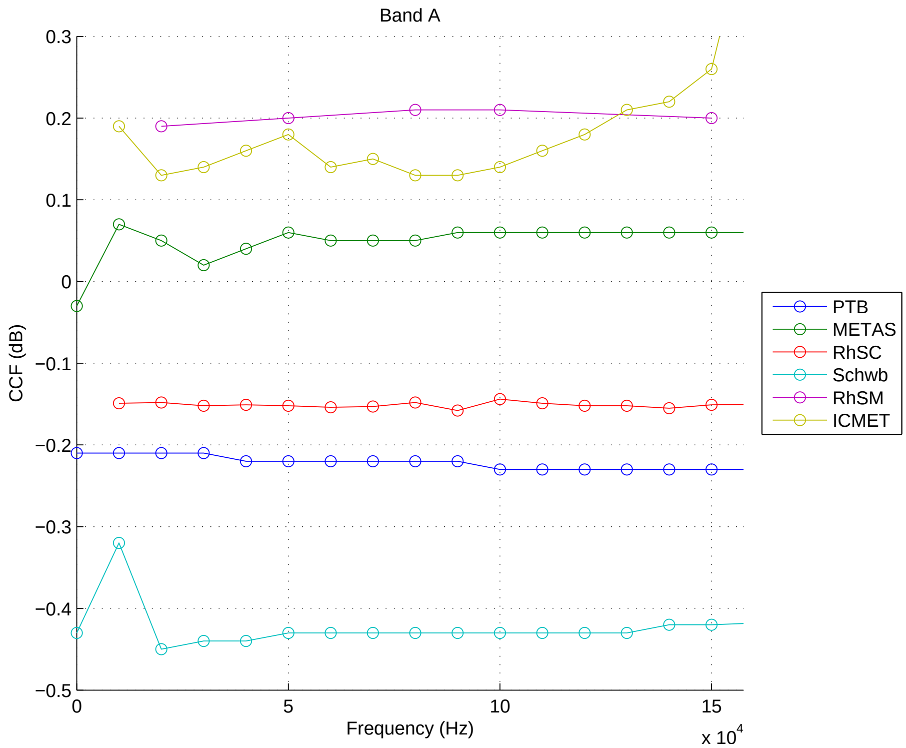

Figure 11: Submitted results of all participants for CISPR Band A

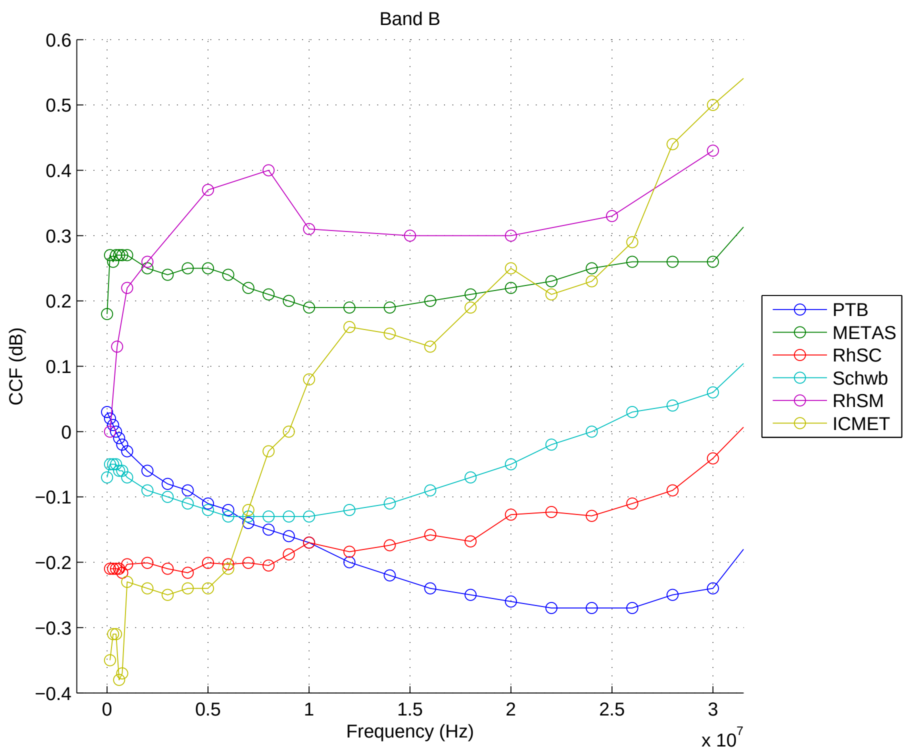

Figure 12: Submitted results of all participants for CISPR Band B

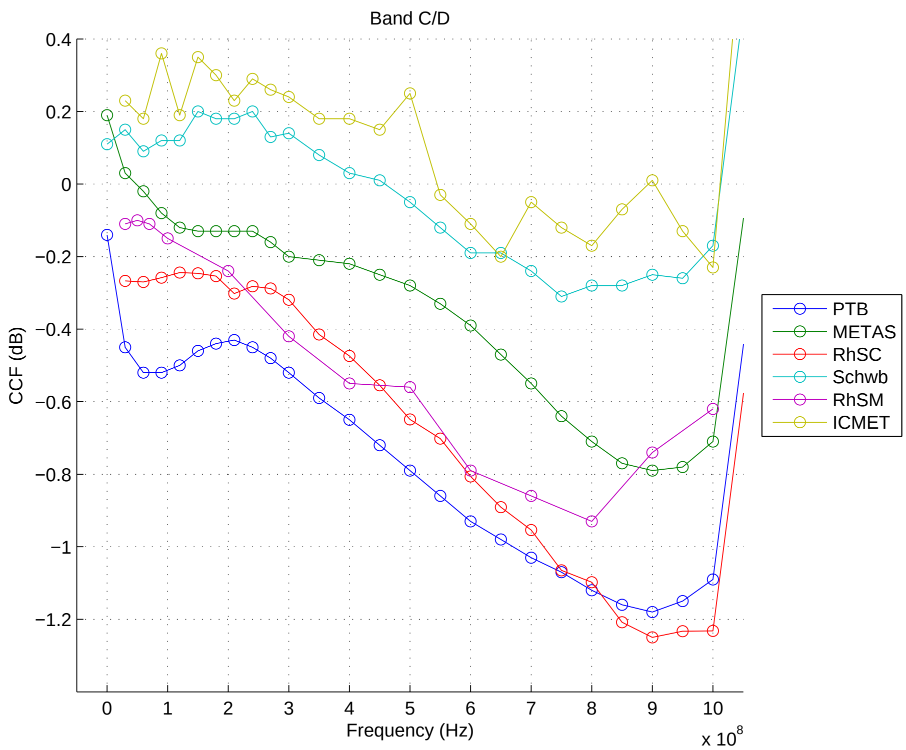

Figure 13: Submitted results of all participants for CISPR Band C/D

Table 11: Data submitted by PTB.

PTB data							
	18.06. 2008	05.08 2008	01.09 2008	06.10 2008	06.11. 2008	05.01. 2009	
Band A							
Frequency (Hz)	*CCF* (dB)						$U(CCF)$ (dB)
0.0E+000	-0.21	-0.15	-0.13	-0.22	-0.18	-0.18	0.25
1.0E+004	-0.21	-0.15	-0.13	-0.22	-0.18	-0.18	0.25
2.0E+004	-0.21	-0.15	-0.13	-0.22	-0.19	-0.19	0.25
3.0E+004	-0.21	-0.15	-0.14	-0.23	-0.19	-0.19	0.25
4.0E+004	-0.22	-0.16	-0.14	-0.23	-0.19	-0.19	0.25
5.0E+004	-0.22	-0.16	-0.14	-0.23	-0.19	-0.20	0.25
6.0E+004	-0.22	-0.16	-0.14	-0.23	-0.20	-0.20	0.25
7.0E+004	-0.22	-0.16	-0.14	-0.23	-0.20	-0.20	0.25
8.0E+004	-0.22	-0.16	-0.14	-0.23	-0.20	-0.20	0.25
9.0E+004	-0.22	-0.16	-0.14	-0.24	-0.20	-0.20	0.25
1.0E+005	-0.23	-0.16	-0.15	-0.24	-0.20	-0.20	0.25
1.1E+005	-0.23	-0.16	-0.15	-0.24	-0.20	-0.20	0.25
1.2E+005	-0.23	-0.16	-0.15	-0.24	-0.20	-0.20	0.25
1.3E+005	-0.23	-0.16	-0.15	-0.24	-0.20	-0.20	0.25
1.4E+005	-0.23	-0.16	-0.15	-0.24	-0.20	-0.20	0.25
1.5E+005	-0.23	-0.17	-0.15	-0.24	-0.20	-0.20	0.25
3.0E+005	-0.23	-0.16	-0.15	-0.24	-0.20	-0.20	0.25
Band B							
Frequency (Hz)	*CCF* (dB)						$U(CCF)$ (dB)
0.0E+000	0.03	-0.03	-0.05	-0.08	-0.07	-0.10	0.25
1.5E+005	0.02	-0.04	-0.06	-0.09	-0.08	-0.11	0.25
3.0E+005	0.01	-0.05	-0.07	-0.10	-0.09	-0.12	0.25
4.5E+005	0.00	-0.06	-0.08	-0.10	-0.10	-0.13	0.25
6.0E+005	-0.01	-0.07	-0.09	-0.11	-0.11	-0.14	0.25
7.5E+005	-0.02	-0.08	-0.10	-0.12	-0.12	-0.14	0.25
1.0E+006	-0.03	-0.09	-0.11	-0.14	-0.13	-0.16	0.25
2.0E+006	-0.06	-0.12	-0.14	-0.16	-0.16	-0.18	0.25
3.0E+006	-0.08	-0.14	-0.16	-0.18	-0.18	-0.20	0.25
4.0E+006	-0.09	-0.16	-0.17	-0.20	-0.19	-0.22	0.25
5.0E+006	-0.11	-0.17	-0.19	-0.21	-0.21	-0.24	0.25
6.0E+006	-0.12	-0.19	-0.20	-0.23	-0.22	-0.25	0.25
7.0E+006	-0.14	-0.20	-0.22	-0.24	-0.24	-0.26	0.25
8.0E+006	-0.15	-0.21	-0.23	-0.25	-0.25	-0.27	0.25
9.0E+006	-0.16	-0.23	-0.24	-0.26	-0.26	-0.28	0.25
1.0E+007	-0.17	-0.24	-0.25	-0.27	-0.27	-0.30	0.25
1.2E+007	-0.20	-0.26	-0.28	-0.29	-0.29	-0.32	0.25
1.4E+007	-0.22	-0.28	-0.29	-0.31	-0.31	-0.33	0.25

PTB data continued							
	18.06. 2008	05.08 2008	01.09 2008	06.10 2008	06.11. 2008	05.01. 2009	
1.6E+007	-0.24	-0.30	-0.31	-0.33	-0.33	-0.35	0.25
1.8E+007	-0.25	-0.31	-0.33	-0.34	-0.34	-0.36	0.25
2.0E+007	-0.26	-0.33	-0.34	-0.34	-0.35	-0.36	0.25
2.2E+007	-0.27	-0.33	-0.34	-0.35	-0.35	-0.37	0.25
2.4E+007	-0.27	-0.33	-0.34	-0.34	-0.35	-0.36	0.25
2.6E+007	-0.27	-0.33	-0.34	-0.34	-0.34	-0.36	0.25
2.8E+007	-0.25	-0.32	-0.32	-0.32	-0.33	-0.34	0.25
3.0E+007	-0.24	-0.30	-0.31	-0.30	-0.31	-0.32	0.25
6.0E+007	0.95	0.91	0.89	0.90	0.91	0.88	0.25

Band C/D							
Frequency (Hz)	CCF (dB)						$U\,(CCF)$ (dB)
0.0E+000	-0.14	-0.06	-0.06	-0.06	-0.14	-0.07	0.27
3.0E+007	-0.45	-0.37	-0.37	-0.37	-0.45	-0.38	0.27
6.0E+007	-0.52	-0.45	-0.45	-0.44	-0.53	-0.45	0.28
9.0E+007	-0.52	-0.46	-0.47	-0.45	-0.53	-0.47	0.30
1.2E+008	-0.50	-0.45	-0.45	-0.42	-0.51	-0.44	0.31
1.5E+008	-0.46	-0.41	-0.42	-0.38	-0.47	-0.41	0.32
1.8E+008	-0.44	-0.39	-0.39	-0.35	-0.43	-0.39	0.32
2.1E+008	-0.43	-0.38	-0.38	-0.33	-0.41	-0.38	0.33
2.4E+008	-0.45	-0.39	-0.39	-0.34	-0.42	-0.40	0.33
2.7E+008	-0.48	-0.41	-0.41	-0.37	-0.44	-0.43	0.33
3.0E+008	-0.52	-0.45	-0.44	-0.41	-0.47	-0.47	0.34
3.5E+008	-0.59	-0.53	-0.51	-0.48	-0.54	-0.55	0.35
4.0E+008	-0.65	-0.60	-0.57	-0.55	-0.60	-0.61	0.36
4.5E+008	-0.72	-0.66	-0.64	-0.62	-0.66	-0.66	0.36
5.0E+008	-0.79	-0.72	-0.71	-0.70	-0.73	-0.72	0.35
5.5E+008	-0.86	-0.78	-0.79	-0.79	-0.80	-0.78	0.35
6.0E+008	-0.93	-0.84	-0.87	-0.88	-0.88	-0.84	0.35
6.5E+008	-0.98	-0.90	-0.94	-0.95	-0.96	-0.90	0.35
7.0E+008	-1.03	-0.94	-1.01	-1.02	-1.02	-0.95	0.35
7.5E+008	-1.07	-0.98	-1.07	-1.07	-1.08	-1.00	0.34
8.0E+008	-1.12	-1.03	-1.12	-1.12	-1.13	-1.06	0.34
8.5E+008	-1.16	-1.07	-1.16	-1.16	-1.17	-1.11	0.34
9.0E+008	-1.18	-1.08	-1.16	-1.16	-1.17	-1.13	0.33
9.5E+008	-1.15	-1.06	-1.13	-1.11	-1.13	-1.12	0.33
1.0E+009	-1.09	-0.99	-1.04	-1.02	-1.03	-1.06	0.32
2.0E+009	11.82	12.02	11.94	11.83	12.11	12.12	0.37

Table 12: Data submitted by METAS.

METAS data		
Band A		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
0.0E+000	-0.03	0.29
1.0E+004	0.07	0.30
2.0E+004	0.05	0.29
3.0E+004	0.02	0.30
4.0E+004	0.04	0.29
5.0E+004	0.06	0.30
6.0E+004	0.05	0.29
7.0E+004	0.05	0.29
8.0E+004	0.05	0.29
9.0E+004	0.06	0.29
1.0E+005	0.06	0.31
1.1E+005	0.06	0.31
1.2E+005	0.06	0.31
1.3E+005	0.06	0.30
1.4E+005	0.06	0.30
1.5E+005	0.06	0.30
3.0E+005	0.06	0.30
Band B		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
0.0E+000	0.18	0.28
1.5E+005	0.27	0.30
3.0E+005	0.26	0.30
4.5E+005	0.27	0.30
6.0E+005	0.27	0.30
7.5E+005	0.27	0.30
1.0E+006	0.27	0.29
2.0E+006	0.25	0.30
3.0E+006	0.24	0.30
4.0E+006	0.25	0.30
5.0E+006	0.25	0.30
6.0E+006	0.24	0.30
7.0E+006	0.22	0.30
8.0E+006	0.21	0.30
9.0E+006	0.20	0.30
1.0E+007	0.19	0.30
1.2E+007	0.19	0.30
1.4E+007	0.19	0.30
1.6E+007	0.20	0.30
1.8E+007	0.21	0.29

METAS data continued		
2.0E+007	0.22	0.29
2.2E+007	0.23	0.29
2.4E+007	0.25	0.29
2.6E+007	0.26	0.30
2.8E+007	0.26	0.30
3.0E+007	0.26	0.30
6.0E+007	1.32	0.30

Band C/D		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
0.0E+000	0.19	0.18
3.0E+007	0.03	0.22
6.0E+007	-0.02	0.22
9.0E+007	-0.08	0.22
1.2E+008	-0.12	0.22
1.5E+008	-0.13	0.21
1.8E+008	-0.13	0.21
2.1E+008	-0.13	0.21
2.4E+008	-0.13	0.21
2.7E+008	-0.16	0.22
3.0E+008	-0.20	0.22
3.5E+008	-0.21	0.22
4.0E+008	-0.22	0.22
4.5E+008	-0.25	0.23
5.0E+008	-0.28	0.23
5.5E+008	-0.33	0.23
6.0E+008	-0.39	0.23
6.5E+008	-0.47	0.23
7.0E+008	-0.55	0.23
7.5E+008	-0.64	0.23
8.0E+008	-0.71	0.23
8.5E+008	-0.77	0.24
9.0E+008	-0.79	0.25
9.5E+008	-0.78	0.25
1.0E+009	-0.71	0.26
2.0E+009	11.56	0.27

Table 13: Data submitted by RhSC.

RhSC data		
Band A		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
1.0E+004	-0.15	0.20
2.0E+004	-0.15	0.20
3.0E+004	-0.15	0.20
4.0E+004	-0.15	0.20
5.0E+004	-0.15	0.20
6.0E+004	-0.15	0.20
7.0E+004	-0.15	0.20
8.0E+004	-0.15	0.20
9.0E+004	-0.16	0.20
1.0E+005	-0.14	0.20
1.1E+005	-0.15	0.20
1.2E+005	-0.15	0.20
1.3E+005	-0.15	0.20
1.4E+005	-0.16	0.20
1.5E+005	-0.15	0.20
3.0E+005	-0.14	0.20
Band B		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
1.5E+005	-0.21	0.20
3.0E+005	-0.21	0.20
4.5E+005	-0.21	0.20
6.0E+005	-0.21	0.20
7.5E+005	-0.22	0.20
1.0E+006	-0.20	0.20
2.0E+006	-0.20	0.20
3.0E+006	-0.21	0.20
4.0E+006	-0.22	0.20
5.0E+006	-0.20	0.20
6.0E+006	-0.20	0.20
7.0E+006	-0.20	0.20
8.0E+006	-0.20	0.20
9.0E+006	-0.19	0.20
1.0E+007	-0.17	0.20
1.2E+007	-0.18	0.20
1.4E+007	-0.17	0.20
1.6E+007	-0.16	0.20
1.8E+007	-0.17	0.20
2.0E+007	-0.13	0.20
2.2E+007	-0.12	0.20

RhSC data continued		
2.4E+007	-0.13	0.20
2.6E+007	-0.11	0.20
2.8E+007	-0.09	0.20
3.0E+007	-0.04	0.20
6.0E+007	0.91	0.20

Band C/D		
Frequency (Hz)	CCF (dB)	$U(CCF)$ (dB)
3.0E+007	-0.27	0.25
6.0E+007	-0.27	0.25
9.0E+007	-0.26	0.25
1.2E+008	-0.24	0.25
1.5E+008	-0.25	0.25
1.8E+008	-0.25	0.25
2.1E+008	-0.30	0.25
2.4E+008	-0.28	0.25
2.7E+008	-0.29	0.25
3.0E+008	-0.32	0.25
3.5E+008	-0.41	0.25
4.0E+008	-0.47	0.25
4.5E+008	-0.56	0.25
5.0E+008	-0.65	0.25
5.5E+008	-0.70	0.25
6.0E+008	-0.81	0.25
6.5E+008	-0.89	0.25
7.0E+008	-0.95	0.25
7.5E+008	-1.06	0.25
8.0E+008	-1.10	0.25
8.5E+008	-1.21	0.25
9.0E+008	-1.25	0.25
9.5E+008	-1.23	0.25
1.0E+009	-1.23	0.25
2.0E+009	11.81	0.50

Table 14: Data submitted by Schwb.

Schwb data		
Band A		
Frequency (Hz)	CCF (dB)	$U(CCF)$ (dB)
0.0E+000	-0.43	0.46
1.0E+004	-0.32	0.46
2.0E+004	-0.45	0.46
3.0E+004	-0.44	0.46
4.0E+004	-0.44	0.46
5.0E+004	-0.43	0.46
6.0E+004	-0.43	0.46
7.0E+004	-0.43	0.46
8.0E+004	-0.43	0.46
9.0E+004	-0.43	0.46
1.0E+005	-0.43	0.46
1.1E+005	-0.43	0.46
1.2E+005	-0.43	0.46
1.3E+005	-0.43	0.46
1.4E+005	-0.42	0.46
1.5E+005	-0.42	0.46
3.0E+005	-0.39	0.46
Band B		
Frequency (Hz)	CCF (dB)	$U(CCF)$ (dB)
0.0E+000	-0.07	0.32
1.5E+005	-0.05	0.32
3.0E+005	-0.05	0.32
4.5E+005	-0.05	0.32
6.0E+005	-0.06	0.32
7.5E+005	-0.06	0.32
1.0E+006	-0.07	0.32
2.0E+006	-0.09	0.32
3.0E+006	-0.10	0.32
4.0E+006	-0.11	0.32
5.0E+006	-0.12	0.32
6.0E+006	-0.13	0.32
7.0E+006	-0.13	0.32
8.0E+006	-0.13	0.32
9.0E+006	-0.13	0.32
1.0E+007	-0.13	0.32
1.2E+007	-0.12	0.32
1.4E+007	-0.11	0.32
1.6E+007	-0.09	0.32
1.8E+007	-0.07	0.32

Schwb data continued		
2.0E+007	-0.05	0.32
2.2E+007	-0.02	0.32
2.4E+007	0.00	0.32
2.6E+007	0.03	0.32
2.8E+007	0.04	0.32
3.0E+007	0.06	0.32
6.0E+007	0.94	0.32

Band C/D		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
0.0E+000	0.11	0.30
3.0E+007	0.15	0.30
6.0E+007	0.09	0.30
9.0E+007	0.12	0.30
1.2E+008	0.12	0.30
1.5E+008	0.20	0.30
1.8E+008	0.18	0.30
2.1E+008	0.18	0.30
2.4E+008	0.20	0.30
2.7E+008	0.13	0.30
3.0E+008	0.14	0.30
3.5E+008	0.08	0.30
4.0E+008	0.03	0.30
4.5E+008	0.01	0.30
5.0E+008	-0.05	0.30
5.5E+008	-0.12	0.30
6.0E+008	-0.19	0.40
6.5E+008	-0.19	0.40
7.0E+008	-0.24	0.40
7.5E+008	-0.31	0.40
8.0E+008	-0.28	0.40
8.5E+008	-0.28	0.40
9.0E+008	-0.25	0.40
9.5E+008	-0.26	0.40
1.0E+009	-0.17	0.40
2.0E+009	12.84	0.40

Table 15: Data submitted by RhSM.

RhSM data		
Band A		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
2.0E+004	0.19	0.21
5.0E+004	0.20	0.21
8.0E+004	0.21	0.21
1.0E+005	0.21	0.21
1.5E+005	0.20	0.23
Band B		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
1.5E+005	0.00	0.23
5.0E+005	0.13	0.23
1.0E+006	0.22	0.23
2.0E+006	0.26	0.23
5.0E+006	0.37	0.23
8.0E+006	0.40	0.23
1.0E+007	0.31	0.23
1.5E+007	0.30	0.23
2.0E+007	0.30	0.23
2.5E+007	0.33	0.23
3.0E+007	0.43	0.23
Band C/D		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
3.0E+007	-0.11	0.26
5.0E+007	-0.10	0.26
7.0E+007	-0.11	0.26
1.0E+008	-0.15	0.26
2.0E+008	-0.24	0.26
3.0E+008	-0.42	0.26
4.0E+008	-0.55	0.26
5.0E+008	-0.56	0.26
6.0E+008	-0.79	0.26
7.0E+008	-0.86	0.26
8.0E+008	-0.93	0.26
9.0E+008	-0.74	0.26
1.0E+009	-0.62	0.26

Table 16: Data submitted by ICMET.

ICMET data		
Band A		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
1.0E+004	0.19	0.31
2.0E+004	0.13	0.30
3.0E+004	0.14	0.30
4.0E+004	0.16	0.30
5.0E+004	0.18	0.31
6.0E+004	0.14	0.30
7.0E+004	0.15	0.30
8.0E+004	0.13	0.30
9.0E+004	0.13	0.30
1.0E+005	0.14	0.30
1.1E+005	0.16	0.30
1.2E+005	0.18	0.31
1.3E+005	0.21	0.31
1.4E+005	0.22	0.32
1.5E+005	0.26	0.33
3.0E+005	3.43	2.00
Band B		
Frequency (Hz)	CCF (dB)	$U\,(CCF)$ (dB)
1.5E+005	-0.35	0.35
3.0E+005	-0.31	0.34
4.5E+005	-0.31	0.34
6.0E+005	-0.38	0.36
7.5E+005	-0.37	0.36
1.0E+006	-0.23	0.32
2.0E+006	-0.24	0.32
3.0E+006	-0.25	0.32
4.0E+006	-0.24	0.32
5.0E+006	-0.24	0.32
6.0E+006	-0.21	0.31
7.0E+006	-0.12	0.30
8.0E+006	-0.03	0.29
9.0E+006	0.00	0.29
1.0E+007	0.08	0.29
1.2E+007	0.16	0.30
1.4E+007	0.15	0.30
1.6E+007	0.13	0.30
1.8E+007	0.19	0.31
2.0E+007	0.25	0.32
2.2E+007	0.21	0.31

ICMET data continued		
2.4E+007	0.23	0.32
2.6E+007	0.29	0.33
2.8E+007	0.44	0.39
3.0E+007	0.50	0.41
6.0E+007	1.31	0.81

Band C/D		
Frequency (Hz)	CCF (dB)	$U(CCF)$ (dB)
3.0E+007	0.23	0.32
6.0E+007	0.18	0.31
9.0E+007	0.36	0.36
1.2E+008	0.19	0.31
1.5E+008	0.35	0.35
1.8E+008	0.30	0.34
2.1E+008	0.23	0.32
2.4E+008	0.29	0.33
2.7E+008	0.26	0.33
3.0E+008	0.24	0.32
3.5E+008	0.18	0.31
4.0E+008	0.18	0.31
4.5E+008	0.15	0.30
5.0E+008	0.25	0.32
5.5E+008	-0.03	0.29
6.0E+008	-0.11	0.30
6.5E+008	-0.20	0.31
7.0E+008	-0.05	0.29
7.5E+008	-0.12	0.30
8.0E+008	-0.17	0.31
8.5E+008	-0.07	0.29
9.0E+008	0.01	0.29
9.5E+008	-0.13	0.30
1.0E+009	-0.23	0.32
2.0E+009	19.31	11.15

B Drift parameter

The tables below list drift parameters at each frequency with uncertainties determined from PTB control measurements as discussed in section 4.1.

Frequency (Hz)	p_1 (dB)	$u(p_1)$ (dB)	p_2 (dB/days)	$u(p_2)$ (dB/days)
0.0E+000	-1.78E-001	3.95E-002	-6.68E-006	3.42E-004
1.0E+004	-1.78E-001	3.95E-002	-6.68E-006	3.42E-004
2.0E+004	-1.75E-001	3.98E-002	-6.63E-005	3.44E-004
3.0E+004	-1.79E-001	3.94E-002	-6.37E-005	3.41E-004
4.0E+004	-1.88E-001	3.95E-002	-6.68E-006	3.42E-004
5.0E+004	-1.85E-001	3.97E-002	-4.84E-005	3.43E-004
6.0E+004	-1.85E-001	3.98E-002	-6.63E-005	3.44E-004
7.0E+004	-1.85E-001	3.98E-002	-6.63E-005	3.44E-004
8.0E+004	-1.85E-001	3.98E-002	-6.63E-005	3.44E-004
9.0E+004	-1.86E-001	4.25E-002	-7.19E-005	3.67E-004
1.0E+005	-1.94E-001	4.16E-002	-2.57E-005	3.60E-004
1.1E+005	-1.94E-001	4.16E-002	-2.57E-005	3.60E-004
1.2E+005	-1.94E-001	4.16E-002	-2.57E-005	3.60E-004
1.3E+005	-1.94E-001	4.16E-002	-2.57E-005	3.60E-004
1.4E+005	-1.94E-001	4.16E-002	-2.57E-005	3.60E-004
1.5E+005	-1.98E-001	3.95E-002	-6.68E-006	3.42E-004
3.0E+005	-1.94E-001	4.16E-002	-2.57E-005	3.60E-004

Table 17: Drift parameters for CISPR Band A.

Frequency (Hz)	p_1 (dB)	$u(p_1)$ (dB)	p_2 (dB/days)	$u(p_2)$ (dB/days)
0.0E+000	7.83E-003	1.94E-002	-6.03E-004	1.68E-004
1.5E+005	-2.17E-003	1.94E-002	-6.03E-004	1.68E-004
3.0E+005	-1.22E-002	1.94E-002	-6.03E-004	1.68E-004
4.5E+005	-2.10E-002	1.69E-002	-5.98E-004	1.46E-004
6.0E+005	-3.10E-002	1.69E-002	-5.98E-004	1.46E-004
7.5E+005	-4.34E-002	1.89E-002	-5.56E-004	1.63E-004
1.0E+006	-5.22E-002	1.94E-002	-6.03E-004	1.68E-004
2.0E+006	-8.34E-002	1.89E-002	-5.56E-004	1.63E-004
3.0E+006	-1.03E-001	1.89E-002	-5.56E-004	1.63E-004
4.0E+006	-1.16E-001	2.11E-002	-5.84E-004	1.82E-004
5.0E+006	-1.31E-001	1.69E-002	-5.98E-004	1.46E-004
6.0E+006	-1.46E-001	2.11E-002	-5.84E-004	1.82E-004
7.0E+006	-1.63E-001	1.89E-002	-5.56E-004	1.63E-004
8.0E+006	-1.73E-001	1.89E-002	-5.56E-004	1.63E-004
9.0E+006	-1.87E-001	2.07E-002	-5.37E-004	1.79E-004
1.0E+007	-1.95E-001	1.90E-002	-5.79E-004	1.64E-004
1.2E+007	-2.22E-001	1.77E-002	-5.33E-004	1.53E-004
1.4E+007	-2.42E-001	1.73E-002	-4.99E-004	1.49E-004
1.6E+007	-2.62E-001	1.73E-002	-4.99E-004	1.49E-004
1.8E+007	-2.75E-001	1.94E-002	-4.91E-004	1.67E-004
2.0E+007	-2.89E-001	2.22E-002	-4.24E-004	1.92E-004
2.2E+007	-2.93E-001	1.79E-002	-4.34E-004	1.55E-004
2.4E+007	-2.95E-001	1.87E-002	-3.86E-004	1.62E-004
2.6E+007	-2.95E-001	1.91E-002	-3.69E-004	1.65E-004
2.8E+007	-2.78E-001	2.14E-002	-3.67E-004	1.85E-004
3.0E+007	-2.66E-001	2.02E-002	-3.21E-004	1.74E-004
6.0E+007	9.32E-001	1.74E-002	-2.66E-004	1.51E-004

Table 18: Drift parameters for CISPR band B.

Frequency (Hz)	p_1 (dB)	$u(p_1)$ (dB)	p_2 (dB/days)	$u(p_2)$ (dB/days)
0.0E+000	-9.97E-002	4.53E-002	1.19E-004	3.91E-004
3.0E+007	-4.10E-001	4.53E-002	1.19E-004	3.91E-004
6.0E+007	-4.86E-001	4.53E-002	1.28E-004	3.91E-004
9.0E+007	-4.91E-001	3.78E-002	7.48E-005	3.27E-004
1.2E+008	-4.75E-001	3.92E-002	1.41E-004	3.39E-004
1.5E+008	-4.35E-001	3.81E-002	1.08E-004	3.29E-004
1.8E+008	-4.12E-001	3.56E-002	1.41E-004	3.08E-004
2.1E+008	-4.01E-001	3.67E-002	1.64E-004	3.17E-004
2.4E+008	-4.14E-001	4.00E-002	1.61E-004	3.46E-004
2.7E+008	-4.38E-001	4.04E-002	1.51E-004	3.49E-004
3.0E+008	-4.75E-001	4.04E-002	1.61E-004	3.49E-004
3.5E+008	-5.47E-001	4.14E-002	1.38E-004	3.58E-004
4.0E+008	-6.11E-001	3.77E-002	1.52E-004	3.26E-004
4.5E+008	-6.82E-001	3.35E-002	2.34E-004	2.89E-004
5.0E+008	-7.52E-001	3.05E-002	2.51E-004	2.63E-004
5.5E+008	-8.26E-001	2.70E-002	2.71E-004	2.34E-004
6.0E+008	-8.99E-001	3.12E-002	2.73E-004	2.69E-004
6.5E+008	-9.58E-001	3.36E-002	2.02E-004	2.91E-004
7.0E+008	-1.01E+000	4.32E-002	1.70E-004	3.73E-004
7.5E+008	-1.05E+000	4.91E-002	1.03E-004	4.24E-004
8.0E+008	-1.10E+000	4.73E-002	6.16E-005	4.09E-004
8.5E+008	-1.14E+000	4.57E-002	1.99E-005	3.95E-004
9.0E+008	-1.15E+000	4.22E-002	3.15E-005	3.65E-004
9.5E+008	-1.12E+000	3.54E-002	-3.83E-006	3.06E-004
1.0E+009	-1.04E+000	3.94E-002	4.09E-005	3.40E-004
2.0E+009	1.18E+001	1.09E-001	1.30E-003	9.45E-004

Table 19: Drift parameters for CISPR Band C/D.

C Additional information by the participants

C.1 PTB

PTB provided a certificate of calibration.

C.1.1 Method of Calibration

PTB uses a delay line consisting of a characterized delay line (with 10 dB and 20 dB attenuators and a 6 dB splitter) between generator and sampling oscilloscope. The delay line is used to attenuate the signal and to create the oscilloscope trigger. The voltage time characteristics of the pulse is sampled with the oscilloscope and subsequently transformed to the frequency domain. The spectral density of the pulse is calculated after applying a frequency response correction.

C.1.2 Uncertainty Budget

The following uncertainty contributions are taken into account:

Sfm: Spectral amplitude density
D: Attenuation of delay line
$k_{\Gamma gen}$: Generator output reflection
$k_{\Gamma osz}$: Oscilloscope input reflection
$k_{timebase}$: Oscilloscope time scale
k_{gain}: Gain of vertical oscilloscope scale
k_{offset}: Offset of vertical oscilloscope scale
k_{method}: Calibration method
k_{dso}: Frequency response of oscilloscope

Figure 14 shows an exemplary uncertainty budget for band C/D at 300 MHz. For the input quantities worst case uncertainties were chosen such that the uncertainties are valid for the whole frequency band. It should be noted however that the budget in figure 14 does not include yet the contribution due to repeatability.

Meßunsicherheits-Budget:

Symbol (Größe)	Wert	Standard-meßunsicherheit	Freiheitsgrad	Sensitivitätskoeffizient	Unsicherheits-beitrag	Korr.-Koeff.	Index
So	-27.131 dB						
Sfm	-69.0400 dB	0.0100 dB	50	-1.00	-0.0100 dBμVs	-0.08	0.006
D	36.9220 dB	0.0150 dB	50	-1.00	-0.0150 dBμVs	-0.12	0.014
$k_{\Gamma gen}$	0.0 dB	0.0566 dB	∞	1.00	0.0566 dBμVs	0.45	0.205
$k_{\Gamma osz}$	0.0 dB	0.0354 dB	∞	1.00	0.0354 dBμVs	0.28	0.080
$k_{timebase}$	0.0 dB	0.0289 dB	∞	1.00	0.0289 dBμVs	0.23	0.053
k_{gain}	0.0 dB	0.0289 dB	∞	1.00	0.0289 dBμVs	0.23	0.053
k_{offset}	0.0 dB	0.0289 dB	∞	1.00	0.0289 dBμVs	0.23	0.053
k_{method}	0.0 dB	0.0289 dB	∞	1.00	0.0289 dBμVs	0.23	0.053
k_{dso}	0.4600 dB	0.0866 dB	∞	1.00	0.0866 dBμVs	0.69	0.481
k_{cd}	-0.574 dBμVs	0.125 dBμVs	∞				

Figure 14: Exemplary PTB uncertainty contributions for CISPR band C/D at 300 MHz. k_{cd} is the CISPR correction factor and So is the nominal CISPR value

C.2 METAS

METAS provided a certificate of calibration.

C.2.1 Method of Calibration

METAS uses the same measurement method as PTB with a characterized delay line between pulse generator and 50 GHz sampling oscilloscope. The voltage scale of the measured pulse spectrum is corrected based on a DC calibration of the vertical oscilloscope scale. The corrected spectrum is fourier transformed to the frequency domain and the resulting frequency spectrum is corrected with a transfer function to obtain the spectral density of the original pulse. The transfer function is formed from S-parameters of the delay line, reflection coefficients of the oscilloscope input and the pulse generator output and the frequency response of the oscilloscope.

C.2.2 Uncertainty Budget

Uncertainties of the input quantities are specified according to characterizations, specifications and evaluation measurements. They are propagated linearly all the way through the analysis procedure to arrive at a combined uncertainty for the spectral density at each frequency point. With this method it is even possible to determine the correlations between the results at the different frequencies. The following uncertainty contributions have been taken into account.

tscale: Time scale of the oscilloscope
vscale calib: DC calibration of vertical scale of oscilloscope
vscale nonlin: Nonlinearity of vertical scale of oscilloscope
vscale ran: Noise of vertical scale of oscilloscope
dline s11, *dline s12*, *dline s21*, *dline s22*: Scattering parameter of delay line
osc s11: Reflection coefficient of oscilloscope input
gen s11: Reflection coefficient of generator output
osc freq resp: Frequency response of oscilloscope

Figures 15, 16 and 17 show a summary of the uncertainty budget. Minimum, mean and maximum uncertainty contributions over the whole range of frequencies are indicated.

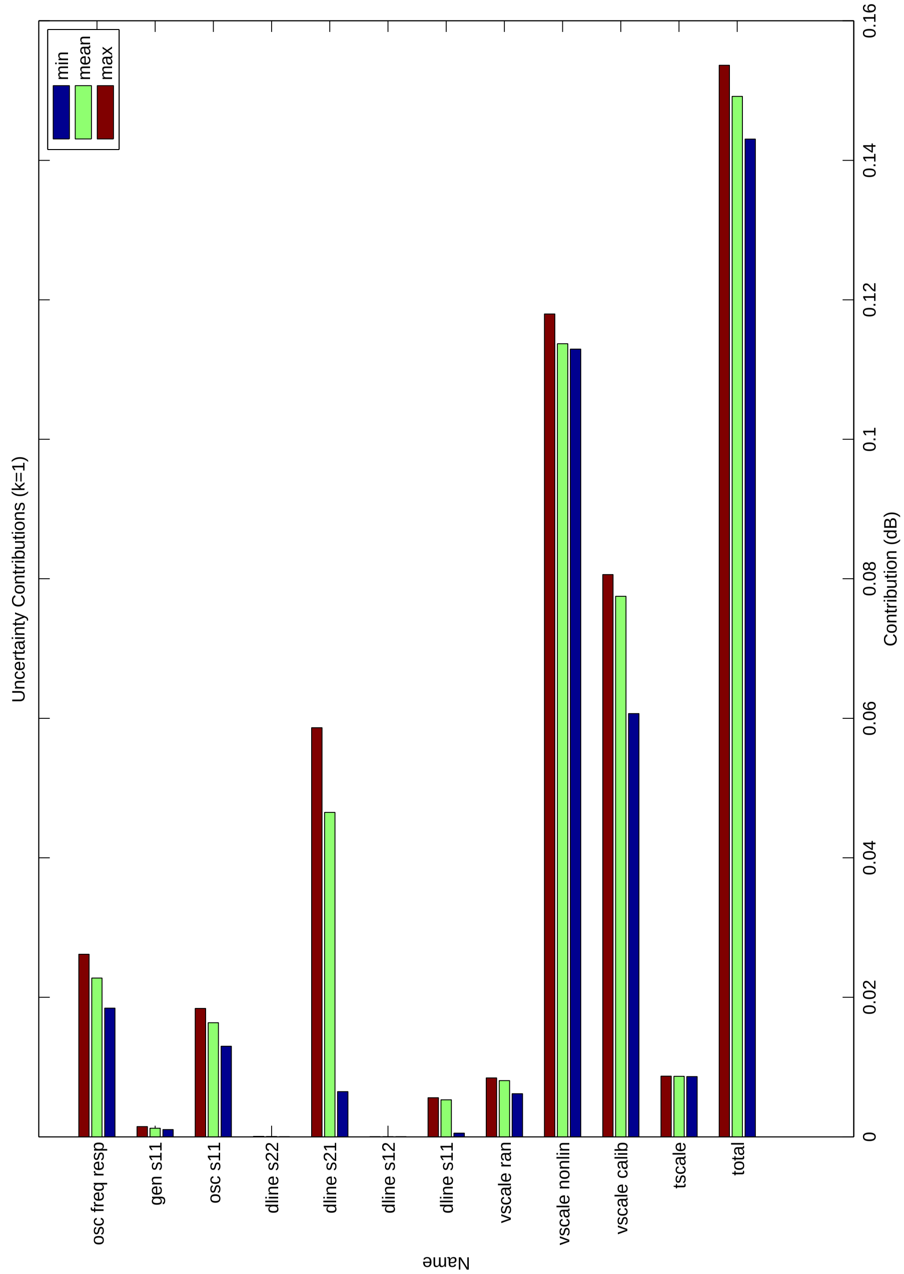

Figure 15: METAS uncertainty contributions for CISPR band A

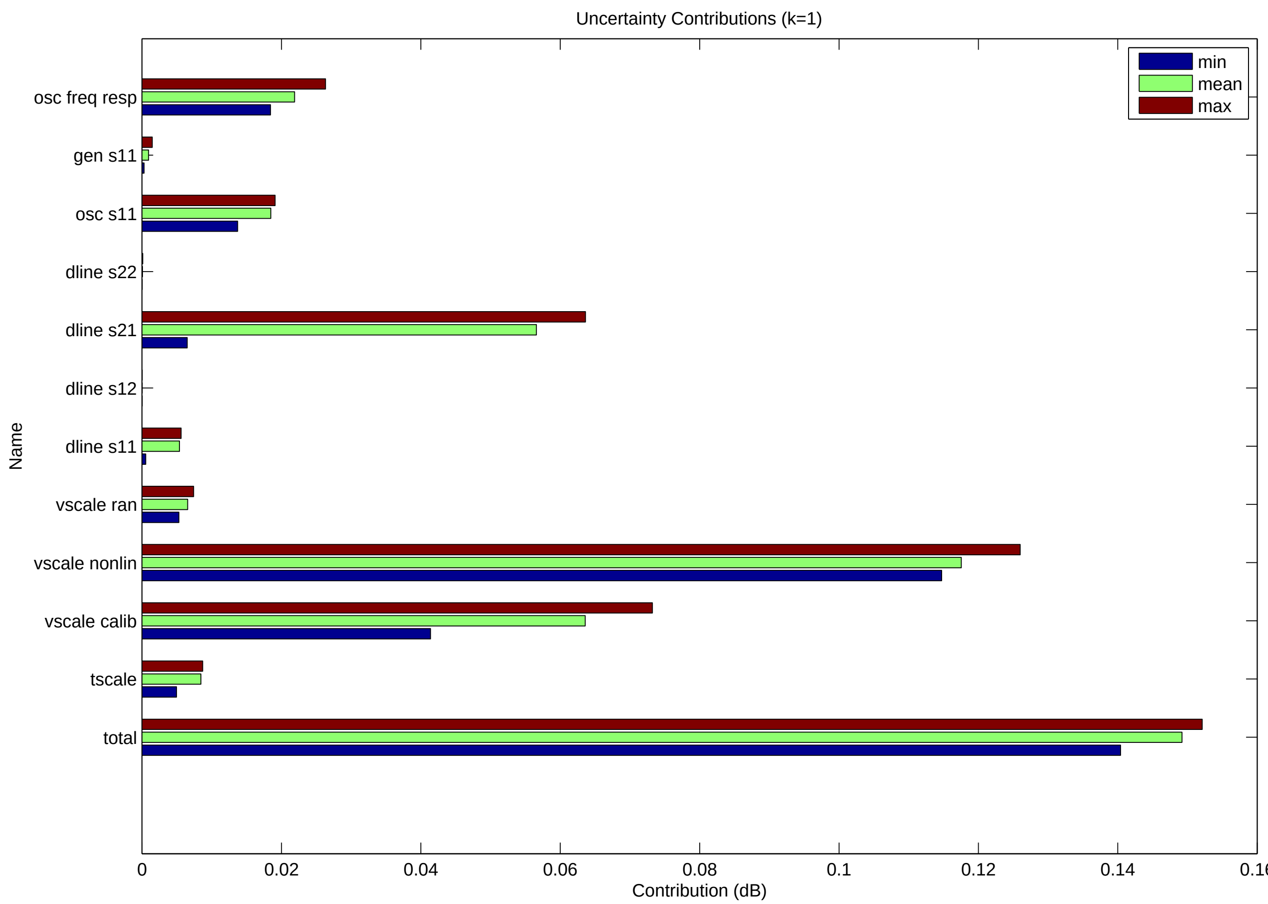

Figure 16: METAS uncertainty contributions for CISPR band B

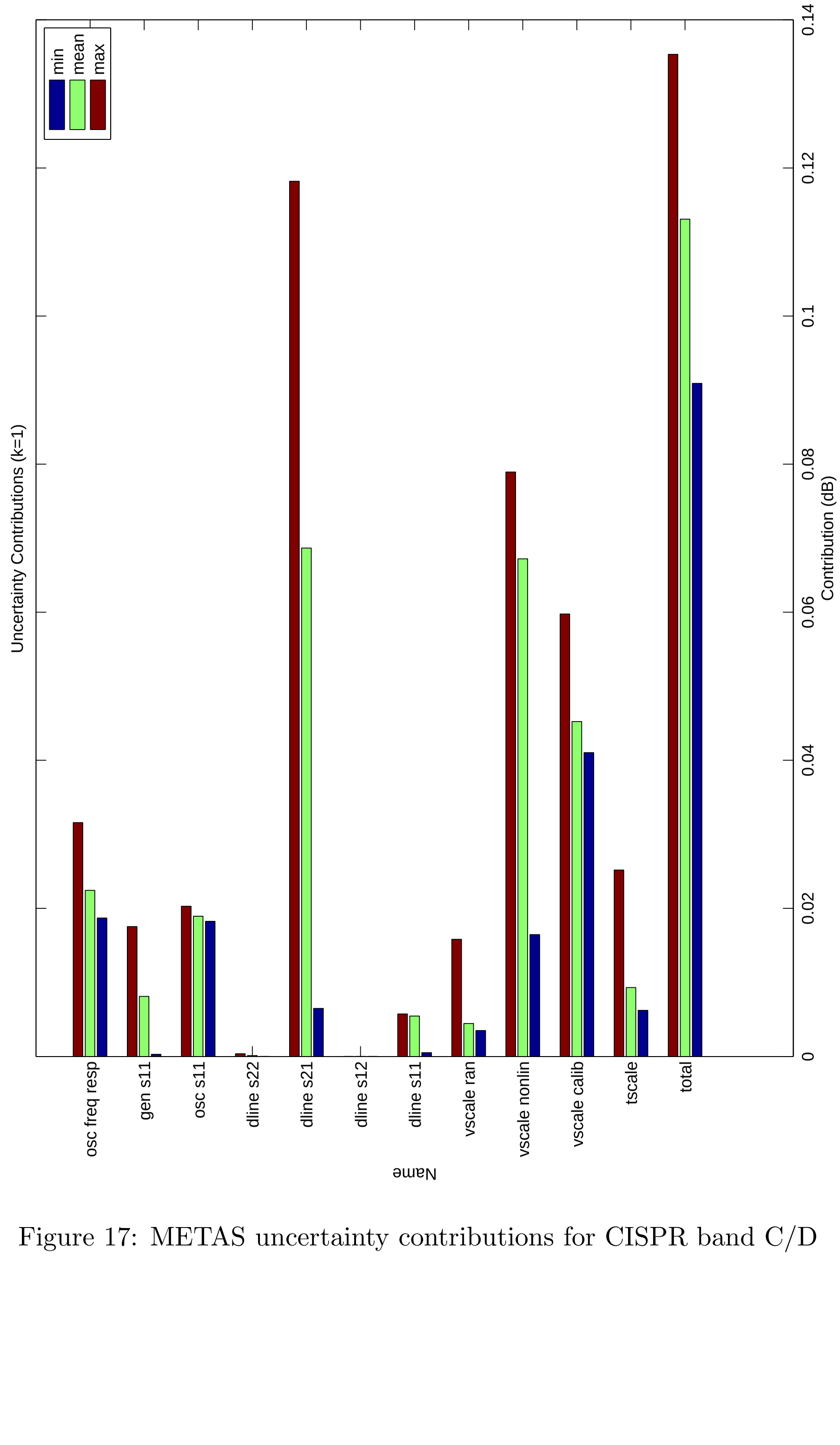

Figure 17: METAS uncertainty contributions for CISPR band C/D

C.3 Schwb

Schwb provided a certificate of calibration.

C.3.1 Method of Calibration

Schwb uses a time domain method as PTB and METAS. The original description as submitted by the participant:

The pulse generator is set to a nominal output level of 60 dBμV, positive polarity and pulse repetition frequencies of 25 Hz in Band A and 100 Hz in Bands B, C and D. The pulses are passing attenuator 1, which provides good impedance matching and divides the voltage by factor 10 (20 dB). A resistive power splitter is used to divide the signal into two ways, resulting in a further reduction of the voltage by factor 2 (6 dB). One signal way is used to trigger the digital sampling oscilloscope after having passed a further 20 dB attenuator, the other way also passes through a 20 dB attenuator and a delay line of 8 m length. The delay line is directly connected to the input of the digital sampling oscilloscope. The oscilloscope has a bandwidth of 20 GHz, which is sufficiently large to display the true shape of the pulses. The measurement data obtained from the oscilloscope in the time domain is transformed into the frequency domain. The transmission characteristics versa frequency of the measurement chain consisting of attenuator 1, power splitter, attenuator 2 and delay line has been checked using a vector network analyzer. The S21-data of the measurement chain is considered in the frequency domain to obtain the spectral amplitude density. A vector network analyzer was also used to measure the impedance matching at all relevant ports of the measurement chain and the oscilloscope. The frequency response of the oscilloscope was checked using a sine wave generator and a thermal power meter. The frequency response of the oscilloscope was not corrected, it was therefore handled as an measurement uncertainty budget.

C.3.2 Uncertainty Budget

Figures 18, 19, 20 and 21 show the uncertainty budgets of Schwb.

Source of Uncertainty Band A	Uncertainty +/- dB	Probability Distribution	Divisor	Standard-Uncertainty dB
Frequency Response Digital Sampling Oszilloscope	0.30	Rectangular	1.73	0.173
Impedance Mismatch Oscilloscope Input	0.05	U-shaped	1.41	0.035
Uncertainty of Transmission Coefficient Measurement Chain Delay Line	0.20	Rectangular	1.73	0.116
Impedance Mismatch Measurement Chain Delay Line	0.10	U-shaped	1.41	0.071
Repeatability of Measurements	0.10	Rectangular	1.73	0.058
Combined Standard Uncertainty				**0.230**
Expanded Measurement Uncertainty		normal	2	**0.460**

Figure 18: Schwb uncertainty budget for CISPR band A

Source of Uncertainty Band B	Uncertainty +/- dB	Probability Distribution	Divisor	Standard-Uncertainty dB
Frequency Response Digital Sampling Oszilloscope	0.15	Rectangular	1.73	0.087
Impedance Mismatch Oscilloscope Input	0.05	U-shaped	1.41	0.035
Uncertainty of Transmission Coefficient Measurement Chain Delay Line	0.15	Rectangular	1.73	0.087
Impedance Mismatch Measurement Chain Delay Line	0.10	U-shaped	1.41	0.071
Repeatability of Measurements	0.10	Rectangular	1.73	0.058
Combined Standard Uncertainty				**0.157**
Expanded Measurement Uncertainty		normal	2	**0.315**

Figure 19: Schwb uncertainty budget for CISPR band B

Source of Uncertainty Band C/D up to 600 MHz	Uncertainty +/- dB	Probability Distribution	Divisor	Standard-Uncertainty dB
Frequency Response Digital Sampling Oszilloscope	0.12	Rectangular	1.73	0.069
Impedance Mismatch Oscilloscope Input	0.05	U-shaped	1.41	0.035
Uncertainty of Transmission Coefficient Measurement Chain Delay Line	0.15	Rectangular	1.73	0.087
Impedance Mismatch Measurement Chain Delay Line	0.10	U-shaped	1.41	0.071
Repeatability of Measurements	0.10	Rectangular	1.73	0.058
Combined Standard Uncertainty				**0.148**
Expanded Measurement Uncertainty		normal	2	**0.296**

Figure 20: Schwb uncertainty budget for CISPR band C/D below 600 MHz

Source of Uncertainty Band C/D above 600 MHz	Uncertainty +/- dB	Probability Distribution	Divisor	Standard-Uncertainty dB
Frequency Response Digital Sampling Oszilloscope	0.20	Rectangular	1.73	0.115
Impedance Mismatch Oscilloscope Input	0.12	U-shaped	1.41	0.085
Uncertainty of Transmission Coefficient Measurement Chain Delay Line	0.15	Rectangular	1.73	0.087
Impedance Mismatch Measurement Chain Delay Line	0.13	U-shaped	1.41	0.092
Repeatability of Measurements	0.10	Rectangular	1.73	0.058
Combined Standard Uncertainty				**0.200**
Expanded Measurement Uncertainty		normal	2	**0.399**

Figure 21: Schwb uncertainty budget for CISPR band C/D above 600 MHz

C.4 RhSC

RhSC provided a certificate of calibration. It also submitted a description of its measurement method and an uncertainty budget compliant with the GUM methodology but prefers to keep this information undisclosed due to its commercial status.

C.5 RhSM

RhSM provided a certificate of calibration. It also submitted a description of its measurement method and an uncertainty budget compliant with the GUM methodology but prefers to keep this information undisclosed due to its commercial status.

C.6 ICMET

ICMET did not provide a certificate of calibration nor any information about the measurement setup or method. It also failed to provide an uncertainty budget.

References

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