Final Report on the EURAMET Key Comparison EURAMET AUV.V-K5

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Abstract

The results of the fifth EURAMET key comparison in the area of primary vibration calibration of the complex sensitivity, here concerning sinusoidal acceleration, are presented. This regional key comparison followed the previous CCAUV comparison over the extended frequency range from 10 Hz to 20 kHz. Measurement results reported by 11 participants for magnitude and phase shift of complex charge sensitivity of single ended and back-to-back accelerometers were compared. A link to the CCAUV.V-K5 with the respective Degrees of Equivalence are reported.

Contents

1. Introduction

This report presents the results of the fifth EURAMET comparison in the area of primary vibration calibration according to ISO 16063-11 standard, which in this case means sinusoidal acceleration. It has the status of a Draft B after having been submitted to the participants for commenting. The comparison was a regional key comparison following the CCAUV.V-K5 key comparison, thus, providing strong support for the CIPM MRA in the field of vibration metrology.

The report defines a weighted means for the total set of data to determine the data that can used in the MoCS (Member of Consistent Set). Following the resolutions of CCAUV no bilateral DoE were calculated.

The Technical Protocol (see Appendix A) specifies in detail the aim and the task of the comparison, the conditions of measurement, the transfer standards used, measurement instructions and other items. A brief survey is given in the following sections.

The monitoring data documenting the stability of the transducers are reported in Section 6.

2. Participants

Eleven national metrology institutes or designated institutes from EURAMET and GULFMET took part in this comparison. They are listed in chronological order of measurement in Table 2.1.

Table 2.1: List of participants and actual schedule of EURAMET.AUV.V-K5.

Laboratory name	Acronym	Country	Country Code	RMO	Calibration week
Danish Primary Lab of Acoustics	HBK-DPLA (or DPLA)	Denmark	DK	EURAMET	27 (2019)
Physikalisch-Technische Bundesanstalt	PTB	Germany	DE	EURAMET	37 (2019)
National Institute of Metrological Research	INRIM	Italy	IT	EURAMET	44 (2019)
TÜBİTAK UME	UME	Turkey	TR	EURAMET	3 (2020)
Czech Metrology Institute	CMI	Czech Republic	CZ	EURAMET	2 (2020)
Central Office of Measures	GUM	Poland	PL	EURAMET	6 (2020)
Centro Español de Metrologa	CEM	Spain	ES	EURAMET	9 (2020)
Laboratoire National de Métrologie et D'essais	LNE	France	FR	EURAMET	19 (2020)
Research Institutes of Sweden	RISE	Sweden	SE	EURAMET	23 (2020)
National Measurements & Calibration Center	SASO-NMCC	Saudi Arabia	SA	GULFMET	41 (2020)
Federal Institute of Metrology	METAS	Switzerland	CH	EURAMET	52 (2020)

3. Task and Purpose of the Comparison

In the field of vibration and shock, the fifth global key comparison (CCAUV.V-K5) was organized to compare measurements of sinusoidal linear accelerations in the frequency range from 10 Hz to 20 kHz. The present EURAMET key comparison was implemented to make the link to the regional laboratories. The technical protocol of EURAMET.AUV.V-K5 was then formatted with this goal in mind. As a degree of equivalence derived from an RMO key comparison has the same status as one derived from a CIPM key comparison this comparison serves to extend the coverage of the CIPM key comparisons.

During the circulation period from June 2019 to March 2021, eleven national metrology institutes (NMIs and DIs) from the EURAMET and GULFMET region calibrated two accelerometers as transfer standards by primary methods. It was the task of the comparison to measure the magnitude and the phase of the complex charge sensitivity of two accelerometer standards (one of single-ended design and one of back-to-back design) at different frequencies specified in the technical protocol (TP) (c.f. Appendix A). The magnitude of the complex charge sensitivity was calculated as the ratio of the amplitude of the accelerometer output charge to the amplitude of the acceleration at its reference surface. The reference surface was defined as the top surface of the mounting adapter (mounting surface) of the accelerometer of single-ended design (SE), and the top surface of the accelerometer of back-to-back design (BB). The charge sensitivity was given in pico-coulombs per metre per second squared: pC/(m/s^2). A calibrated charge amplifier was used to measure the output charge of the accelerometer standards. This charge amplifier was not part of the set of traveling artifacts but part of the participants laboratory inventory.

For the calibration of the two accelerometers, all participants applied laser interferometry in compliance with the international standards ISO 16063-1:1998 [1] and ISO 16063-11:1999 [2], to cover the entire frequency range chosen, within a specified range of the acceleration amplitudes with specified uncertainties. Although the TP left the option to apply different methods with similar known uncertainties, no other method (e.g. the reciprocity method) was applied.

The scaled sensitivities and associated uncertainties including the scaling mechanism were used for the calculation of the unilateral DoE between each NMI/DI and the CCAUV.V-K5 key comparison reference value. The results of this KC will be used as the foundation for the submission of calibration and measurement capabilities (CMC) in the framework of the CIPM MRA. Besides the direct support to primary calibration of accelerometer complex charge sensitivity, the results might also be used to support voltage sensitivity of accelerometers / acceleration measuring chains, under the assumption that charge sensitivity depends on the calibration of voltage sensitivity of an acceleration measuring chain and the sensitivity of the charge amplifier used. In addition, the uncertainty budgets provided by the participants give supporting evidence about the contribution of the charge conditioner used by each NMI. Therefore, this information can also be used to support future claims of CMCs related to electrical calibration of charge and voltage sensitivity of vibration signal conditioners.

4. Transfer Standards as Artifacts

For the comparison, the pilot laboratory selected two accelerometers for this KC. The SE had a history of stability at the reference frequency dating back to 2009 and was subsequently monitored since 2017 over the full frequency range prior to the key comparison. The BB had an even longer monitoring history and a history over the range 10 Hz to 10 kHz from 2013. It was subsequently monitored since 2017 over the full frequency range prior to the key comparison measurements.

- One transfer standard accelerometer (single-ended), type 8305-001 SN 2381734 (manufacturer: Brüel & Kjaer) named SE-transducer subsequently.
- One reference standard accelerometer (back-to-back), type 8305 SN 606545 (manufacturer: Brüel & Kjaer) named BB-transducer subsequently.

The SE type accelerometer was mounted on a mechanical adapter and this set should be handled as a single mechanical unit for mounting, following the guidelines in the technical protocol.

5. Circulation of the Artifacts

A modified star type circulation was used for this comparison, i.e., after the measurements at two or three participant's laboratories, the pilot laboratory checked the artifacts for stability (see Section 6) and general condition.

The investigation of the long-term stability was continued throughout the circulation period, whenever the artifacts returned to the pilot laboratory. The results of the DPLA stability measurements and other individual data of the transfer standards are given in Section 6.

6. Results of monitoring measurements

The artifacts were monitored by the pilot laboratory during the whole comparison. Due to the modified star-type circulation a monitoring measurement was performed in between the participant's measurements.

As the variations over the whole frequency range were very small over the whole period, only a combined plot of the different frequency responses is presented and a deviation plot including the uncertainties stated for the pilot laboratory. The vertical axis gives the deviation from the mean of all monitoring measurements. The certificate numbering A2.00-5016-0.1 to A2.00-5356-0.1 indicates the sequence and thereby also a time for the measurements. It was not found necessary to link the measurements to the specific time between two laboratories, but that can naturally be traced.

The series A2.00-5020-0.1 and A2.00-5016-0.1 are the data submitted for the comparison.

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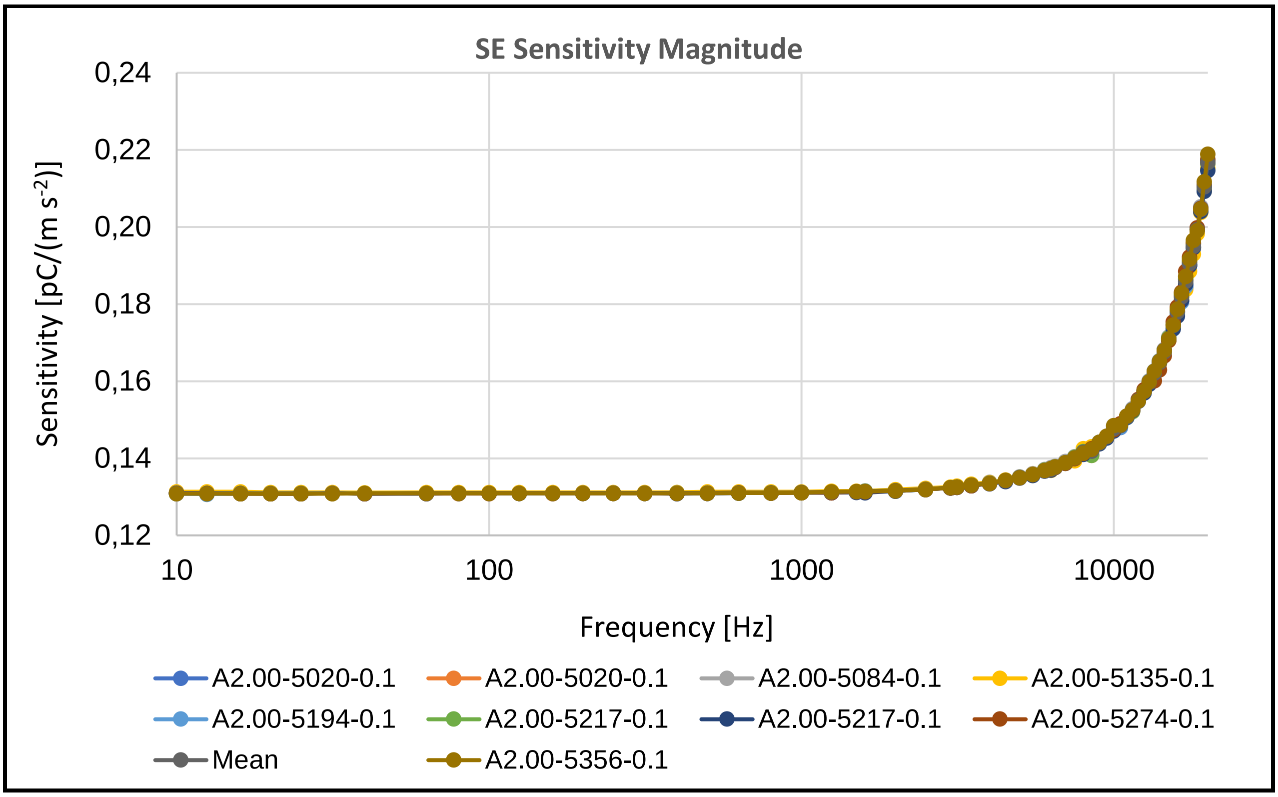

Figure 1. Magnitude monitoring results on the SE accelerometer. The double entrance of A2.00-5020-0.1 and A2.00-5217-0.1 means repeated measurements.

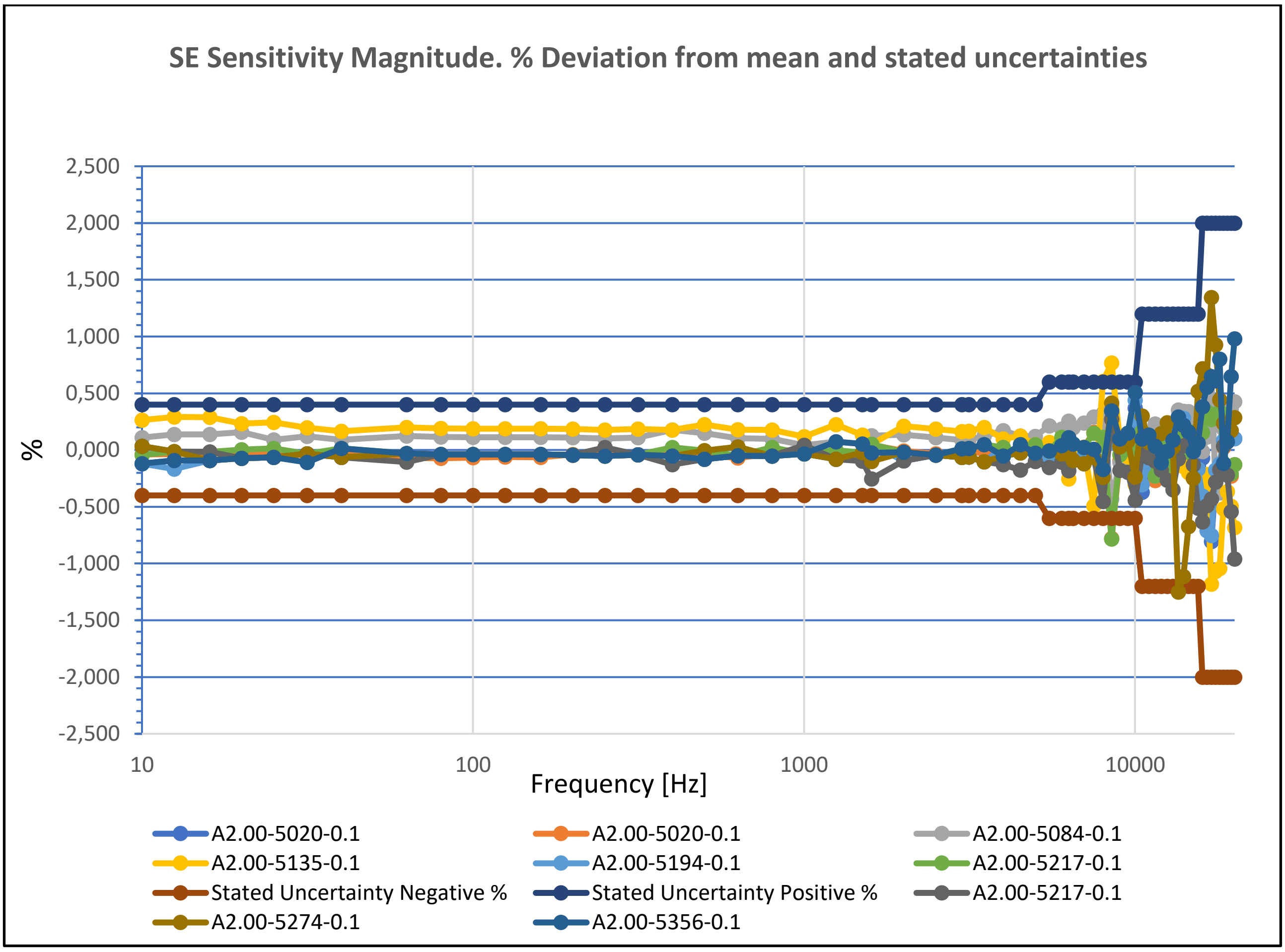

Figure 2. Magnitude monitoring results on the SE accelerometer. Relative deviation from the mean and with laboratory stated uncertainties. The double entrance of A2.00-5020-0.1 and A2.00-5217-0.1 means repeated measurements.

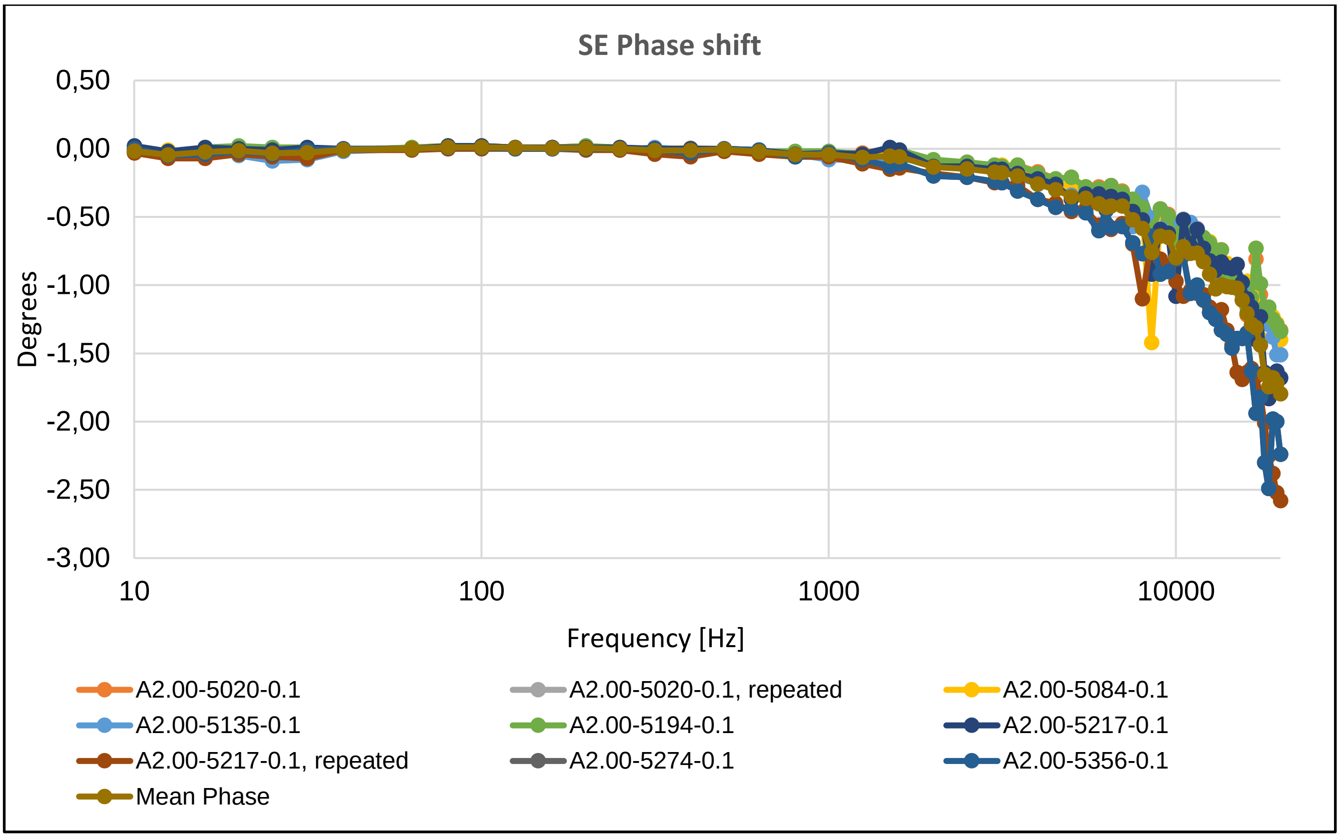

Figure 3. Phase shift monitoring results on the SE accelerometer.

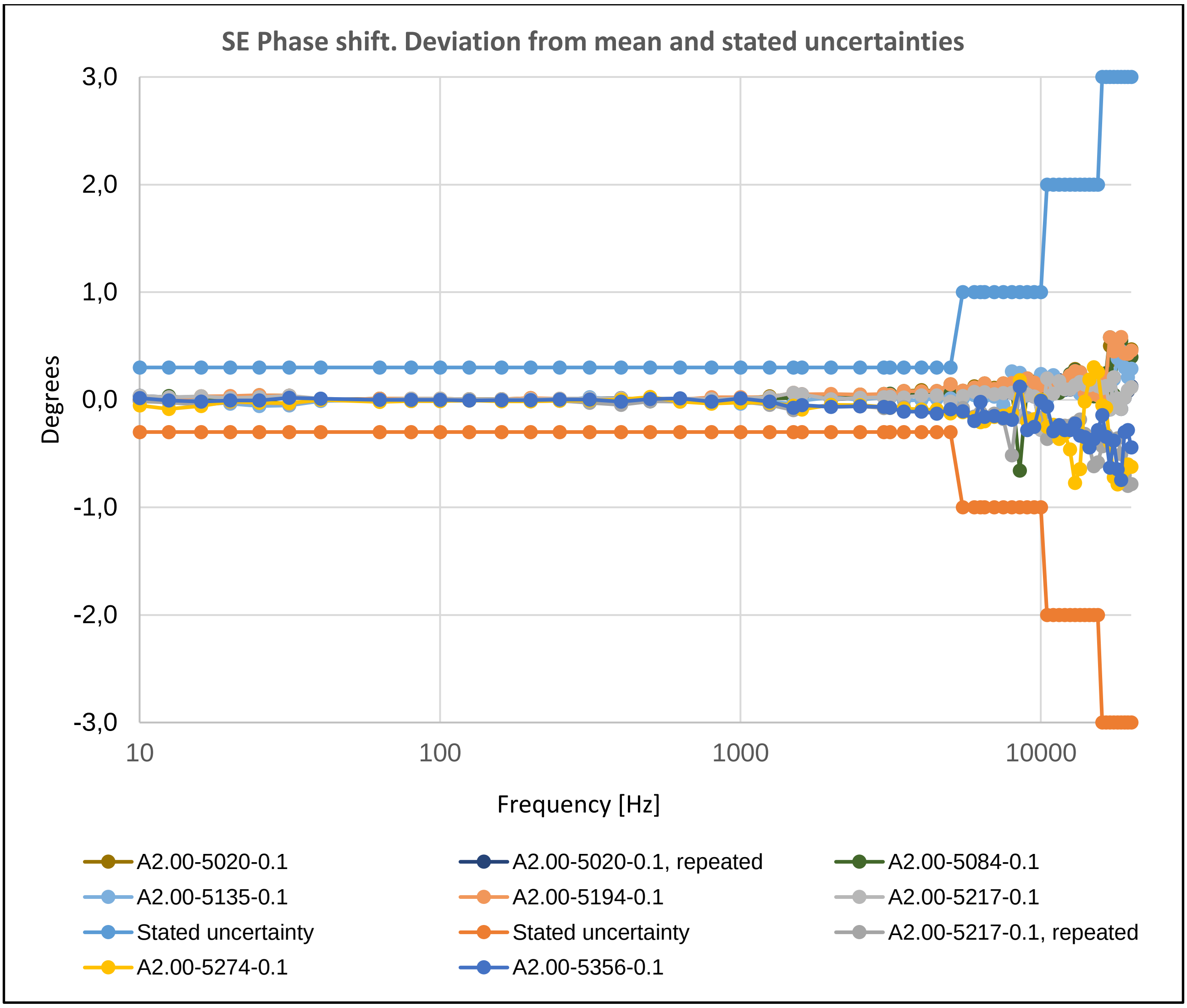

Figure 4. Phase shift monitoring results on the SE accelerometer. Relative deviation from the mean and with laboratory stated uncertainties.

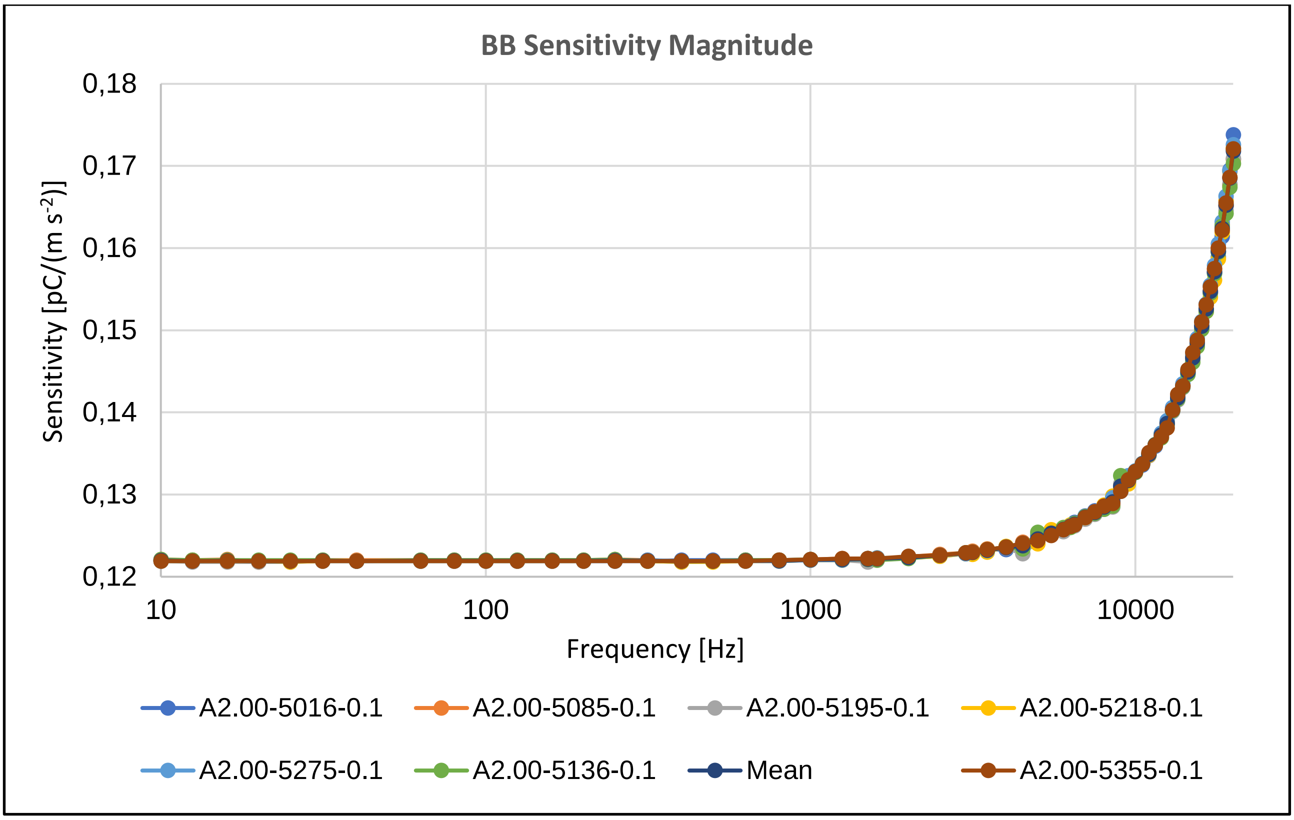

Figure 5. Magnitude monitoring results on the BB accelerometer.

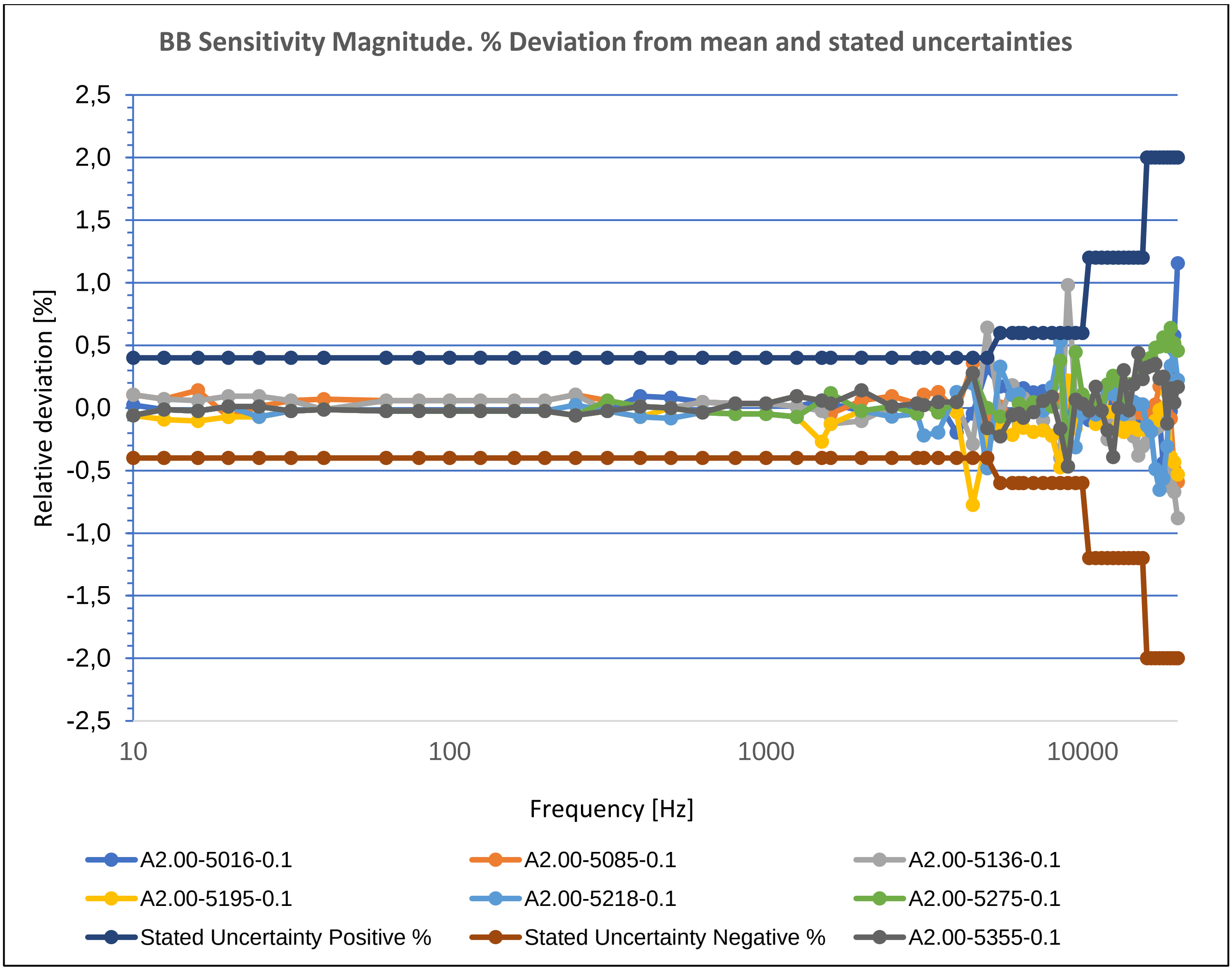

Figure 6. Magnitude monitoring results on the BB accelerometer. Relative deviation from the mean and with laboratory stated uncertainties.

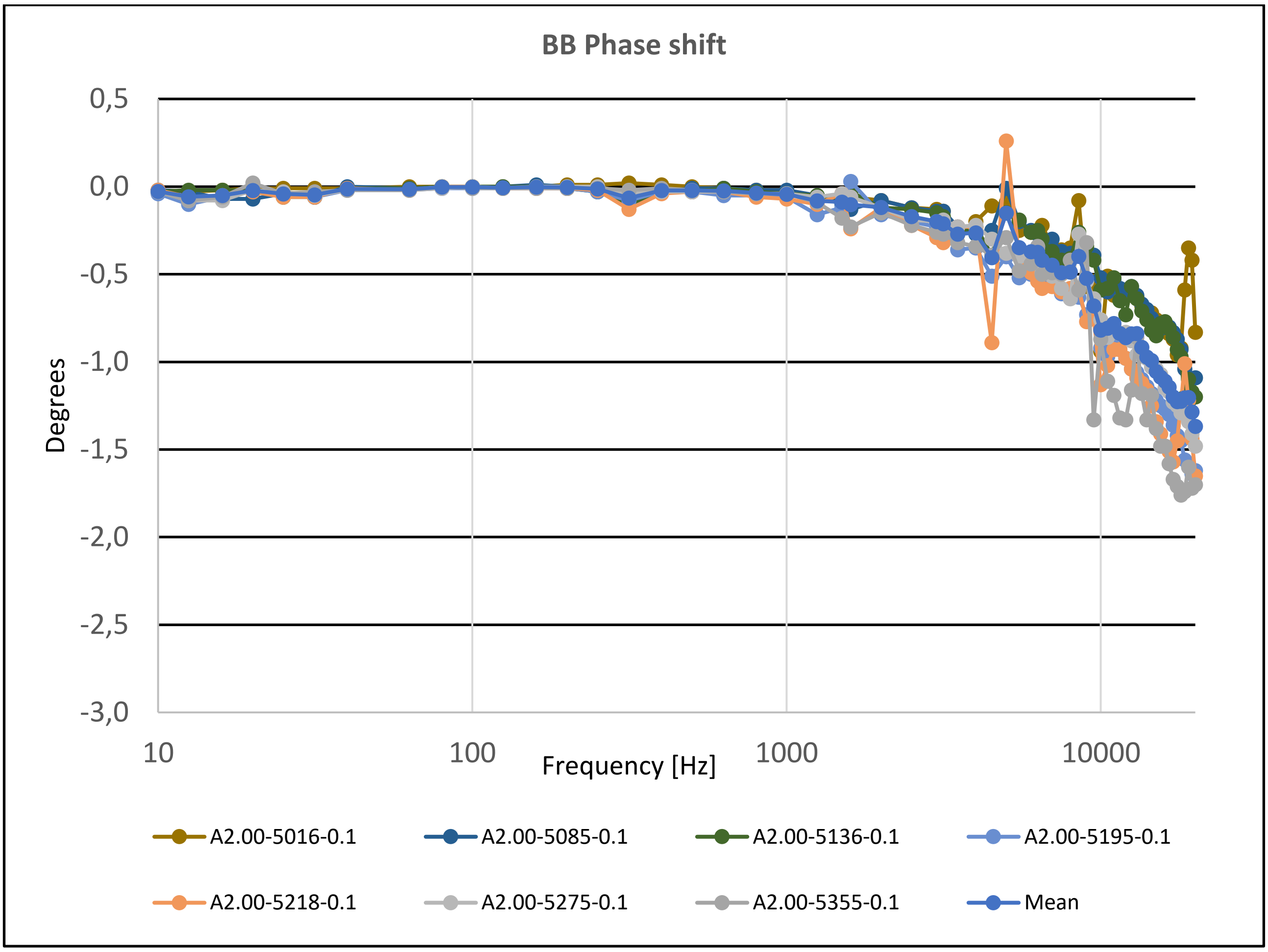

Figure 7. Phase shift monitoring results on the BB accelerometer.

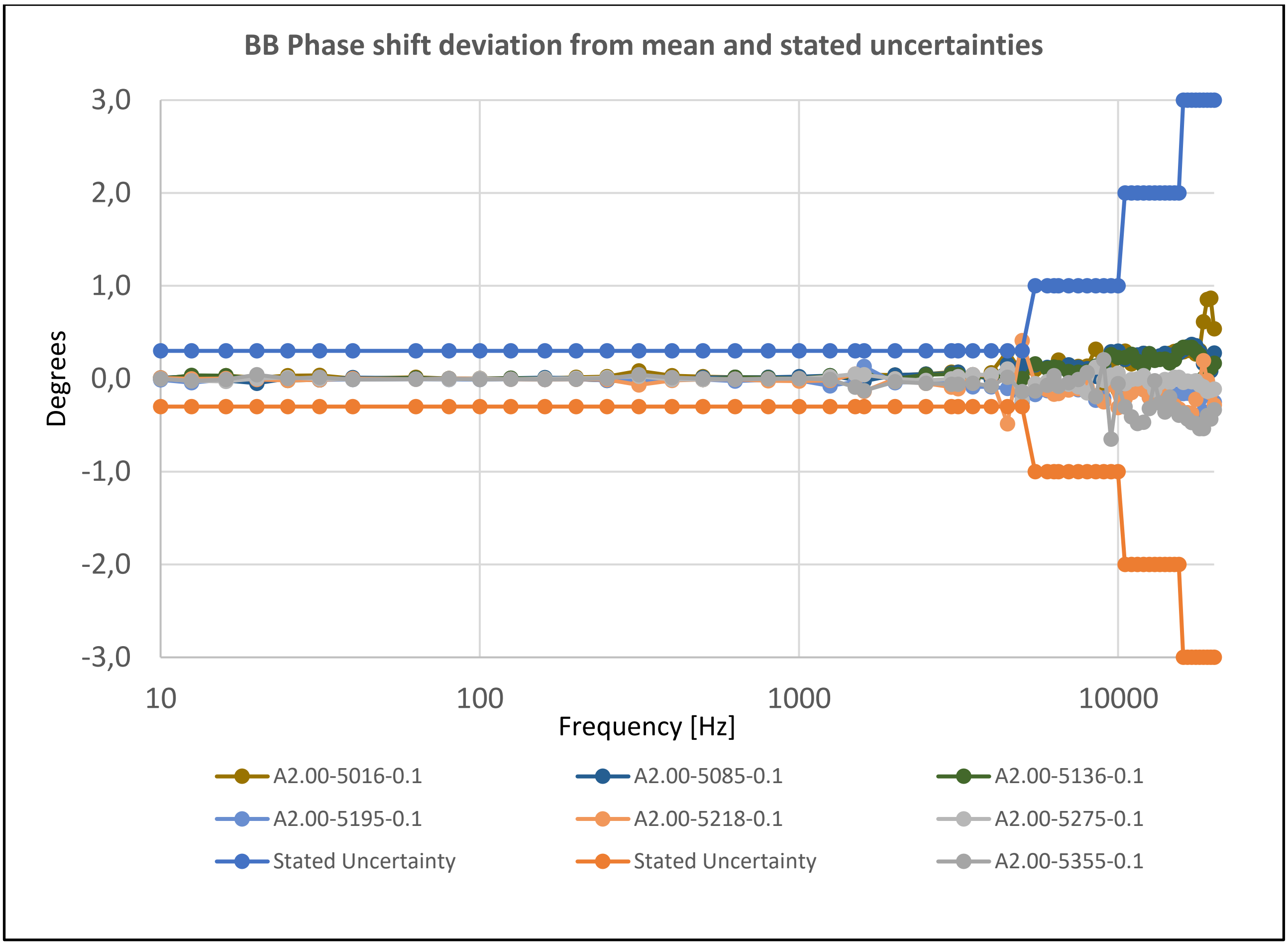

Figure 8. Phase shift monitoring results on the BB accelerometer. Relative deviation from the mean and with laboratory stated uncertainties.

The visual inspection of the graphed results indicates that both artifacts were quite stable within the measurement uncertainty of the pilot laboratory. Between 8 kHz and 11 kHz the BB transducer exhibits some dispersion in the results which is attributed to an interaction of the cross-sensitivity with the cross-motion and a transverse resonance that is in that frequency range. Similar dispersion can be observed in several of the participants' results. At half and double of that frequency some dispersion is also observed. For the SE transducer there is a similar effect, but less pronounced and nothing at half the frequency.

The conclusion must be that the transducers were stable during the intercomparison.

7. Results of the Participants

The following sections report the results submitted by the participants of the comparison to the pilot laboratory using the reporting spreadsheet. The results presented are given as

quantity	component	variable	unit
magnitude	value	X_i	$pC/(m/s^2)$
	exp. rel. uncertainty	U_{rel,X_i}	%
phase	value	ϕ_i	°
	exp. uncertainty	$U_{\phi i}$	°

where *i* is the index for the frequency.

7.1 Results for the Magnitude of the Complex Sensitivity

7.1.1 The Single-Ended Accelerometer (SN 2381734)

Table 7.1.1. Reported participant's results for the magnitude of the SE with relative expanded uncertainties (*k*=2)

Frequen-cy	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
10,0	0,13083	0,4	0,13091	0,1	0,13090	0,4	0,13144	0,5	0,13120	0,5	0,13113	0,6
12,5	0,13077	0,4	0,13092	0,1	0,13076	0,4	0,13134	0,5	0,13117	0,5	0,13111	0,6
16,0	0,13081	0,4	0,13096	0,1	0,13077	0,4	0,13127	0,5	0,13120	0,5	0,13107	0,6
20,0	0,13083	0,4	0,13090	0,1	0,13082	0,4	0,13124	0,3	0,13123	0,3	0,13103	0,5
25,0	0,13084	0,4	0,13088	0,1	0,13078	0,4	0,13122	0,3	0,13128	0,3	0,13103	0,5
31,5	0,13089	0,4	0,13087	0,1	0,13086	0,4	0,13119	0,3	0,13130	0,3	0,13101	0,5
40,0	0,13084	0,4	0,13086	0,1	0,13085	0,4	0,13116	0,3	0,13131	0,3	0,13102	0,5
63,0	0,13087	0,4	0,13084	0,1	0,13082	0,4	0,13115	0,3	0,13125	0,3	0,13100	0,5
80,0	0,13088	0,4	0,13086	0,1	0,13089	0,4	0,13112	0,3	0,13122	0,3	0,13101	0,5
100	0,13089	0,4	0,13087	0,1	0,13084	0,4	0,13103	0,3	0,13121	0,3	0,13108	0,5
125	0,13090	0,4	0,13087	0,1	0,13084	0,4	0,13117	0,3	0,13123	0,3	0,13109	0,5
160	0,13091	0,4	0,13091	0,1	0,13074	0,4	0,13113	0,3	0,13124	0,3	0,13103	0,5
200	0,13094	0,4	0,13093	0,1	0,13084	0,4	0,13116	0,3	0,13134	0,3	0,13103	0,5
250	0,13096	0,4	0,13094	0,1	0,13088	0,4	0,13115	0,3	0,13133	0,3	0,13103	0,5
315	0,13090	0,4	0,13095	0,1	0,13095	0,4	0,13116	0,3	0,13132	0,3	0,13103	0,5
400	0,13094	0,4	0,13097	0,1	0,13096	0,4	0,13118	0,3	0,13136	0,3	0,13104	0,5
500	0,13095	0,4	0,13100	0,1	0,13095	0,4	0,13117	0,3	0,13134	0,3	0,13107	0,5
630	0,13098	0,4	0,13103	0,1	0,13096	0,4	0,13120	0,3	0,13133	0,3	0,13109	0,5
800	0,13099	0,4	0,13105	0,1	0,13102	0,4	0,13123	0,3	0,13138	0,3	0,13113	0,5
1000	0,13109	0,4	0,13113	0,1	0,13112	0,4	0,13128	0,3	0,13144	0,3	0,13118	0,5
1250	0,13114	0,4	0,13121	0,1	0,13118	0,5	0,13131	0,5	0,13151	0,5	0,13127	0,5
1500	0,13131	0,4	0,13134	0,1	0,13131	0,5	0,13146	0,5	0,13164	0,5	0,13136	0,5

Frequen-cy	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
1600	0,13148	0,4	0,13136	0,1	0,13136	0,5	0,13147	0,5	0,13164	0,5	0,13138	0,5
2000	0,13153	0,4	0,13159	0,1	0,13155	0,5	0,13168	0,5	0,13189	0,5	0,13161	0,5
2500	0,13192	0,4	0,13191	0,1	0,13184	0,5	0,13205	0,5	0,13224	0,5	0,13195	0,5
3000	0,13234	0,4	0,13231	0,1	0,13220	0,5	0,13247	0,5	0,13270	0,5	0,13235	0,5
3150	0,13249	0,4	0,13245	0,1	0,13240	0,5	0,13245	0,5	0,13278	0,5	0,13246	0,5
3500	0,13293	0,4	0,13283	0,1	0,13271	0,5	0,13294	0,5	0,13310	0,5	0,13289	0,5
4000	0,13356	0,4	0,13336	0,1	0,13336	0,5	0,13355	0,5	0,13371	0,5	0,13342	0,5
4500	0,13420	0,4	0,13400	0,1	0,13398	0,5	0,13426	0,5	0,13441	0,5	0,13397	0,5
5000	0,13503	0,4	0,13472	0,1	0,13468	0,6	0,13502	0,5	0,13514	0,5	0,13458	0,6
5500	0,13578	0,6	0,13552	0,3	0,13553	0,6	0,13590	1,0	0,13588	1,0	0,13553	1,1
6000	0,13675	0,6	0,13636	0,3	0,13637	0,6	0,13681	1,0	0,13683	1,0	0,13642	1,1
6300	0,13731	0,6	0,13697	0,3	0,13694	0,6	0,13739	1,0	0,13736	1,0	0,13695	1,1
6500	0,13767	0,6	0,13738	0,3	0,13740	0,6	0,13779	1,0	0,13785	1,0	0,13742	1,1
7000	0,13879	0,6	0,13837	0,3	0,13849	0,6	0,13896	1,0	0,13892	1,0	0,13854	1,1
7500	0,14013	0,6	0,13977	0,5	0,14000	0,6	0,14043	1,0	0,14033	1,0	0,13957	1,1
8000	0,14146	0,6	0,14104	0,5	0,14128	0,6	0,14175	1,0	0,14170	1,0	0,14083	1,1
8500	0,14206	0,6	0,14279	0,8	0,14240	0,6	0,14329	1,0	0,14300	1,0	0,14168	1,1
9000	0,14422	0,6	0,14329	0,3	0,14377	0,6	0,14360	1,0	0,14400	1,0	0,14325	1,1
9500	0,14560	0,6	0,14494	0,3	0,14547	0,6	0,14617	1,0	0,14523	1,0	0,14505	1,1
10000	0,14834	0,6	0,14671	0,3	0,14723	0,6	0,14809	1,0	0,14713	1,0	0,14663	1,1
10500	0,14804	1	0,14849	0,5	0,14948	0,8	0,15011	2,0	0,14902	2,0		
11000	0,15058	1	0,15041	0,5	0,15137	0,8	0,15215	2,0	0,15100	2,0		
11500	0,15278	1	0,15254	0,5	0,15333	0,8	0,15440	2,0	0,15309	2,0		
12000	0,15519	1	0,15472	0,5	0,15575	0,8	0,15678	2,0	0,15537	2,0		
12500	0,15748	1,2	0,15710	0,5	0,15859	0,8	0,15938	2,0	0,15811	2,0		
13000	0,15988	1,2	0,15974	0,5	0,16103	0,8	0,16212	2,0	0,16037	2,0		
13500	0,16258	1,2	0,16244	0,5	0,16377	0,8	0,16482	2,0	0,16304	2,0		
14000	0,16518	1,2	0,16537	0,5	0,16683	0,8	0,16787	2,0	0,16566	2,0		
14500	0,16793	1,2	0,16852	0,5	0,17021	0,8	0,17137	2,0	0,16897	2,0		
15000	0,17121	1,2	0,17188	0,5	0,17373	0,8	0,17516	2,0	0,17234	2,0		
15500	0,17467	1,2	0,17555	1,0	0,17755	1,0	0,17897	2,5	0,17603	2,5		
16000	0,17793	2	0,17843	1,0	0,18163	1,0	0,18301	2,5	0,17981	2,5		
16500	0,18089	2	0,18341	1,0	0,18586	1,0	0,18737	2,5	0,18481	2,5		
17000	0,18454	2	0,18746	1,0	0,19118	1,0	0,19273	2,5	0,18938	2,5		
17500	0,19005	2	0,19142	1,0	0,19604	1,0	0,19825	2,5	0,19398	2,5		
18000	0,19472	2	0,19711	1,0	0,20139	1,0	0,20383	2,5	0,19857	2,5		
18500	0,19946	2	0,20235	1,0	0,20737	1,0	0,20803	2,5	0,20361	2,5		
19000	0,20479	2	0,20783	1,0	0,21388	1,0	0,21446	2,5	0,20929	2,5		
19500	0,21072	2	0,21336	1,0	0,22086	1,0	0,22134	2,5	0,21596	2,5		
20000	0,21699	2	0,22034	1,0	0,22847	1,0	0,22971	2,5	0,22303	2,5		

(continued) Reported participant's results for the magnitude of the SE with relative expanded uncertainties (k=2)

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
10,0	0,13139	0,5	0,13092	0,3	0,13112	0,6	0,13112	0,23	0,13129	0,4
12,5	0,13129	0,4	0,13108	0,3	0,13112	0,6	0,13114	0,23	0,13117	0,4
16,0	0,13123	0,4	0,13106	0,3	0,13106	0,6	0,13115	0,23	0,13120	0,4
20,0	0,13123	0,4	0,13099	0,3	0,13103	0,5	0,13119	0,20	0,13115	0,4
25,0	0,13122	0,4	0,13099	0,3	0,13100	0,5	0,13121	0,20	0,13110	0,4
31,5	0,1312	0,4	0,13103	0,3	0,13103	0,5	0,13123	0,20	0,13111	0,4
40,0	0,13123	0,4	0,13102	0,3	0,13100	0,5	0,13123	0,20	0,13112	0,4
63,0	0,13118	0,4	0,13098	0,3	0,13098	0,5	0,13124	0,20	0,13109	0,4
80,0	0,13106	0,4	0,13100	0,3	0,13096	0,5	0,13124	0,20	0,13109	0,4
100	0,13126	0,4	0,13103	0,3	0,13090	0,5	0,13121	0,20	0,13110	0,4
125	0,13027	0,4	0,13104	0,3	0,13089	0,5	0,13122	0,20	0,13110	0,4
160	0,13118	0,4	0,13107	0,3	0,13109	0,5	0,13124	0,20	0,13109	0,4
200	0,13121	0,4	0,13097	0,3	0,13102	0,5	0,13129	0,24	0,13104	0,4
250	0,13123	0,4	0,13102	0,3	0,13102	0,5	0,13121	0,22	0,13117	0,4
315	0,13122	0,4	0,13104	0,3	0,13102	0,5	0,13123	0,21	0,13118	0,4
400	0,13126	0,4	0,13105	0,3	0,13104	0,5	0,13125	0,20	0,13103	0,4
500	0,13125	0,4	0,13104	0,3	0,13105	0,5	0,13126	0,20	0,13112	0,4
630	0,13127	0,4	0,13110	0,3	0,13108	0,5	0,13129	0,20	0,13112	0,4
800	0,13129	0,4	0,13113	0,3	0,13110	0,5	0,13130	0,20	0,13123	0,4
1000	0,13132	0,4	0,13119	0,3	0,13116	0,5	0,13134	0,23	0,13128	0,4
1250	0,13145	0,4	0,13125	0,3	0,13121	0,6	0,13144	0,24	0,13141	0,4
1500	0,13148	0,4	0,13140	0,3	0,13133	0,6	0,13151	0,24	0,13148	0,4
1600	0,1316	0,4	0,13144	0,3	0,13139	0,6	0,13157	0,24	0,13156	0,4
2000	0,13175	0,4	0,13165	0,3	0,13161	0,6	0,13182	0,24	0,13186	0,4
2500	0,13192	0,4	0,13197	0,3	0,13196	0,6	0,13222	0,27	0,13212	0,5
3000	0,13256	0,4	0,13237	0,3	0,13239	0,6	0,13246	0,24	0,13254	0,5
3150	0,13257	0,4	0,13250	0,3	0,13252	0,6	0,13268	0,32	0,13272	0,5
3500	0,13294	0,4	0,13283	0,3	0,13287	0,6	0,13299	0,27	0,13304	0,5
4000	0,13349	0,4	0,13338	0,3	0,13353	0,6	0,13365	0,26	0,13371	0,5
4500	0,13411	0,4	0,13397	0,3	0,13424	0,6	0,13427	0,45	0,13431	0,6
5000	0,13479	0,4	0,13463	0,6	0,13501	0,6	0,13505	0,39	0,13504	0,6
5500	0,1356	0,8	0,13541	0,6	0,13594	1,2	0,13592	0,76	0,13561	0,7
6000	0,1364	0,8	0,13639	0,6	0,13682	1,2	0,13663	0,95	0,13640	0,7
6300	0,137	0,8	0,13695	0,6	0,13743	1,2	0,13727	0,72	0,13685	0,7
6500	0,1374	0,8	0,13729	0,6	0,13781	1,2	0,13767	0,82	0,13712	0,9
7000	0,1386	0,8	0,1384	1,0	0,13914	1,2	0,13876	0,70	0,13842	0,9
7500	0,1397	0,8	0,1396	1,0	0,14058	1,2	0,14009	0,72	0,13943	0,9
8000	0,1409	0,8	0,1412	1,0	0,14207	1,2	0,14105	0,77	0,14186	0,9
8500	0,1422	0,8	0,1418	1,0	0,14350	1,2	0,14116	0,77	0,14314	1,2
9000	0,1435	0,8	0,1425	1,0	0,14396	1,2	0,14495	0,75	0,14449	1,2

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
9500	0,1451	0,8	0,1445	1,0	0,14611	1,2	0,14617	0,74	0,14541	1,2
10000	0,1468	0,8	0,1462	1,0	0,14792	1,2	0,14769	0,81	0,14668	1,2
10500	0,1486	1,5			0,14987	2,0	0,14942	1,69		
11000	0,1505	1,5			0,15196	2,0	0,15126	1,71		
11500	0,1525	1,5			0,15417	2,0	0,15318	1,87		
12000	0,1548	1,5			0,15655	2,0	0,15564	1,74		
12500	0,1573	1,5			0,15920	2,0	0,15814	1,78		
13000	0,1594	1,5			0,16189	2,0	0,16044	1,81		
13500	0,1623	1,5			0,16489	2,0	0,16326	1,81		
14000	0,1653	1,5			0,16811	2,0	0,16588	2,07		
14500	0,1682	1,5			0,17138	2,0	0,16874	1,76		
15000	0,1715	1,5			0,17504	2,0	0,17168	1,82		
15500	0,1749	2			0,17906	2,5	0,17606	1,90		
16000	0,1784	2			0,18303	2,5	0,17939	2,31		
16500	0,1824	2			0,18664	2,5	0,18350	2,61		
17000	0,1866	2			0,19241	2,5	0,18943	4,86		
17500	0,1912	2			0,19739	2,5	0,19328	2,28		
18000	0,1959	2			0,20314	2,5	0,19742	2,08		
18500	0,2013	2			0,20905	2,5	0,20303	1,89		
19000	0,2065	2			0,21524	2,5	0,20878	1,77		
19500	0,2129	2			0,22222	2,5	0,21519	1,76		
20000	0,2199	2			0,22990	2,5	0,22157	1,73		

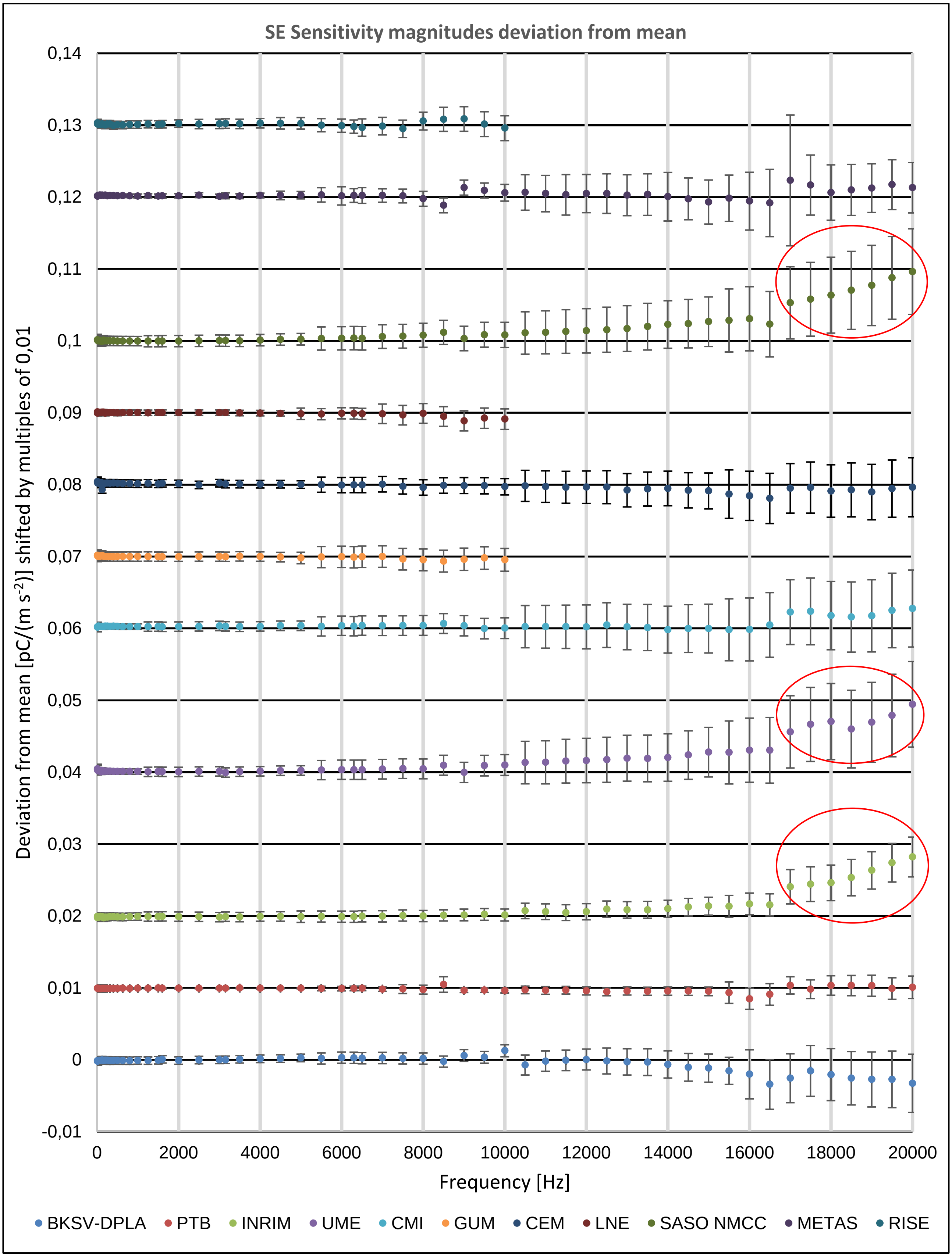

Figure 9. SE sensitivity magnitudes deviation from mean. For each laboratory the horizontal line (shifted by a multiple of 0,01 to give overview) represent zero deviation. The non MoCS (member of consistent subset, see section 8) points are inside the red ovals.

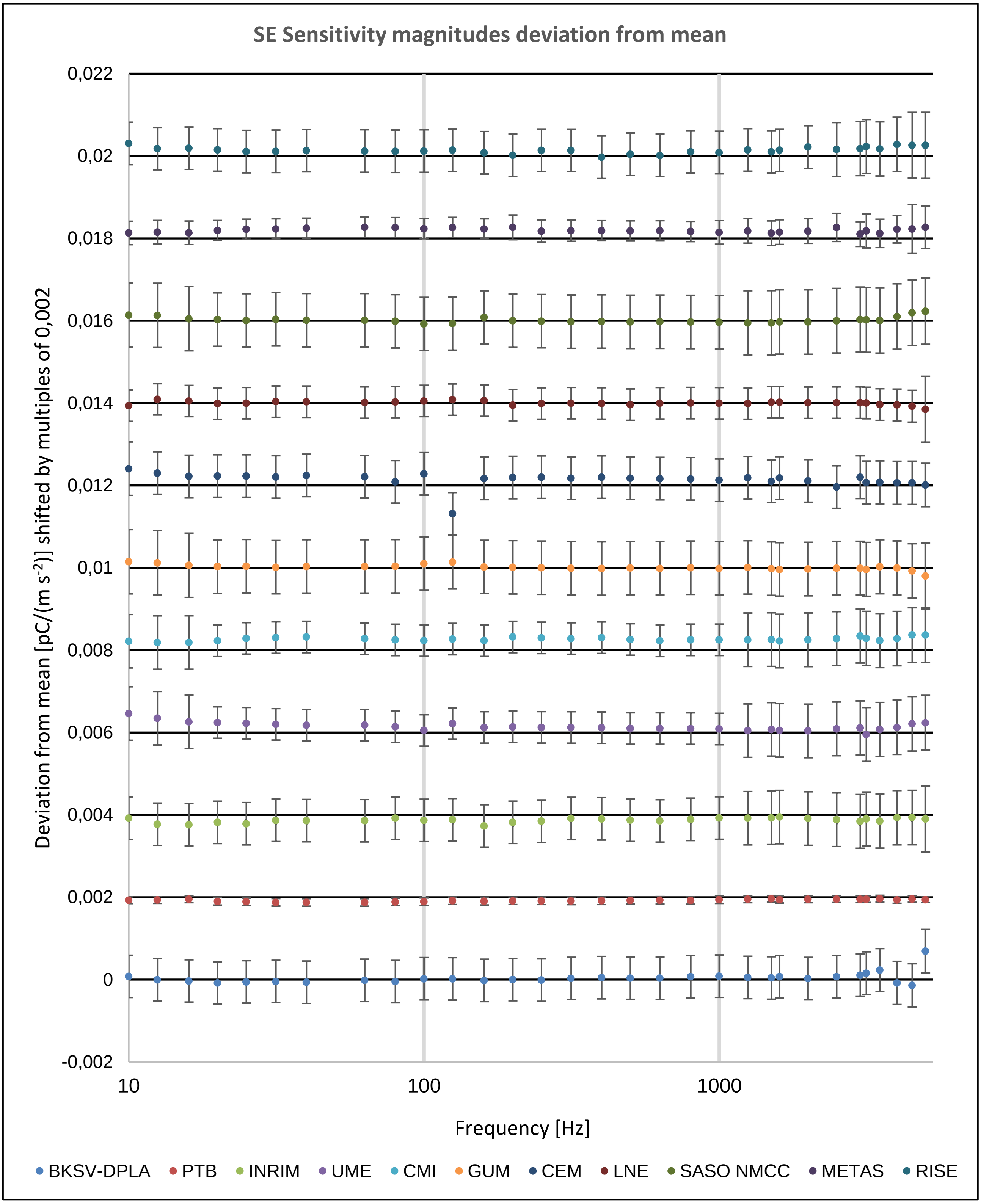

Figure 10. SE sensitivity magnitudes deviation from mean up to 5000 Hz. For each laboratory the horizontal line (shifted by a multiple of 0,002 to give overview) represent zero deviation.

7.1.2 The Back-to-Back Accelerometer (S/N 606545)

Table 7.1.2. Reported participant's results for the magnitude of the BB with relative expanded uncertainties (*k*=2)

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
10	0,12200	0,4	0,12194	0,1	0,12172	0,4	0,12212	0,5	0,12227	0,5	0,12201	0,6
12,5	0,12194	0,4	0,12196	0,1	0,12170	0,4	0,12197	0,5	0,12218	0,5	0,12205	0,6
16,0	0,12196	0,4	0,12201	0,1	0,12174	0,4	0,12224	0,5	0,12218	0,5	0,12198	0,6
20,0	0,12192	0,4	0,12200	0,1	0,12177	0,4	0,12217	0,3	0,12219	0,3	0,12194	0,5
25,0	0,12194	0,4	0,12200	0,1	0,12177	0,4	0,12213	0,3	0,12217	0,3	0,12194	0,5
31,5	0,12193	0,4	0,12195	0,1	0,12168	0,4	0,12210	0,3	0,12217	0,3	0,12194	0,5
40,0	0,12190	0,4	0,12194	0,1	0,12183	0,4	0,12209	0,3	0,12215	0,3	0,12195	0,5
63,0	0,12193	0,4	0,12194	0,1	0,12176	0,4	0,12201	0,3	0,12217	0,3	0,12193	0,5
80,0	0,12193	0,4	0,12197	0,1	0,12180	0,4	0,12201	0,3	0,12214	0,3	0,12194	0,5
100	0,12193	0,4	0,12190	0,1	0,12168	0,4	0,12196	0,3	0,12214	0,3	0,12197	0,5
125	0,12193	0,4	0,12190	0,1	0,12163	0,4	0,12184	0,3	0,12219	0,3	0,12197	0,5
160	0,12193	0,4	0,12191	0,1	0,12170	0,4	0,12202	0,3	0,12218	0,3	0,12193	0,5
200	0,12194	0,4	0,12191	0,1	0,12175	0,4	0,12200	0,3	0,12213	0,3	0,12192	0,5
250	0,12192	0,4	0,12192	0,1	0,12173	0,4	0,12201	0,3	0,12208	0,3	0,12195	0,5
315	0,12197	0,4	0,12192	0,1	0,12177	0,4	0,12201	0,3	0,12212	0,3	0,12195	0,5
400	0,12200	0,4	0,12193	0,1	0,12174	0,4	0,12202	0,3	0,12211	0,3	0,12196	0,5
500	0,12200	0,4	0,12194	0,1	0,12180	0,4	0,12203	0,3	0,12214	0,3	0,12198	0,5
630	0,12202	0,4	0,12196	0,1	0,12185	0,4	0,12203	0,3	0,12216	0,3	0,12200	0,5
800	0,12206	0,4	0,12196	0,1	0,12192	0,4	0,12205	0,3	0,12216	0,3	0,12205	0,5
1000	0,12213	0,4	0,12202	0,1	0,12194	0,4	0,12209	0,3	0,12225	0,3	0,12208	0,5
1250	0,12214	0,4	0,12207	0,1	0,12204	0,5	0,12209	0,5	0,12227	0,5	0,12215	0,5
1500	0,12220	0,4	0,12215	0,1	0,12198	0,5	0,12222	0,5	0,12232	0,5	0,12221	0,5
1600	0,12226	0,4	0,12216	0,1	0,12205	0,5	0,12225	0,5	0,12235	0,5	0,12223	0,5
2000	0,12234	0,4	0,12230	0,1	0,12216	0,5	0,12229	0,5	0,12250	0,5	0,12239	0,5
2500	0,12260	0,4	0,12251	0,1	0,12237	0,5	0,12250	0,5	0,12272	0,5	0,12264	0,5
3000	0,12289	0,4	0,12276	0,1	0,12254	0,5	0,12278	0,5	0,12299	0,5	0,12292	0,5
3150	0,12302	0,4	0,12284	0,1	0,12267	0,5	0,12266	0,5	0,12306	0,5	0,12305	0,5
3500	0,12335	0,4	0,12309	0,1	0,12288	0,5	0,12303	0,5	0,12326	0,5	0,12336	0,5
4000	0,12337	0,4	0,12342	0,1	0,12325	0,5	0,12338	0,5	0,12366	0,5	0,12374	0,5
4500	0,12371	0,4	0,12382	0,1	0,12363	0,5	0,12379	0,5	0,12413	0,5	0,12417	0,5
5000	0,12499	0,4	0,12425	0,1	0,12409	0,6	0,12418	0,5	0,12451	0,5	0,12449	0,6
5500	0,12550	0,6	0,12474	0,3	0,12448	0,6	0,12469	1,0	0,12498	1,0	0,12529	1,1
6000	0,12593	0,6	0,12525	0,3	0,12510	0,6	0,12518	1,0	0,12544	1,0	0,12582	1,1
6300	0,12621	0,6	0,12561	0,3	0,12542	0,6	0,12553	1,0	0,12575	1,0	0,12622	1,1
6500	0,12663	0,6	0,12584	0,3	0,12564	0,6	0,12572	1,0	0,12601	1,0	0,12658	1,1
7000	0,12744	0,6	0,12673	0,3	0,12661	0,6	0,12663	1,0	0,12695	1,0	0,12750	1,1
7500	**0,12798**	0,6	0,12731	0,3	0,12708	0,6	0,12721	1,0	0,12752	1,0	0,12825	1,1

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
8000	0,12860	0,6	0,12807	0,3	0,12765	0,6	0,12797	1,0	0,12803	1,0	0,12911	1,1
8500	0,12919	0,6	0,12917	0,3	0,12836	0,6	0,12802	1,0	0,12900	1,0	0,12956	1,1
9000	0,13101	0,6	0,13002	0,3	0,12989	0,6	0,12920	1,0	0,13000	1,0	0,13139	1,1
9500	0,13175	0,6	0,13092	0,3	0,13091	0,6	0,13041	1,0	0,13100	1,0	0,13279	1,1
10000	0,13275	0,6	0,13199	0,3	0,13164	0,6	0,13199	1,0	0,13195	1,0	0,13347	1,1
10500	0,13362	1,0	0,13293	0,5	0,13319	0,8	0,13288	2,0	0,13355	2,0		
11000	0,13478	1,0	0,13412	0,5	0,13432	0,8	0,13396	2,0	0,13487	2,0		
11500	0,13593	1,0	0,13552	0,5	0,13569	0,8	0,13501	2,0	0,13628	2,0		
12000	0,13732	1,0	0,13702	0,5	0,13702	0,8	0,13626	2,0	0,13736	2,0		
12500	0,13872	1,2	0,13830	0,5	0,13852	0,8	0,13757	2,0	0,13881	2,0		
13000	0,14025	1,2	0,13986	0,5	0,13996	0,8	0,13910	2,0	0,14032	2,0		
13500	0,14172	1,2	0,14139	0,5	0,14154	0,8	0,14060	2,0	0,14195	2,0		
14000	0,14322	1,2	0,14310	0,5	0,14325	0,8	0,14229	2,0	0,14369	2,0		
14500	0,14486	1,2	0,14498	0,5	0,14510	0,8	0,14402	2,0	0,14558	2,0		
15000	0,14655	1,2	0,14649	0,5	0,14705	0,8	0,14607	2,0	0,14754	2,0		
15500	0,14837	1,2	0,14868	1,0	0,14910	1,0	0,14809	2,5	0,14946	2,5		
16000	0,15047	2,0	0,15086	1,0	0,15129	1,0	0,15030	2,5	0,15180	2,5		
16500	0,15240	2,0	0,15310	1,0	0,15363	1,0	0,15260	2,5	0,15412	2,5		
17000	0,15460	2,0	0,15560	1,0	0,15607	1,0	0,15514	2,5	0,15670	2,5		
17500	0,15702	2,0	0,15844	1,0	0,15871	1,0	0,15781	2,5	0,15929	2,5		
18000	0,15891	2,0	0,16117	1,0	0,16150	1,0	0,16070	2,5	0,16222	2,5		
18500	0,16140	2,0	0,16407	1,0	0,16445	1,0	0,16383	2,5	0,16527	2,5		
19000	0,16520	2,0	0,16720	1,0	0,16765	1,0	0,16717	2,5	0,16851	2,5		
19500	0,16958	2,0	0,17058	1,0	0,17107	1,0	0,17107	2,5	0,17200	2,5		
20000	0,17379	2,0	0,17415	1,0	0,17487	1,0	0,17431	2,5	0,17571	2,5		

(continued) Reported participant's results for the magnitude of the BB with relative expanded uncertainties (k = 2)

Frequency	CEM		LNE		SASO NMCC		METAS		RISE	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
10,0	0,12167	0,5	0,12166	0,3	0,12202	0,6	0,12181	0,23	0,12210	0,40
12,5	0,12184	0,4	0,12177	0,3	0,12207	0,6	0,12189	0,23	0,12204	0,40
16,0	0,12206	0,4	0,12182	0,3	0,12210	0,6	0,12195	0,23	0,12207	0,40
20,0	0,12196	0,4	0,12186	0,3	0,12212	0,5	0,12202	0,20	0,12204	0,40
25,0	0,12193	0,4	0,12188	0,3	0,12211	0,5	0,12204	0,20	0,12202	0,40
31,5	0,12222	0,4	0,12194	0,3	0,12213	0,5	0,12204	0,20	0,12204	0,40
40,0	0,12203	0,4	0,12194	0,3	0,12214	0,5	0,12202	0,20	0,12201	0,40
63,0	0,12200	0,40	0,12189	0,3	0,12210	0,5	0,12202	0,20	0,12202	0,40
80,0	0,12206	0,40	0,12196	0,3	0,12208	0,5	0,12202	0,20	0,12201	0,40

Frequency	CEM		LNE		SASO NMCC		METAS		RISE	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
100	0,12183	0,40	0,12190	0,3	0,12204	0,5	0,12201	0,20	0,12201	0,40
125	0,12206	0,40	0,12192	0,3	0,12203	0,5	0,12203	0,20	0,12201	0,40
160	0,12232	0,40	0,12195	0,3	0,12215	0,5	0,12207	0,20	0,12201	0,40
200	0,12211	0,40	0,12198	0,3	0,12206	0,5	0,12199	0,20	0,12203	0,40
250	0,12210	0,40	0,12190	0,3	0,12207	0,5	0,12192	0,22	0,12201	0,40
315	0,12209	0,40	0,12195	0,3	0,12208	0,5	0,12196	0,21	0,12201	0,40
400	0,12208	0,40	0,12194	0,3	0,12208	0,5	0,12199	0,20	0,12206	0,40
500	0,12212	0,40	0,12197	0,3	0,12210	0,5	0,12210	0,21	0,12207	0,40
630	0,12213	0,40	0,12197	0,3	0,12211	0,5	0,12209	0,20	0,12210	0,40
800	0,12212	0,40	0,12201	0,3	0,12213	0,5	0,12214	0,21	0,12211	0,40
1000	0,12214	0,40	0,12205	0,3	0,12214	0,5	0,12211	0,23	0,12213	0,40
1250	0,12224	0,40	0,12213	0,3	0,12217	0,6	0,12219	0,23	0,12220	0,40
1500	0,12227	0,40	0,12221	0,3	0,12225	0,6	0,12222	0,23	0,12224	0,40
1600	0,12240	0,40	0,12224	0,3	0,12230	0,6	0,12230	0,24	0,12229	0,40
2000	0,12245	0,40	0,12239	0,3	0,12240	0,6	0,12243	0,24	0,12249	0,40
2500	0,12260	0,40	0,12263	0,3	0,12265	0,6	0,12275	0,23	0,12269	0,50
3000	0,12296	0,40	0,12289	0,3	0,12287	0,6	0,12288	0,24	0,12289	0,50
3150	0,12300	0,40	0,12298	0,3	0,12294	0,6	0,12301	0,24	0,12299	0,50
3500	0,12325	0,40	0,12322	0,3	0,12313	0,6	0,12321	0,24	0,12325	0,50
4000	0,12366	0,40	0,12363	0,3	0,12355	0,6	0,12361	0,26	0,12362	0,50
4500	0,12400	0,40	0,12401	0,3	0,12392	0,6	0,12402	0,27	0,12397	0,60
5000	0,12449	0,40	0,12445	0,6	0,12434	0,6	0,12449	0,31	0,12438	0,60
5500	0,12498	0,80	0,12494	0,6	0,12489	1,2	0,12502	0,73	0,12478	0,70
6000	0,1256	0,80	0,12561	0,6	0,12534	1,2	0,12547	0,77	0,12500	0,70
6300	0,126	0,80	0,12601	0,6	0,12570	1,2	0,12584	0,80	0,12600	0,70
6500	0,1262	0,80	0,12604	0,6	0,12593	1,2	0,12609	0,81	0,12608	0,90
7000	0,1274	0,80	0,12720	1,0	0,12688	1,2	0,12696	0,90	0,12683	0,90
7500	0,1298	0,80	0,12790	1,0	0,12752	1,2	0,12771	0,92	0,12758	0,90
8000	0,1275	0,80	0,12830	1,0	0,12841	1,2	0,12860	0,95	0,12892	0,90
8500	0,1288	0,80	0,12920	1,0	0,12867	1,2	0,12876	1,08	0,12956	1,20
9000	0,1308	0,80	0,13000	1,0	0,12981	1,2	0,13032	0,96	0,13092	1,20
9500	0,1321	0,80	0,13070	1,0	0,12783	1,2	0,13204	2,36	0,13237	1,20
10000	0,1324	0,80	0,13140	1,0	0,13667	1,2	0,13317	2,44	0,13309	1,20
10500	0,1335	1,5			0,13370	2,0	0,13400	2,20		
11000	0,1348	1,5			0,13470	2,0	0,13521	1,95		
11500	0,1363	1,5			0,13563	2,0	0,13646	1,82		
12000	0,1378	1,5			0,13710	2,0	0,13773	1,72		
12500	0,1393	1,5			0,13866	2,0	0,13907	1,69		
13000	0,1409	1,5			0,14017	2,0	0,14068	1,68		
13500	0,1427	1,5			0,14179	2,0	0,14222	1,69		
14000	0,1446	1,5			0,14354	2,0	0,14381	1,71		
14500	0,1463	1,5			0,14539	2,0	0,14557	1,70		
15000	0,1485	1,5			0,14745	2,0	0,14759	1,69		

Frequency	CEM		LNE		SASO NMCC		METAS		RISE	
	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.	Magnitude of charge sensitivity	Rel. exp. Unc.
Hz	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%	pC/(m/s²)	%
15500	0,1507	2,0			0,14953	2,5	0,14957	1,69		
16000	0,1531	2,0			0,15186	2,5	0,15177	1,70		
16500	0,1556	2,0			0,15430	2,5	0,15406	1,70		
17000	0,1584	2,0			0,15693	2,5	0,15650	1,70		
17500	0,1612	2,0			0,15978	2,5	0,15888	1,71		
18000	0,1642	2,0			0,16278	2,5	0,16173	1,70		
18500	0,1675	2,0			0,16606	2,5	0,16468	1,70		
19000	0,1710	2,0			0,16951	2,5	0,16784	1,70		
19500	0,1747	2,0			0,17326	2,5	0,17099	1,70		
20000	0,1784	2,0			0,17729	2,5	0,17445	1,70		

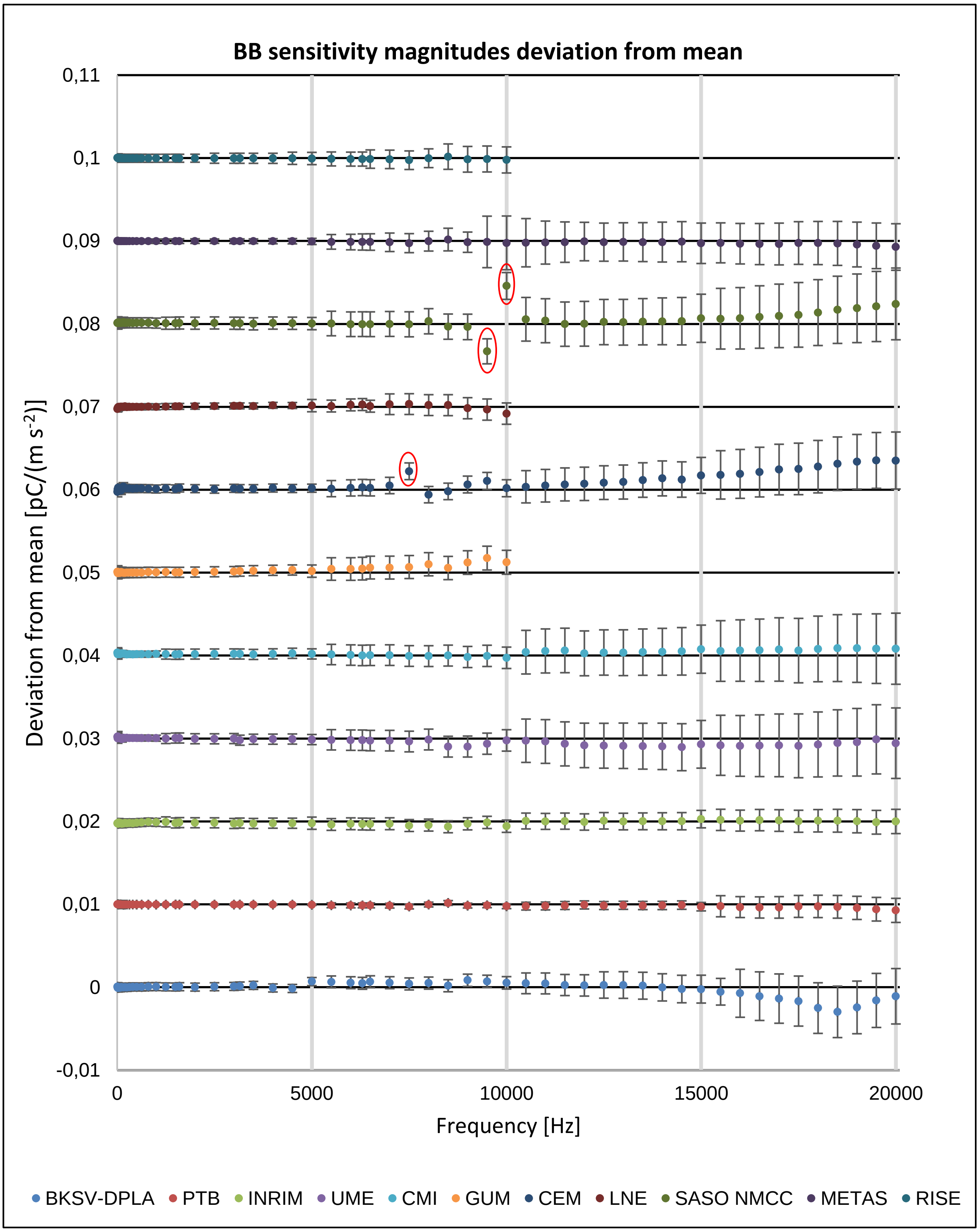

Figure 11. BB sensitivity magnitudes deviation from mean. For each laboratory the horizontal line (shifted by a multiple of 0,01 to give overview) represent zero deviation. The non MoCS (member of consistent subset, see section 8) points are inside the red ovals.

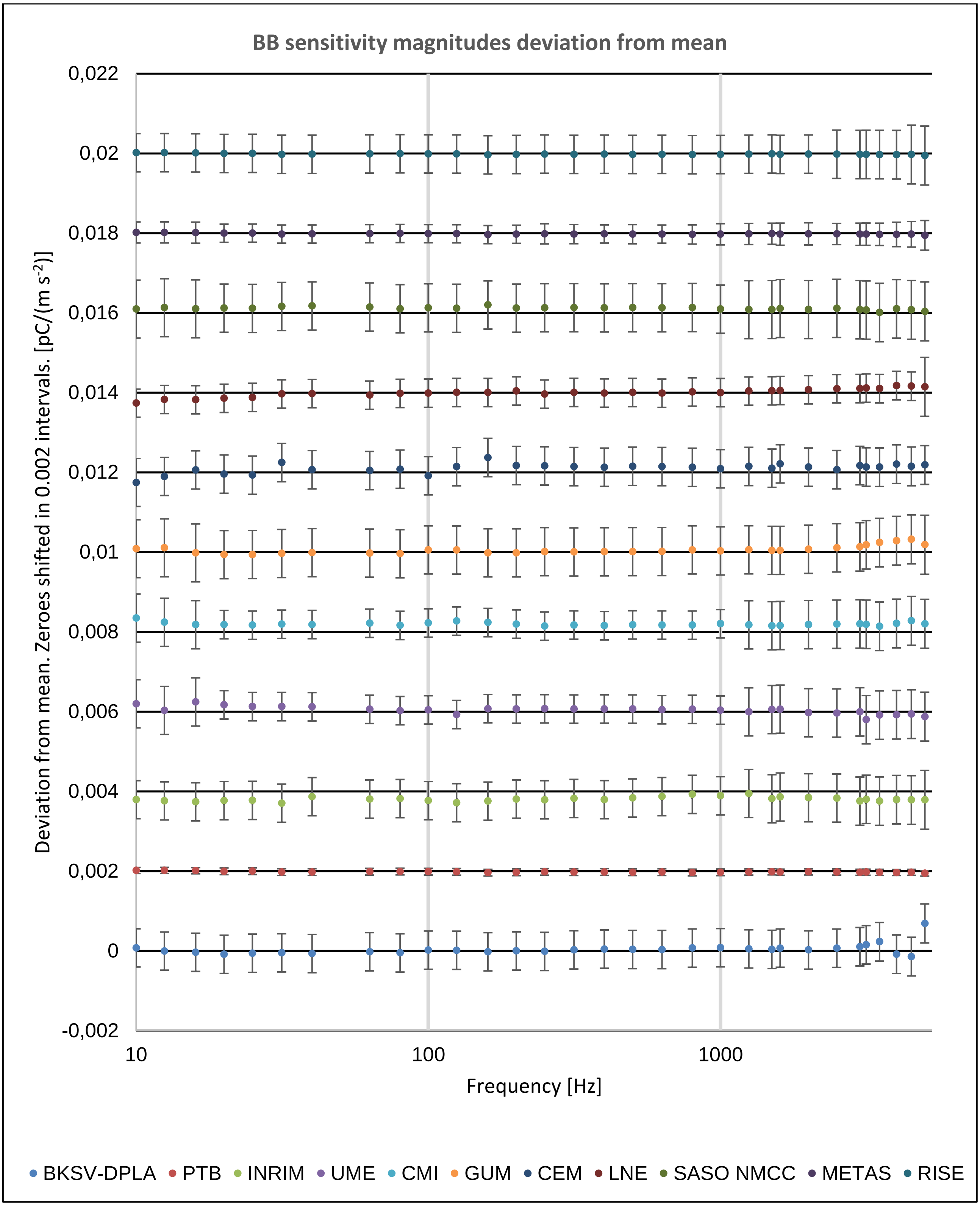

Figure 12. BB sensitivity magnitudes deviation from mean up to 5 kHz. For each laboratory the horizontal line (shifted by a multiple of 0,002 to give overview) represent zero deviation.

7.2 Results for the Phase shift of the Complex Sensitivity

7.2.1 The Single-Ended Accelerometer (S/N 2381734)

Table 7.2.1. Reported participant's results for the phase of the SE with expanded uncertainties (*k*=2)

Frequen-cy	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°	°	°
10,0	-0,02	0,3	-0,02	0,2			-0,06	0,50	-0,04	0,50	-0,02	0,70
12,5	-0,03	0,3	0,00	0,2			-0,08	0,50	-0,06	0,50	-0,02	0,70
16,0	0,01	0,3	0,01	0,2			-0,03	0,50	-0,06	0,50	-0,01	0,70
20,0	0,01	0,3	-0,02	0,2			-0,03	0,50	0,01	0,50	-0,03	0,60
25,0	0,01	0,3	-0,02	0,2			-0,01	0,50	-0,06	0,50	-0,04	0,60
31,5	0,01	0,3	-0,03	0,2			-0,01	0,50	0,01	0,50	-0,04	0,60
40,0	-0,01	0,3	-0,01	0,2			0,01	0,50	0,02	0,50	-0,05	0,60
63,0	0,01	0,3	0,01	0,2			0,02	0,50	0,01	0,50	-0,04	0,60
80,0	0,02	0,3	-0,01	0,2			0,02	0,50	0,02	0,50	-0,03	0,60
100	0,02	0,3	0,00	0,2			0,07	0,50	0,01	0,50	-0,02	0,60
125	0,01	0,3	-0,02	0,2			0,03	0,50	0,02	0,50	-0,01	0,60
160	0,01	0,3	0,01	0,2			0,02	0,50	0,02	0,50	0,00	0,60
200	0,02	0,3	0,02	0,2			0,02	0,50	0,02	0,50	0,00	0,60
250	0,00	0,3	0,01	0,2			0,03	0,50	0,02	0,50	0,00	0,60
315	-0,03	0,3	0,01	0,2			0,03	0,50	0,02	0,50	0,01	0,60
400	0,00	0,3	0,01	0,2			0,02	0,50	0,02	0,50	0,02	0,60
500	-0,01	0,3	0,01	0,2			0,03	0,50	0,02	0,50	0,04	0,60
630	-0,02	0,3	0,03	0,2			0,03	0,50	0,01	0,50	0,05	0,60
800	-0,03	0,3	0,00	0,2			0,02	0,50	0,01	0,50	0,04	0,60
1000	-0,03	0,3	0,01	0,2			0,04	0,50	0,01	0,50	0,04	0,60
1250	-0,03	0,3	-0,01	0,5			0,03	0,50	0,00	0,50	0,04	0,60
1500	0,00	0,3	-0,01	0,5			0,02	0,50	-0,02	0,50	0,04	0,60
1600	-0,02	0,3	-0,01	0,5			0,02	0,50	-0,01	0,50	0,06	0,60
2000	-0,09	0,3	-0,01	0,5			0,04	0,50	-0,01	0,50	0,07	0,60
2500	-0,10	0,3	-0,02	0,5			0,04	0,50	-0,03	0,50	0,09	0,60
3000	-0,13	0,3	-0,03	0,5			0,06	0,50	-0,04	0,50	0,10	0,60
3150	-0,13	0,3	-0,04	0,5			0,01	0,50	-0,05	0,50	0,10	0,60
3500	-0,12	0,3	-0,03	0,5			0,06	0,50	-0,04	0,50	0,11	0,60
4000	-0,17	0,3	-0,04	0,5			0,08	0,50	-0,04	0,50	0,15	0,60
4500	-0,22	0,3	-0,06	0,5			0,09	0,50	-0,03	0,50	0,14	0,60
5000	-0,21	0,3	-0,05	0,5			0,11	0,50	-0,05	0,50	0,11	0,80
5500	-0,28	0,5	-0,07	0,5			0,11	1,00	-0,08	1,00	0,15	1,00
6000	-0,28	0,5	-0,08	0,5			0,13	1,00	-0,08	1,00	0,19	1,00
6300	-0,37	0,5	-0,08	0,5			0,11	1,00	-0,09	1,00	0,18	1,00
6500	-0,27	0,5	-0,09	0,5			0,18	1,00	-0,06	1,00	0,14	1,00

Frequen-cy	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°	°	°
7000	-0,31	0,5	-0,05	0,5			0,23	1,00	-0,04	1,00	0,17	1,00
7500	-0,37	1	-0,10	0,5			0,19	1,00	-0,10	1,00	0,14	1,00
8000	-0,43	1	-0,19	0,5			0,15	1,00	-0,10	1,00	0,18	1,00
8500	-0,60	1	-0,46	0,5			0,17	1,00	-0,10	1,00	0,11	1,00
9000	-0,44	1	-0,11	0,5			-0,03	1,00	-0,10	1,00	0,17	1,00
9500	-0,48	1	-0,14	0,5			0,26	1,00	-0,17	1,00	0,22	1,00
10000	-0,64	1	-0,17	0,5			0,27	1,00	-0,21	1,00	0,23	1,00
10500	-0,61	2	-0,19	1,0			0,28	2,00	-0,23	2,00		
11000	-0,61	2	-0,18	1,0			0,29	2,00	-0,26	2,00		
11500	-0,62	2	-0,20	1,0			0,33	2,00	-0,27	2,00		
12000	-0,67	2	-0,20	1,0			0,33	2,00	-0,28	2,00		
12500	-0,73	2	-0,21	1,0			0,34	2,00	-0,34	2,00		
13000	-0,74	2	-0,22	1,0			0,31	2,00	-0,42	2,00		
13500	-0,74	2	-0,24	1,0			0,37	2,00	-0,52	2,00		
14000	-0,95	2	-0,30	1,0			0,40	2,00	-0,52	2,00		
14500	-0,86	2	-0,32	1,0			0,48	2,00	-0,46	2,00		
15000	-0,85	2	-0,39	1,0			0,49	2,00	-0,45	2,00		
15500	-0,99	2	-0,54	1,0			0,47	3,00	-0,50	3,00		
16000	-1,22	3	-0,65	1,0			0,48	3,00	-0,49	3,00		
16500	-1,23	3	-0,28	1,0			0,49	3,00	-0,50	3,00		
17000	-0,81	3	-0,56	1,0			0,59	3,00	-0,60	3,00		
17500	-1,07	3	-0,47	1,0			0,42	3,00	-0,60	3,00		
18000	-1,20	3	-0,49	1,0			0,22	3,00	-0,63	3,00		
18500	-1,19	3	-0,65	1,0			0,18	3,00	-0,77	3,00		
19000	-1,24	3	-0,89	1,0			0,34	3,00	-0,79	3,00		
19500	-1,28	3	-0,88	1,0			0,32	3,00	-0,92	3,00		
20000	-1,33	3	-0,86	1,0			0,27	3,00	-0,99	3,00		

(continued) Reported participant's results for the phase of the SE with expanded uncertainties (k=2)

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE	
	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°
10,0	-0,02	0,51	-0,40	2,00	-0,03	0,5	0,03	0,41		
12,5	-0,02	0,51	-0,19	2,00	-0,02	0,5	0,02	0,41		
16,0	-0,03	0,51	-0,22	2,00	-0,01	0,5	0,02	0,41		
20,0	-0,02	0,51	-0,22	2,00	0,00	0,5	0,02	0,38		
25,0	-0,01	0,51	-0,19	2,00	0,01	0,5	0,01	0,38		
31,5	0,00	0,51	1,13	2,00	0,01	0,5	0,01	0,38		
40,0	-0,01	0,51	-0,10	2,00	0,02	0,5	0,01	0,38		
63,0	-0,01	0,51	0,07	2,00	0,03	0,5	0,01	0,38		
80,0	0,00	0,51	0,13	2,00	0,03	0,5	0,01	0,38		
100	-0,01	0,51	0,06	2,00	0,03	0,5	0,02	0,38		
125	-0,49	0,51	0,04	2,00	0,05	0,5	0,02	0,38		
160	0,01	0,51	0,09	2,00	0,06	0,5	0,02	0,38		
200	0,00	0,51	0,10	2,00	0,03	0,5	0,01	0,39		
250	0,00	0,51	0,03	2,00	0,03	0,5	0,00	0,39		
315	0,00	0,51	0,10	2,00	0,03	0,5	0,01	0,38		
400	-0,01	0,51	0,08	2,00	0,02	0,5	0,01	0,38		
500	-0,02	0,51	0,08	2,00	0,02	0,5	0,01	0,38		
630	0,01	0,51	0,10	2,00	0,02	0,5	0,01	0,38		
800	0,01	0,51	0,14	2,00	0,01	0,5	0,00	0,38		
1000	0,02	0,51	0,18	2,00	0,01	0,5	0,00	0,47		
1250	0,00	1,00	0,24	2,00	0,01	0,5	-0,01	0,48		
1500	0,00	1,00	0,30	2,00	0,00	0,5	-0,01	0,48		
1600	0,00	1,00	0,36	2,00	0,01	0,5	-0,01	0,48		
2000	0,00	1,00	0,38	5,00	0,00	0,5	0,04	0,48		
2500	0,00	1,00	0,48	5,00	-0,03	0,5	-0,05	0,48		
3000	0,00	1,00	0,59	5,00	-0,01	0,5	-0,05	0,48		
3150	0,00	1,00	0,62	5,00	-0,03	0,5	-0,04	0,48		
3500	0,00	1,00	0,70	5,00	-0,03	0,5	-0,02	0,48		
4000	0,00	1,00	0,77	5,00	-0,05	0,5	-0,05	0,50		
4500	0,00	1,00	0,88	5,00	-0,04	0,5	-0,06	0,49		
5000	0,00	1,00	0,97	5,00	-0,06	0,5	-0,14	0,49		
5500	-0,10	1,00	1,05	5,00	-0,07	1,0	-0,12	0,88		
6000	0,00	1,00	1,18	5,00	-0,07	1,0	-0,14	0,91		
6300	0,00	1,00	1,25	5,00	-0,08	1,0	-0,16	0,88		
6500	0,00	1,00	1,31	5,00	-0,04	1,0	-0,15	0,88		
7000	0,10	1,00	1,40	5,00	-0,01	1,0	-0,15	0,87		
7500	0,00	1,00	1,41	5,00	-0,10	1,0	-0,24	0,87		
8000	-0,10	1,00	1,56	5,00	-0,27	1,0	-0,42	0,87		
8500	-0,10	1,00	1,65	5,00	-0,64	1,0	-0,49	0,87		

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE	
	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°
9000	-0,10	1,00	1,73	5,00	-0,11	1,0	0,54	0,87		
9500	-0,10	1,00	1,94	5,00	-0,06	1,0	-0,22	0,87		
10000	-0,10	1,00	2,02	5,00	-0,11	1,0	-0,29	0,87		
10500	-0,10	1,50			-0,11	2,0	-0,37	2,00		
11000	-0,10	1,50			-0,11	2,0	-0,40	2,00		
11500	-0,20	1,50			-0,09	2,0	-0,51	2,00		
12000	-0,20	1,50			-0,09	2,0	-0,53	2,00		
12500	0,00	1,50			-0,09	2,0	-0,53	2,00		
13000	-0,60	1,50			-0,09	2,0	-0,54	2,00		
13500	-0,20	1,50			-0,08	2,0	-0,64	2,00		
14000	-0,30	1,50			-0,08	2,0	-0,81	2,00		
14500	-0,40	1,50			-0,13	2,0	-0,56	2,00		
15000	-0,40	1,50			-0,15	2,0	-0,51	2,00		
15500	-0,50	2,00			-0,11	3,0	-0,74	2,00		
16000	-0,50	2,00			-0,14	3,0	-0,79	2,00		
16500	-0,60	2,00			-0,24	3,0	-0,72	2,00		
17000	-0,60	2,00			-0,26	3,0	-0,92	2,00		
17500	-0,70	2,00			-0,30	3,0	-1,17	2,00		
18000	-0,90	2,00			-0,32	3,0	-0,97	2,00		
18500	-0,90	2,00			-0,37	3,0	-1,14	2,00		
19000	-0,90	2,00			-0,45	3,0	-1,06	2,00		
19500	-0,90	2,00			-0,50	3,0	-1,17	2,00		
20000	-1,00	2,00			-0,56	3,0	-1,17	2,00		

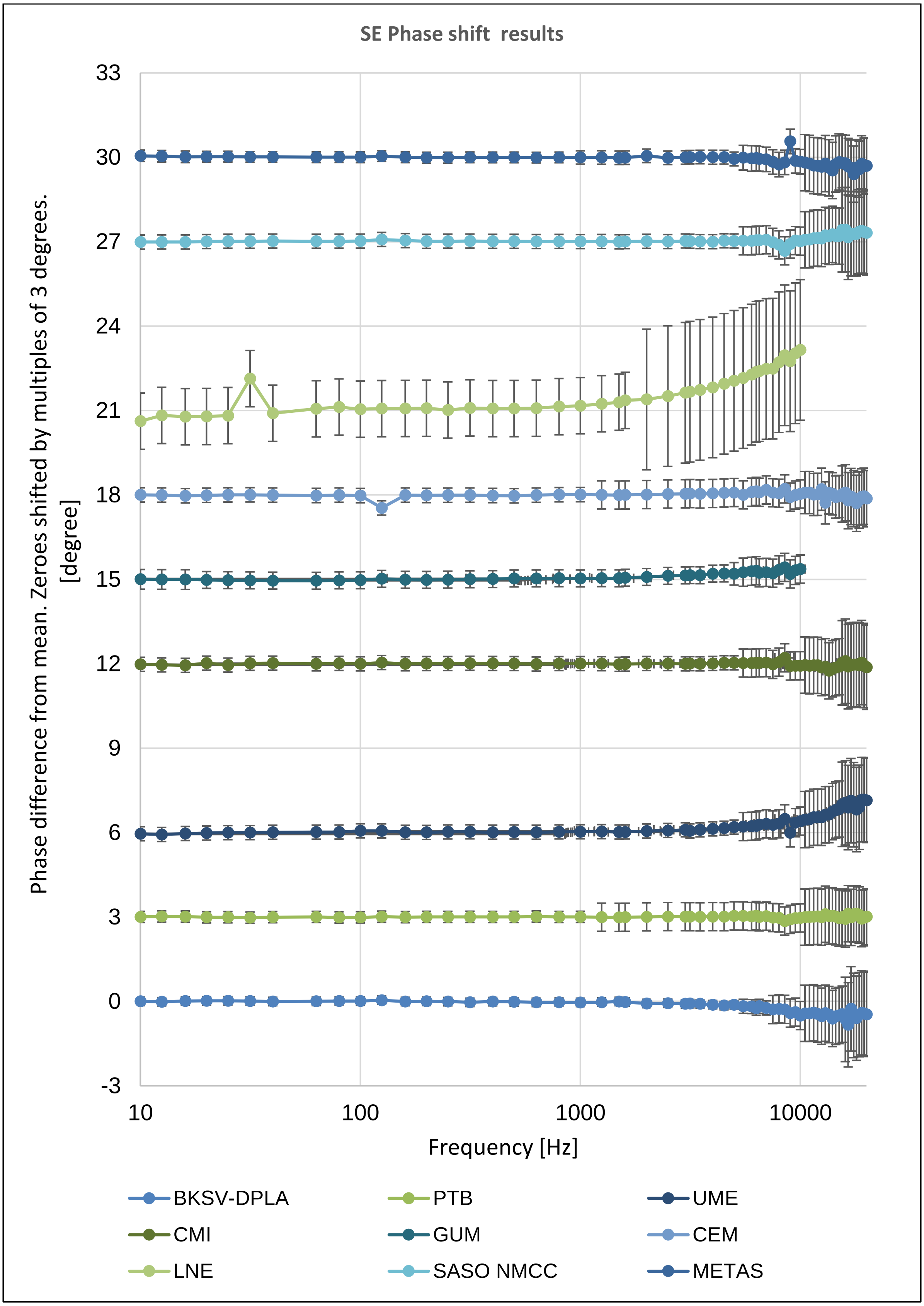

Figure 13. SE phase shift deviation from mean. For each laboratory the horizontal line (shifted by a multiple of 3 to give overview) represent zero deviation. All results are MoCS (member of consistent subset, see section 8).

7.2.2 The Back-to-Back Accelerometer (SN 606545)

Table 7.2.2. Reported participant's results for the phase of the BB with expanded uncertainties (*k*=2)

Frequen-cy	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	Phase shift	Expanded uncertainty on phase shift	Phase shift (180° added)	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift (180° sub-tracted)	Expanded uncertainty on phase shift	Phase shift (180° subtracted)	Expanded uncertainty on phase shift	Phase shift (180° sub-tracted)	Expanded uncertainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°	°	°
10,0	-0,02	0,3	-0,04	0,2			0,00	0,50	-0,02	0,50	-0,02	0,70
12,5	-0,03	0,3	-0,01	0,2			0,06	0,50	-0,04	0,50	-0,02	0,70
16,0	-0,02	0,3	-0,07	0,2			0,03	0,50	-0,02	0,50	-0,05	0,70
20,0	-0,01	0,3	-0,03	0,2			0,01	0,50	-0,01	0,50	-0,05	0,60
25,0	-0,01	0,3	-0,04	0,2			0,01	0,50	-0,01	0,50	-0,05	0,60
31,5	-0,01	0,3	-0,05	0,2			0,01	0,50	-0,02	0,50	-0,05	0,60
40,0	-0,01	0,3	-0,03	0,2			0,01	0,50	-0,01	0,50	-0,05	0,60
63,0	0	0,3	-0,03	0,2			0,00	0,50	-0,01	0,50	-0,05	0,60
80,0	0	0,3	-0,05	0,2			0,01	0,50	-0,01	0,50	-0,06	0,60
100	0	0,3	0,00	0,2			0,03	0,50	-0,01	0,50	-0,04	0,60
125	0	0,3	0,00	0,2			0,07	0,50	-0,02	0,50	-0,03	0,60
160	0	0,3	0,00	0,2			0,02	0,50	-0,02	0,50	-0,04	0,60
200	0,01	0,3	0,00	0,2			0,04	0,50	-0,01	0,50	-0,01	0,60
250	0,01	0,3	0,00	0,2			0,03	0,50	-0,01	0,50	0,00	0,60
315	0,02	0,3	0,00	0,2			0,03	0,50	-0,02	0,50	0,01	0,60
400	0,01	0,3	0,01	0,2			0,04	0,50	-0,01	0,50	0,02	0,60
500	0	0,3	0,00	0,2			0,03	0,50	-0,03	0,50	0,04	0,60
630	-0,01	0,3	0,03	0,2			0,04	0,50	-0,02	0,50	0,06	0,60
800	-0,02	0,3	0,00	0,2			0,04	0,50	-0,01	0,50	0,03	0,60
1000	-0,03	0,3	0,01	0,2			0,05	0,50	-0,02	0,50	0,05	0,60
1250	-0,06	0,3	-0,01	0,5			0,05	0,50	0,00	0,50	0,06	0,60
1500	-0,06	0,3	-0,01	0,5			0,05	0,50	0,00	0,50	0,06	0,60
1600	-0,06	0,3	-0,01	0,5			0,03	0,50	0,00	0,50	0,07	0,60
2000	-0,08	0,3	-0,01	0,5			0,06	0,50	-0,01	0,50	0,09	0,60
2500	-0,12	0,3	-0,01	0,5			0,09	0,50	-0,02	0,50	0,12	0,60
3000	-0,13	0,3	-0,02	0,5			0,09	0,50	-0,02	0,50	0,14	0,60
3150	-0,14	0,3	-0,02	0,5			0,16	0,50	-0,04	0,50	0,16	0,60
3500	-0,27	0,3	-0,02	0,5			0,09	0,50	-0,03	0,50	0,13	0,60
4000	-0,2	0,3	-0,03	0,5			0,10	0,50	-0,03	0,50	0,18	0,60
4500	-0,11	0,3	-0,04	0,5			0,09	0,50	-0,04	0,50	0,19	0,60
5000	-0,09	0,3	-0,04	0,5			0,09	0,50	-0,08	0,50	0,14	0,80
5500	-0,25	0,5	-0,05	0,5			0,08	1,00	-0,07	1,00	0,21	1,00
6000	-0,26	0,5	-0,04	0,5			0,09	1,00	-0,09	1,00	0,27	1,00
6300	-0,27	0,5	-0,05	0,5			0,05	1,00	-0,10	1,00	0,28	1,00
6500	-0,22	0,5	-0,03	0,5			0,13	1,00	-0,05	1,00	0,29	1,00
7000	-0,34	0,5	-0,03	0,5			0,07	1,00	-0,11	1,00	0,36	1,00
7500	-0,36	1	-0,05	0,5			-0,02	1,00	-0,11	1,00	0,38	1,00

8000	-0,35	1	-0,06	0,5			-0,14	1,00	-0,14	1,00	0,28	1,00
8500	-0,08	1	0,08	0,5			0,12	1,00	-0,24	1,00	0,50	1,00
9000	-0,57	1	-0,04	0,5			0,11	1,00	-0,24	1,00	0,54	1,00
9500	-0,54	1	-0,08	0,5			0,07	1,00	-0,24	1,00	0,52	1,00
10000	-0,94	1	-0,12	0,5			0,43	1,00	-0,24	1,00	0,34	1,00
10500	-0,51	2	-0,06	1,0			0,13	2,00	-0,24	2,00		
11000	-0,62	2	0,01	1,0			0,08	2,00	-0,21	2,00		
11500	-0,61	2	-0,04	1,0			0,03	2,00	-0,31	2,00		
12000	-0,59	2	-0,04	1,0			-0,04	2,00	-0,23	2,00		
12500	-0,62	2	-0,11	1,0			-0,01	2,00	-0,27	2,00		
13000	-0,63	2	-0,09	1,0			-0,06	2,00	-0,28	2,00		
13500	-0,68	2	-0,13	1,0			-0,09	2,00	-0,31	2,00		
14000	-0,73	2	-0,11	1,0			-0,10	2,00	-0,29	2,00		
14500	-0,72	2	-0,13	1,0			-0,10	2,00	-0,34	2,00		
15000	-0,76	2	-0,14	1,0			-0,08	2,00	-0,40	2,00		
15500	-0,81	2	-0,11	1,0			-0,05	3,00	-0,38	3,00		
16000	-0,82	3	-0,10	1,0			-0,06	3,00	-0,40	3,00		
16500	-0,84	3	-0,09	1,0			-0,06	3,00	-0,42	3,00		
17000	-0,87	3	-0,03	1,0			-0,08	3,00	-0,44	3,00		
17500	-0,96	3	-0,05	1,0			-0,06	3,00	-0,47	3,00		
18000	-0,92	3	-0,09	1,0			-0,06	3,00	-0,50	3,00		
18500	-0,59	3	-0,09	1,0			-0,06	3,00	-0,54	3,00		
19000	-0,35	3	-0,10	1,0			-0,07	3,00	-0,56	3,00		
19500	-0,42	3	-0,11	1,0			-0,10	3,00	-0,59	3,00		
20000	-0,83	3	-0,11	1,0			-0,10	3,00	-0,62	3,00		

(continued) Reported participant's results for the phase of the BB with expanded uncertainties (*k* = 2)

Frequency	CEM		LNE		SASO NMCC		METAS		RISE	
	Phase shift (180° subtracted)	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift (180° subtracted)	Expanded uncertainty on phase shift	Phase shift (180° subtracted)	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°
10,0	-0,22	0,51	0,24	2,00	-0,04	0,5	-0,04	0,41		
12,5	-0,01	0,51	0,32	2,00	-0,03	0,5	-0,02	0,41		
16,0	0,01	0,51	0,18	2,00	-0,02	0,5	-0,01	0,41		
20,0	-0,01	0,51	0,09	2,00	-0,01	0,5	-0,01	0,38		
25,0	0,04	0,51	0,05	2,00	0,00	0,5	0,00	0,38		
31,5	0,03	0,51	1,28	2,00	0,00	0,5	0,01	0,38		
40,0	0,00	0,51	0,04	2,00	-0,01	0,5	0,00	0,38		
63,0	0,02	0,51	0,16	2,00	-0,01	0,5	0,02	0,38		
80,0	0,03	0,51	0,21	2,00	-0,01	0,5	0,02	0,38		
100	0,03	0,51	0,14	2,00	-0,01	0,5	0,02	0,38		
125	0,01	0,51	0,09	2,00	-0,03	0,5	0,01	0,38		
160	0,11	0,51	0,14	2,00	-0,04	0,5	-0,01	0,38		

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE	
	Phase shift (180° sub-tracted)	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift	Phase shift (180° subtrac-ted)	Expanded uncer-tainty on phase shift	Phase shift (180° subtrac-ted)	Expanded uncer-tainty on phase shift	Phase shift	Expanded uncer-tainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°
200	0,02	0,51	0,08	2,00	-0,01	0,5	-0,05	0,38		
250	0,01	0,51	0,07	2,00	-0,02	0,5	0,03	0,39		
315	0,01	0,51	0,11	2,00	-0,02	0,5	0,03	0,38		
400	0,01	0,51	0,11	2,00	-0,02	0,5	0,06	0,38		
500	0,00	0,51	0,08	2,00	-0,02	0,5	0,03	0,38		
630	0,02	0,51	0,15	2,00	-0,02	0,5	0,01	0,38		
800	0,02	0,51	0,15	2,00	-0,01	0,5	0,02	0,38		
1000	0,04	0,51	0,19	2,00	-0,02	0,5	0,01	0,47		
1250	0,00	1,00	0,25	2,00	-0,02	0,5	0,00	0,47		
1500	0,00	1,00	0,30	2,00	-0,01	0,5	0,00	0,47		
1600	0,00	1,00	0,32	2,00	-0,01	0,5	0,00	0,47		
2000	0,00	1,00	0,37	5,00	-0,01	0,5	0,04	0,47		
2500	0,00	1,00	0,48	5,00	-0,02	0,5	-0,03	0,47		
3000	0,00	1,00	0,56	5,00	0,00	0,5	-0,04	0,47		
3150	0,00	1,00	0,60	5,00	-0,01	0,5	-0,03	0,47		
3500	0,00	1,00	0,66	5,00	-0,01	0,5	-0,04	0,47		
4000	0,00	1,00	0,75	5,00	-0,02	0,5	-0,03	0,48		
4500	0,00	1,00	0,85	5,00	-0,04	0,5	-0,06	0,48		
5000	0,00	1,00	0,93	5,00	-0,06	0,5	-0,14	0,48		
5500	0,00	1,00	0,97	5,00	-0,07	1,0	-0,04	0,87		
6000	0,00	1,00	1,09	5,00	-0,07	1,0	-0,06	0,88		
6300	0,00	1,00	1,10	5,00	-0,09	1,0	-0,05	0,88		
6500	0,10	1,00	1,22	5,00	-0,04	1,0	-0,01	0,88		
7000	0,10	1,00	1,39	5,00	-0,08	1,0	0,02	0,92		
7500	-0,70	1,00	1,55	5,00	-0,13	1,0	-0,02	0,95		
8000	0,10	1,00	1,86	5,00	-0,21	1,0	-0,02	1,14		
8500	0,60	1,00	1,93	5,00	-0,26	1,0	0,45	1,27		
9000	1,30	1,00	2,08	5,00	-0,53	1,0	0,32	1,58		
9500	-0,90	1,00	2,19	5,00	-1,00	1,0	0,23	1,44		
10000	-0,50	1,00	2,53	5,00	-0,36	1,0	0,00	0,91		
10500	-0,30	1,50			-0,36	2,0	-0,17	2,00		
11000	-0,20	1,50			-0,32	2,0	-0,14	2,00		
11500	-0,20	1,50			-0,25	2,0	-0,17	2,00		
12000	-0,20	1,50			-0,31	2,0	-0,18	2,00		
12500	-0,20	1,50			-0,34	2,0	-0,32	2,00		
13000	-0,30	1,50			-0,41	2,0	-0,17	2,00		
13500	-0,30	1,50			-0,45	2,0	-0,17	2,00		
14000	-0,30	1,50			-0,48	2,0	-0,12	2,00		
14500	-0,30	1,50			-0,53	2,0	-0,20	2,00		
15000	-0,30	1,50			-0,57	2,0	-0,27	2,00		

Frequency	CEM		LNE		SASO NMCC		METAS		RISE	
	Phase shift (180° subtracted)	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift	Phase shift (180° subtracted)	Expanded uncertainty on phase shift	Phase shift (180° subtracted)	Expanded uncertainty on phase shift	Phase shift	Expanded uncertainty on phase shift
Hz	°	°	°	°	°	°	°	°	°	°
15500	-0,30	2,00			-0,59	3,0	-0,27	2,00		
16000	-0,30	2,00			-0,58	3,0	-0,25	2,00		
16500	-0,30	2,00			-0,60	3,0	-0,26	2,00		
17000	-0,30	2,00			-0,64	3,0	-0,30	2,00		
17500	-0,30	2,00			-0,65	3,0	-0,35	2,00		
18000	-0,30	2,00			-0,66	3,0	-0,39	2,00		
18500	-0,30	2,00			-0,67	3,0	-0,42	2,00		
19000	-0,40	2,00			-0,68	3,0	-0,45	2,00		
19500	-0,40	2,00			-0,69	3,0	-0,53	2,00		
20000	-0,30	2,00			-0,70	3,0	-0,55	2,00		

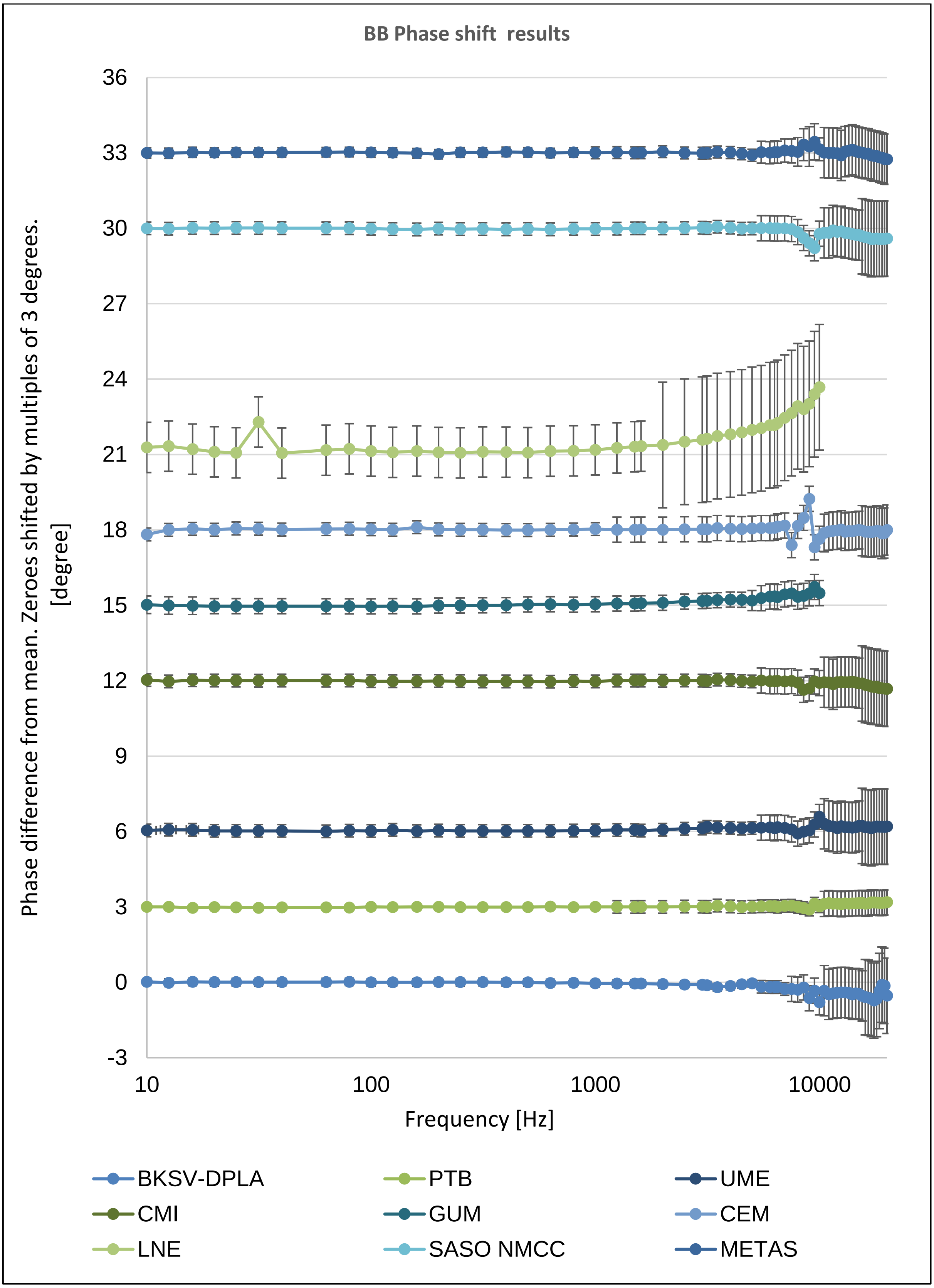

Figure 14. BB phase shift deviation from mean. For each laboratory the horizontal line (shifted by a multiple of 3 to give overview) represent zero deviation. All results are MoCS (member of consistent subset, see section 8).

8. Degree of Equivalence with Respect to the CIPM KC Reference Value

8.1. Linking

Introduction

A comparison within a regional metrology organization (RMO) can be approved as a regional key comparison within the framework of the CIPM MRA and included in the Key comparison data base (KCDB) if the results are linked to the key comparison reference values (KCRVs) of the respective CIPM key comparison. It is therefore required to link the results of the European comparison carried out within the agreed EURAMET Project to the KCRVs established in the CIPM key comparison CCAUV.V-K5.

The methodology used to link the results of the regional key comparison EURAMET.AUV.V-K5 to those of the CIPM key comparison CCAUV.V-K5 is described below. In the following, the CIPM key comparison CCAUV.V-K5 is referred to as the CIPM comparison and the RMO key comparison EURAMET.AUV.V-K5 is referred to as the RMO comparison.

Task of linking

The CIPM has key comparison reference values (KCRVs) at the frequencies used in the RMO comparison.

The participating laboratories of the RMO submitted results for the calibration of a BB accelerometer and a SE accelerometer at selected frequencies in the frequency range from 10 Hz to 20000 Hz, using laser interferometry in accordance with ISO 16063-11. The DOEs were calculated for the laboratories' results relative to the respective KCRV for the BB accelerometer and the SE accelerometer separately.

The linking task requires the transformation of the RMO calibration results into quantities appropriate for the CIPM comparison. The transformed RMO results can then be compared with the CIPM KCRV. It includes the calculation of

(a) the differences between the combined RMO results and the CIPM quantities for the NMIs and DIs participating in both the CIPM and the RMO comparisons and
(b) the differences between the transformed RMO results and the corresponding KCRV for all laboratories.
(c) the uncertainties associated with these differences.

NOTE: As described earlier the MoCS was found for the total RMO comparison, and a few results excluded. The group of laboratories participating in the CIPM too was tested in the same way as required in [3]. This revealed that the group had problems at a few frequencies. It was considered to remove the involved results, but the resulting tables of degrees of equivalence would not show any changes, and the problematic results at certain frequencies for some laboratories are found in the tables of equivalence anyhow. Therefore, it was decided to keep these results in the calculations. It should however be input to the laboratories to reconsider stated uncertainties.

8.2. Linking procedure for magnitude

The linking follows the method outlined in [3] which has been used in earlier accelerometer RMO comparisons. The complete mathematical deduction is shown to avoid any confusion. The only assumption made is, that there is no correlation between the measurements made by a laboratory on one accelerometer for the CIPM comparison and the measurements made on another accelerometer for the RMO comparison by the same laboratory.

The measurand in the CIPM comparison is denoted by X. The values x_1, $u(x_1)$,...,x_N ,$u(x_N)$ denote the best estimates and associated standard uncertainties of the laboratories.

The measurand in the RMO comparison is denoted by Y. The values y_1, $u(y_1)$,..., y_M, $u(y_M)$ denote the best estimates and associated standard uncertainties of the laboratories.

Furthermore, G = {1,..., p} (p ≤ min(N,M)) is the index set of the linking laboratories which participate in both the CIPM and RMO comparison. The laboratories are labelled such that any number within G denotes the same laboratory in both comparisons.

The value $r = x/y$ denotes the transformation factor between the two *measurands* to make the link between the two comparisons. The transformation factor is estimated using the KCRV of the CIPM comparison and the combined results in the RMO comparison of the linking laboratories. The estimated transformation factor is then applied to the results of the RMO comparison. For reference, the r values are listed as the last column in the DOE tables.

Since no information about correlations is available, the estimators $x_1, ..., x_N, y_1, ..., y_M$ are treated as being uncorrelated. Let x denote the KCRV of the CIPM comparison and y the weighted mean of the linking laboratories in the RMO comparison

$$x = \frac{\sum_{l=1}^{N} x_l/u^2(x_l)}{\sum_{l=1}^{N} 1/u^2(x_l)} \qquad u^2(x) = \frac{1}{\sum_{l=1}^{N} 1/u^2(x_l)}$$

$$y = \frac{\sum_{l\in G} \frac{y_l}{u^2(y_l)}}{\sum_{l\in G} \frac{1}{u^2(y_l)}} \qquad u^2(y) = \frac{1}{\sum_{l\in G} 1/u^2(y_l)}$$

Then r is estimated according to

$$r = \frac{x}{y} \qquad u^2(r) = \frac{u^2(x)}{y^2} + \frac{x^2}{y^4}u^2(y)$$

$z_l = ry_l$ denotes the corrected measurand in the regional comparison.

The uncertainty on the difference
$d_l = ry_l - x$

is given by the following equations where

$p_l = y_l/y$

To calculate the uncertainties on d_l the proper mathematical tool is the law of error propagation. This requires partial differentiation of the formulas with proper respect to dependencies.
The calculations split up in two cases:

1) *l* is **not** a participant of the CIPM comparison. This means that *y* and *r* are independent of y_l. By use of the law of error propagation we find

$$u^2(d_l) = \left(\frac{\partial d_l}{\partial x}\right)^2 u^2(x) + \left(\frac{\partial d_l}{\partial y}\right)^2 u^2(y) + \left(\frac{\partial d_l}{\partial y_l}\right)^2 u^2(y_l)$$
$$= (p_l - 1)^2 u^2(x) + r^2(1 + {p_l}^2 \frac{u^2(y)}{u^2(y_l)}) u^2(y_l)$$

2) *l* is a participant of the CIPM comparison. This means that *y* and *r* are dependent of y_l. By use of the
law of error propagation we find

$$u^2(d_l) = \left(\frac{\partial d_l}{\partial x}\right)^2 u^2(x) + \left(\frac{\partial d_l}{\partial y_l}\right)^2 u^2(y_l)$$
$$= (p_l - 1)^2 u^2(x) + r^2(1 - p_l \frac{u^2(y)}{u^2(y_l)})^2 u^2(y_l)$$

The degrees of equivalence are defined as the differences between the corrected results in the RMO comparison and the KCRV of the CIPM comparison compared to the uncertainties on d_l with a confidence of 95% or *k=2*, i.e.

$$U_l = 2\sqrt{u^2(d_l)}$$

8.3. Linking procedure for phase shift

The known procedures for linking have no examples of phase measurements.

Basically, the results should be treated as complex numbers or vectors and the uncertainties would be an area around the end of the vector.

After thorough considerations and testing of methods the following was concluded:

The differences expected for the phase shift for the two transducer sets used in the CIPM and RMO comparisons are minimal. The physics behind is the properties of quarts and the resonance frequency.

If a correction should be made it would be a bias correction, i.e., an addition of the difference found from the mean of the common group of participants to the KCRV of CIPM. This method is described in [4] and was used in EURAMET.AUV.V-K1.1 but not for phase.

This takes the form for any given frequency

$$\delta = \varphi_{RV}^{CIPM} - \varphi$$

Where φ is the weighted average of the linking laboratories (following the same procedure as for magnitude).

$$d_l = \varphi_l^{EURAMET} + \delta - \varphi_{RV}^{CIPM} = \varphi_l^{EURAMET} - \varphi$$

The calculations split up in two cases:

1) *l* is **not** a participant of the CIPM comparison. This means that φ and δ are independent of φ_l. By use of the law of error propagation we find

$$u^2(d_l) = \left(\frac{\partial d_l}{\partial \varphi_l}\right)^2 u^2(\varphi_l) + \left(\frac{\partial d_l}{\partial \varphi}\right)^2 u^2(\varphi) = \left(1 + \frac{u^2(\varphi)}{u^2(\varphi_l)}\right) u^2(\varphi_l) = u^2(\varphi_l) + u^2(\varphi)$$

2) *l* is a participant of the CIPM comparison. This means that φ and δ are dependent of φ_l. By use of the law of error propagation we find

$$u^2(d_l) = \left(\frac{\partial d_l}{\partial \varphi_l}\right)^2 u^2(\varphi_l) = (1 - \frac{u^2(\varphi)}{u^2(\varphi_l)})^2 u^2(\varphi_l)$$

The degrees of equivalence are again defined as the differences between the corrected results in the RMO comparison and the KCRV of the CIPM comparison compared to the uncertainties on d_l with a confidence of 95% or *k=2*, i.e.

$$U_l = 2\sqrt{u^2(d_l)}$$

It was not found relevant to include the correction values (or their uncertainties) in the tables as they were way below the stated uncertainties.

8.4. Analysis

The measurement results were reported by the participants using the mandatory report spreadsheet (Excel file). For this file the displayed resolution of the data was limited, however, sometimes the resolution of the data stored in the file was representing many more significant digits. To comply with the resolution implied by the measurement uncertainty and to generate a consistent picture in this report, all input data were rounded before further calculation in the following way:

Quantity	Unit	Representation
Magnitude of complex sensitivity	pC/(ms^{-2})	0,xxxxx
Relative uncertainty	%	x,xx
Phase shift of complex sensitivity	Degrees [°]	x,xx
Uncertainty of phase shift	Degrees [°]	x,xx

8.5. The Mode of Presentation of the Results

In the subsequently presented tables results with $|d_l(f)| > U_l(f)$ where $U_l(f) = 2 \cdot u_l(f)$ are marked by a yellow background.

Results which were excluded from the largest consistent subset (non-MoCS results) according to the result of the consistency check, and which therefore did not contribute to the EURAMET average value are (in addition) marked with an asterisk.

8.6. Magnitude of the Complex Sensitivity of the SE

Table 8.6. Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the SE

Frequen-cy	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)
10,0	-0,113	0,506	-0,040	0,127	-0,048	0,506	0,476	0,635	0,241	0,635	0,173	0,634
12,5	-0,185	0,506	-0,041	0,127	-0,195	0,506	0,360	0,649	0,204	0,648	0,143	0,780
16,0	-0,176	0,506	-0,031	0,127	-0,217	0,505	0,269	0,649	0,196	0,648	0,075	0,780
20,0	-0,133	0,506	-0,062	0,127	-0,142	0,506	0,269	0,382	0,254	0,382	0,063	0,648
25,0	-0,107	0,506	-0,071	0,126	-0,172	0,506	0,254	0,382	0,312	0,382	0,074	0,648
31,5	-0,055	0,506	-0,078	0,126	-0,085	0,506	0,235	0,382	0,337	0,382	0,058	0,648
40,0	-0,100	0,506	-0,081	0,126	-0,093	0,506	0,212	0,382	0,350	0,382	0,074	0,648
63,0	-0,055	0,506	-0,086	0,126	-0,101	0,506	0,210	0,382	0,307	0,382	0,069	0,648
80,0	-0,058	0,506	-0,075	0,126	-0,044	0,506	0,173	0,382	0,274	0,382	0,070	0,648
100	-0,058	0,506	-0,078	0,126	-0,104	0,506	0,074	0,382	0,251	0,382	0,125	0,649
125	-0,008	0,506	-0,036	0,126	-0,068	0,506	0,256	0,382	0,307	0,382	0,176	0,649
160	-0,070	0,506	-0,070	0,126	-0,233	0,505	0,146	0,382	0,249	0,382	0,046	0,648
200	-0,051	0,506	-0,059	0,126	-0,150	0,506	0,159	0,381	0,334	0,382	0,037	0,648
250	-0,035	0,506	-0,054	0,127	-0,116	0,506	0,153	0,382	0,320	0,382	0,033	0,648
315	-0,101	0,506	-0,055	0,127	-0,053	0,506	0,152	0,382	0,306	0,382	0,022	0,648
400	-0,087	0,506	-0,060	0,127	-0,068	0,506	0,138	0,382	0,317	0,383	0,008	0,648
500	-0,099	0,506	-0,054	0,127	-0,105	0,506	0,114	0,382	0,270	0,382	0,014	0,648
630	-0,105	0,506	-0,054	0,127	-0,124	0,506	0,112	0,382	0,236	0,382	0,004	0,649
800	-0,108	0,506	-0,051	0,127	-0,080	0,506	0,118	0,382	0,267	0,383	0,026	0,649
1000	-0,073	0,506	-0,036	0,127	-0,049	0,507	0,108	0,382	0,267	0,382	0,012	0,649
1250	-0,110	0,507	-0,038	0,127	-0,067	0,633	0,055	0,649	0,255	0,650	0,020	0,648
1500	-0,058	0,507	-0,026	0,127	-0,058	0,634	0,086	0,649	0,259	0,650	-0,007	0,649
1600	0,071	0,508	-0,044	0,127	-0,040	0,634	0,063	0,649	0,227	0,650	-0,025	0,649
2000	-0,097	0,508	-0,034	0,127	-0,072	0,635	0,052	0,650	0,258	0,651	-0,015	0,650
2500	-0,028	0,510	-0,034	0,127	-0,101	0,637	0,099	0,652	0,286	0,653	0,005	0,651
3000	-0,006	0,511	-0,033	0,128	-0,137	0,638	0,124	0,654	0,346	0,655	0,006	0,654
3150	0,009	0,512	-0,025	0,128	-0,076	0,639	-0,025	0,654	0,297	0,655	-0,016	0,654
3500	0,071	0,513	-0,026	0,128	-0,139	0,640	0,079	0,656	0,232	0,657	0,031	0,656
4000	0,141	0,515	-0,047	0,129	-0,051	0,643	0,138	0,659	0,287	0,660	0,010	0,659
4500	0,169	0,518	-0,027	0,129	-0,046	0,646	0,222	0,662	0,371	0,663	-0,056	0,661
5000	0,265	0,521	-0,037	0,130	-0,075	0,779	0,249	0,665	0,373	0,666	-0,172	0,799
5500	0,167	0,785	-0,086	0,392	-0,077	0,783	0,279	1,335	0,265	1,335	-0,077	1,469
6000	0,293	0,790	-0,084	0,394	-0,079	0,788	0,347	1,343	0,373	1,344	-0,027	1,478
6300	0,244	0,793	-0,087	0,396	-0,118	0,791	0,316	1,350	0,289	1,349	-0,106	1,484
6500	0,207	0,795	-0,072	0,397	-0,050	0,794	0,323	1,353	0,378	1,353	-0,034	1,489
7000	0,273	0,801	-0,127	0,399	-0,009	0,800	0,441	1,363	0,401	1,362	0,037	1,500
7500	0,203	0,809	-0,140	0,672	0,082	0,808	0,490	1,367	0,398	1,366	-0,332	1,501
8000	0,311	0,816	-0,092	0,678	0,138	0,815	0,594	1,379	0,547	1,379	-0,294	1,514
8500	0,024	0,821	0,725	1,100	0,351	0,823	1,206	1,387	0,928	1,384	-0,343	1,516
9000	0,571	0,832	-0,323	0,413	0,140	0,830	-0,029	1,407	0,360	1,411	-0,361	1,550
9500	0,393	0,839	-0,239	0,418	0,274	0,839	0,947	1,433	0,041	1,423	-0,133	1,569
10000	1,223	0,854	-0,344	0,422	0,153	0,848	0,979	1,451	0,055	1,442	-0,421	1,586

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)
10500	-0,420	1,420	0,014	0,712	0,962	1,147	1,571	2,956	0,525	2,934		
11000	0,079	1,442	-0,082	0,720	0,837	1,160	1,581	2,996	0,482	2,973		
11500	0,162	1,463	-0,067	0,730	0,693	1,175	1,713	3,041	0,463	3,014		
12000	0,316	1,485	-0,133	0,740	0,849	1,192	1,833	3,088	0,489	3,059		
12500	0,243	1,808	-0,118	0,751	1,305	1,214	2,060	3,137	0,848	3,111		
13000	0,110	1,833	-0,028	0,763	1,204	1,231	2,249	3,191	0,577	3,155		
13500	0,084	1,857	-0,049	0,773	1,217	1,247	2,219	3,244	0,519	3,208		
14000	-0,177	1,888	0,008	0,787	1,396	1,271	2,389	3,304	0,287	3,259		
14500	-0,479	1,922	0,085	0,804	1,695	1,299	2,798	3,373	0,513	3,325		
15000	-0,516	1,951	0,122	0,816	1,881	1,320	3,235	3,448	0,562	3,391		
15500	-0,561	1,989	0,272	1,665	2,170	1,684	3,512	4,379	0,725	4,304		
16000	-0,504	3,400	-0,025	1,705	3,032	1,735	4,352	4,462	1,298	4,380		
16500	-1,877	3,426	0,508	1,737	2,833	1,760	4,257	4,567	1,832	4,501		
17000	-2,224	3,501	0,543	1,778	4,076*	1,814	5,539*	4,600	2,366	4,512		
17500	-1,267	3,598	0,029	1,812	4,400*	1,856	6,495*	4,752	2,447	4,641		
18000	-1,803	3,688	0,462	1,867	4,512*	1,907	6,822*	4,891	1,847	4,754		
18500	-2,294	3,768	0,433	1,911	5,174*	1,959	5,794*	4,994	1,625	4,879		
19000	-2,426	3,834	0,420	1,945	6,079*	2,002	6,630*	5,155	1,783	5,020		
19500	-2,377	3,974	0,110	2,012	7,185*	2,083	7,637*	5,322	2,557	5,182		
20000	-2,862	4,079	0,291	2,071	7,929*	2,148	9,094*	5,527	2,816	5,353		

(continued) Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the SE

Frequency	CEM		LNE		SASO NMCC		METAS		RISE		CCAUV/ EURAMET	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	r	$u(r)$
Hz	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	Abs.	%
10,0	0,424	0,635	-0,030	0,380	0,163	0,760	0,159	0,291	0,328	0,508	0,9666	0,05
12,5	0,317	0,515	0,114	0,380	0,153	0,780	0,173	0,284	0,201	0,515	0,9666	0,05
16,0	0,230	0,515	0,065	0,380	0,065	0,780	0,149	0,284	0,201	0,515	0,9664	0,05
20,0	0,257	0,516	0,025	0,381	0,063	0,648	0,220	0,245	0,179	0,516	0,9665	0,05
25,0	0,257	0,516	0,035	0,381	0,045	0,648	0,250	0,245	0,141	0,516	0,9665	0,05
31,5	0,241	0,516	0,077	0,382	0,077	0,648	0,266	0,245	0,154	0,516	0,9665	0,05
40,0	0,277	0,516	0,074	0,381	0,055	0,648	0,280	0,245	0,171	0,516	0,9665	0,05
63,0	0,243	0,516	0,049	0,381	0,049	0,648	0,299	0,245	0,156	0,516	0,9665	0,05
80,0	0,118	0,516	0,060	0,381	0,021	0,648	0,288	0,245	0,147	0,516	0,9666	0,05
100	0,298	0,516	0,076	0,382	-0,049	0,648	0,255	0,245	0,144	0,516	0,9662	0,05
125	-0,616	0,512	0,128	0,382	-0,017	0,648	0,304	0,245	0,186	0,516	0,9665	0,05
160	0,191	0,516	0,085	0,382	0,104	0,649	0,250	0,245	0,104	0,516	0,9660	0,05
200	0,211	0,516	-0,021	0,381	0,028	0,648	0,285	0,300	0,047	0,515	0,9661	0,05
250	0,226	0,516	0,023	0,381	0,023	0,648	0,204	0,272	0,168	0,516	0,9662	0,05
315	0,206	0,516	0,032	0,381	0,012	0,648	0,216	0,259	0,167	0,516	0,9662	0,05
400	0,220	0,516	0,018	0,382	0,008	0,648	0,206	0,245	-0,002	0,515	0,9661	0,05
500	0,187	0,516	-0,015	0,382	-0,006	0,648	0,195	0,245	0,062	0,516	0,9660	0,05
630	0,178	0,516	0,014	0,382	-0,005	0,649	0,197	0,245	0,033	0,516	0,9659	0,05
800	0,181	0,517	0,026	0,382	-0,003	0,649	0,187	0,245	0,123	0,516	0,9659	0,05

Frequency	CEM		LNE		SASO NMCC		METAS		RISE		CCAUV/ EURAMET	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	r	$u(r)$
Hz	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	fC/(m/s^2)	Abs.	%
1000	0,147	0,516	0,022	0,382	-0,007	0,649	0,167	0,286	0,109	0,516	0,9659	0,05
1250	0,194	0,516	0,001	0,380	-0,038	0,781	0,189	0,299	0,155	0,516	0,9657	0,05
1500	0,109	0,516	0,032	0,381	-0,036	0,781	0,134	0,299	0,109	0,516	0,9658	0,05
1600	0,188	0,516	0,033	0,381	-0,015	0,782	0,161	0,299	0,149	0,516	0,9659	0,05
2000	0,121	0,517	0,024	0,382	-0,015	0,783	0,187	0,299	0,227	0,517	0,9656	0,05
2500	-0,024	0,517	0,024	0,382	0,015	0,785	0,270	0,341	0,169	0,652	0,9657	0,05
3000	0,209	0,520	0,025	0,383	0,045	0,788	0,116	0,301	0,189	0,655	0,9653	0,05
3150	0,091	0,520	0,023	0,383	0,042	0,788	0,195	0,411	0,235	0,657	0,9652	0,06
3500	0,080	0,521	-0,026	0,384	0,012	0,790	0,125	0,343	0,176	0,657	0,9645	0,06
4000	0,078	0,524	-0,028	0,386	0,117	0,794	0,229	0,331	0,290	0,660	0,9644	0,05
4500	0,079	0,525	-0,056	0,387	0,204	0,798	0,237	0,594	0,272	0,798	0,9641	0,06
5000	0,031	0,527	-0,123	0,800	0,243	0,802	0,280	0,514	0,272	0,802	0,9638	0,06
5500	-0,009	1,054	-0,192	0,771	0,318	1,611	0,297	1,001	0,000	0,914	0,9633	0,13
6000	-0,046	1,060	-0,055	0,776	0,359	1,621	0,180	1,272	-0,046	0,919	0,9632	0,14
6300	-0,058	1,066	-0,106	0,781	0,356	1,629	0,199	0,954	-0,202	0,923	0,9631	0,13
6500	-0,053	1,067	-0,159	0,781	0,342	1,633	0,211	1,098	-0,323	1,206	0,9628	0,14
7000	0,094	1,075	-0,098	1,357	0,614	1,647	0,251	0,933	-0,079	1,216	0,9623	0,13
7500	-0,207	1,070	-0,303	1,358	0,639	1,656	0,167	0,956	-0,467	1,213	0,9618	0,17
8000	-0,227	1,078	0,062	1,373	0,898	1,673	-0,080	1,035	0,696	1,234	0,9616	0,17
8500	0,157	1,079	-0,228	1,371	1,409	1,684	-0,840	1,025	1,062	1,679	0,9628	0,19
9000	-0,121	1,112	-1,083	1,396	0,322	1,704	1,271	1,049	0,831	1,710	0,9618	0,14
9500	-0,085	1,124	-0,661	1,416	0,886	1,729	0,947	1,042	0,213	1,721	0,9608	0,14
10000	-0,258	1,137	-0,833	1,432	0,817	1,750	0,599	1,160	-0,373	1,735	0,9595	0,14
10500	0,119	2,167			1,338	2,952	0,907	2,471			0,9594	0,23
11000	0,004	2,194			1,402	2,993	0,734	2,532			0,9577	0,23
11500	-0,106	2,223			1,493	3,036	0,547	2,813			0,9575	0,24
12000	-0,057	2,257			1,617	3,083	0,748	2,653			0,9566	0,24
12500	0,073	2,291			1,891	3,133	0,876	2,757			0,9566	0,25
13000	-0,353	2,321			2,026	3,186	0,644	2,847			0,9556	0,24
13500	-0,183	2,363			2,282	3,246	0,732	2,897			0,9518	0,25
14000	-0,058	2,406			2,618	3,309	0,498	3,381			0,9524	0,26
14500	-0,221	2,449			2,812	3,374	0,294	2,907			0,9538	0,26
15000	-0,239	2,497			3,123	3,446	-0,065	3,063			0,9499	0,25
15500	-0,344	3,376			3,602	4,382	0,754	3,217			0,9487	0,37
16000	-0,054	3,422			4,370	4,463	0,890	4,019			0,9553	0,42
16500	-0,448	3,496			3,568	4,548	0,595	4,675			0,9471	0,42
17000	-0,273	3,445			5,239*	4,591	2,415	9,094			0,9487	0,43
17500	-0,180	3,555			5,681*	4,730	1,790	4,176			0,9467	0,42
18000	-0,684	3,647			6,173*	4,873	0,751	3,849			0,9471	0,42
18500	-0,559	3,756			6,762*	5,021	1,074	3,553			0,9446	0,42
19000	-0,825	3,858			7,356*	5,175	1,308	3,388			0,9361	0,40
19500	-0,324	3,979			8,463*	5,345	1,831	3,471			0,9429	0,40
20000	-0,123	4,112			9,277*	5,532	1,446	3,501			0,9400	0,40

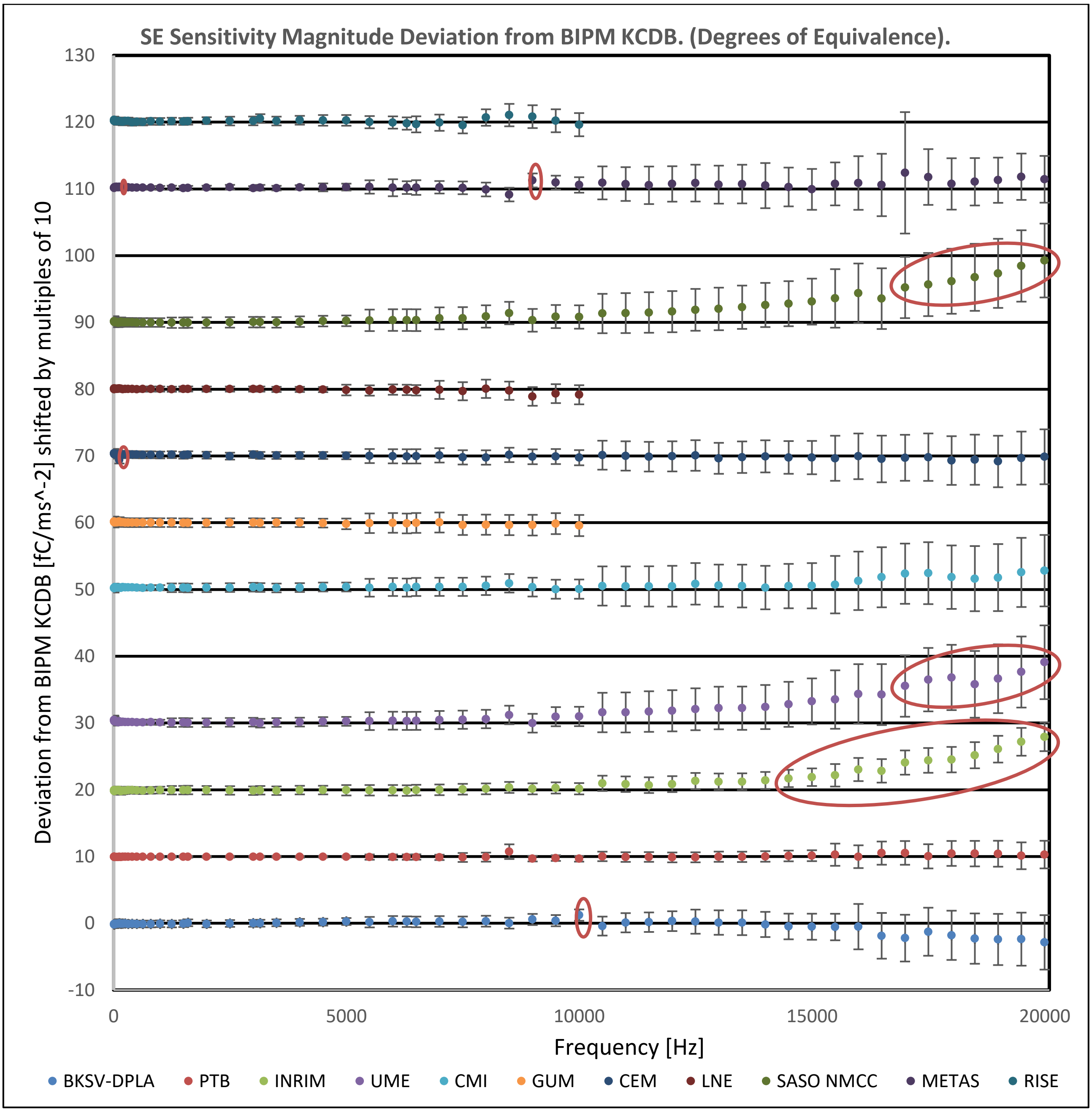

Figure 15. Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the SE sensitivity. The points inside the red ovals are not proving equivalence.

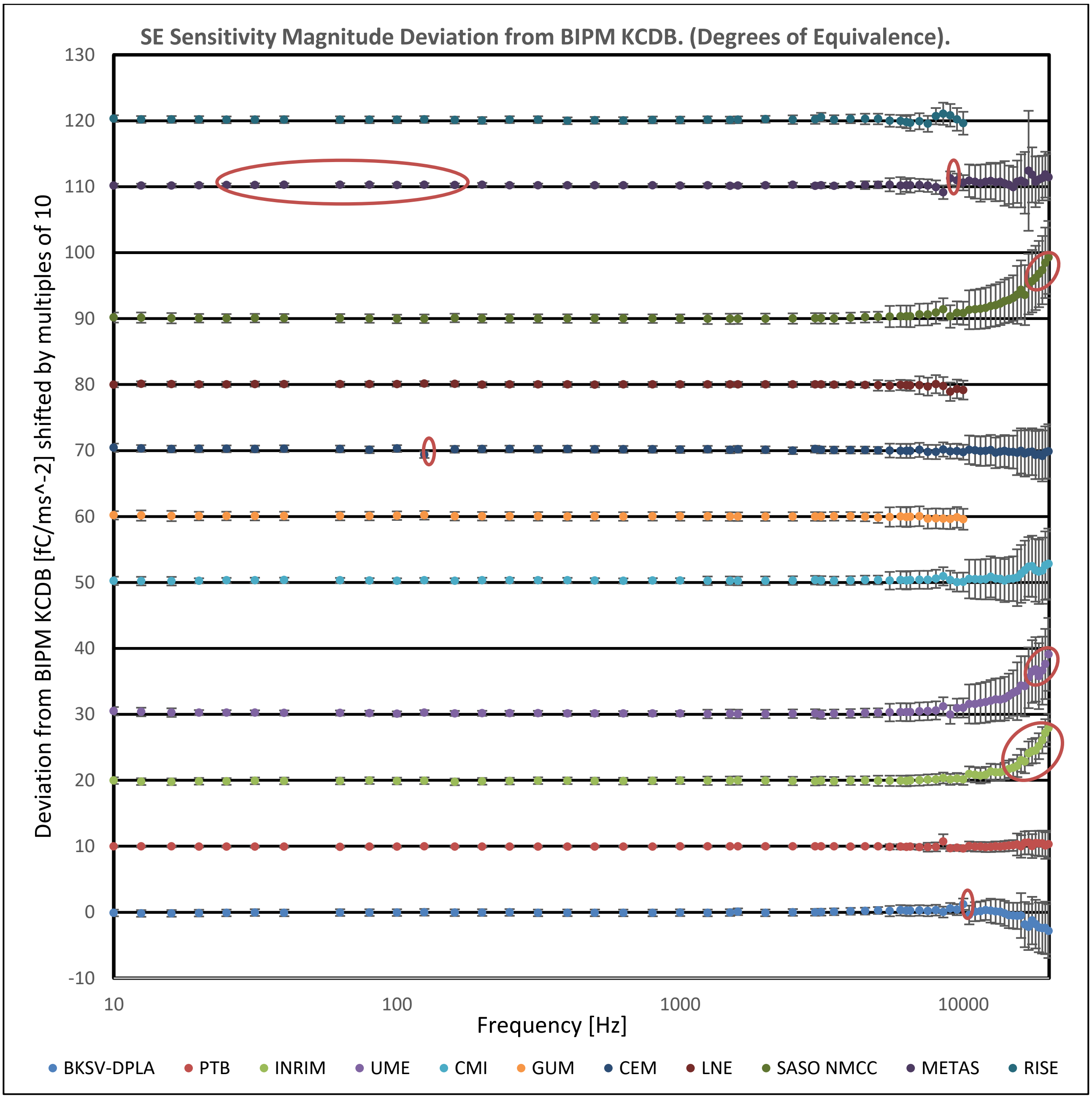

Figure 16. Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the SE sensitivity. The points inside the red ovals are not proving equivalence. Logarithmic frequency scale to show details in the low frequency area.

8.7. Magnitude of the Complex Sensitivity of the BB

Table 8.7. Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the BB

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
[Hz]	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)
10,0	0,068	0,512	0,006	0,128	-0,230	0,511	0,195	0,641	0,351	0,642	0,079	0,768
12,5	-0,016	0,512	0,007	0,128	-0,261	0,511	0,020	0,640	0,240	0,641	0,102	0,769
16,0	-0,049	0,512	0,000	0,128	-0,286	0,511	0,243	0,641	0,176	0,641	-0,032	0,768
20,0	-0,081	0,512	0,006	0,128	-0,234	0,511	0,187	0,385	0,200	0,385	-0,057	0,640
25,0	-0,055	0,512	0,006	0,128	-0,231	0,511	0,138	0,384	0,181	0,385	-0,057	0,640
31,5	-0,037	0,512	-0,012	0,128	-0,297	0,511	0,146	0,385	0,214	0,385	-0,022	0,640
40,0	-0,048	0,512	-0,002	0,128	-0,116	0,512	0,150	0,384	0,216	0,385	0,008	0,640
63,0	-0,010	0,512	-0,003	0,128	-0,190	0,511	0,073	0,384	0,239	0,385	-0,013	0,640
80,0	-0,045	0,512	-0,002	0,128	-0,181	0,511	0,034	0,384	0,177	0,384	-0,034	0,640
100	0,036	0,512	0,002	0,128	-0,227	0,511	0,063	0,384	0,251	0,385	0,075	0,640
125	0,025	0,512	-0,009	0,128	-0,290	0,511	-0,068	0,384	0,293	0,385	0,064	0,640
160	-0,004	0,512	-0,020	0,128	-0,238	0,511	0,098	0,384	0,265	0,385	0,001	0,640
200	0,017	0,512	-0,011	0,128	-0,183	0,511	0,088	0,384	0,225	0,385	0,000	0,640
250	-0,004	0,512	-0,009	0,128	-0,211	0,511	0,084	0,384	0,161	0,384	0,022	0,640
315	0,043	0,512	-0,011	0,128	-0,171	0,511	0,083	0,384	0,196	0,385	0,021	0,640
400	0,060	0,512	-0,010	0,128	-0,206	0,511	0,082	0,384	0,175	0,384	0,021	0,640
500	0,053	0,512	-0,012	0,128	-0,158	0,511	0,084	0,384	0,201	0,385	0,030	0,640
630	0,051	0,512	-0,011	0,128	-0,122	0,512	0,066	0,384	0,194	0,385	0,031	0,640
800	0,096	0,512	-0,013	0,128	-0,056	0,512	0,083	0,384	0,199	0,385	0,082	0,641
1000	0,104	0,513	-0,011	0,128	-0,096	0,512	0,060	0,384	0,233	0,385	0,052	0,641
1250	0,063	0,513	-0,012	0,128	-0,044	0,640	0,005	0,641	0,197	0,642	0,072	0,641
1500	0,047	0,513	-0,009	0,128	-0,186	0,640	0,063	0,641	0,170	0,642	0,054	0,641
1600	0,084	0,513	-0,017	0,128	-0,137	0,640	0,076	0,642	0,179	0,642	0,057	0,641
2000	0,034	0,514	-0,010	0,128	-0,157	0,641	-0,018	0,642	0,201	0,643	0,085	0,642
2500	0,085	0,515	-0,009	0,129	-0,161	0,642	-0,023	0,643	0,216	0,644	0,127	0,643
3000	0,124	0,516	-0,017	0,129	-0,243	0,643	0,007	0,644	0,223	0,645	0,151	0,645
3150	0,171	0,517	-0,017	0,129	-0,198	0,644	-0,202	0,644	0,211	0,646	0,203	0,646
3500	0,251	0,518	-0,021	0,129	-0,246	0,645	-0,081	0,645	0,158	0,647	0,262	0,647
4000	-0,062	0,518	-0,010	0,130	-0,192	0,647	-0,057	0,647	0,246	0,649	0,326	0,649
4500	-0,123	0,520	-0,003	0,130	-0,200	0,650	-0,038	0,651	0,319	0,653	0,365	0,653
5000	0,730	0,525	-0,052	0,131	-0,217	0,782	-0,127	0,652	0,219	0,654	0,200	0,785
5500	0,645	0,790	-0,149	0,393	-0,421	0,784	-0,198	1,309	0,099	1,312	0,428	1,446
6000	0,568	0,793	-0,149	0,395	-0,307	0,788	-0,219	1,314	0,054	1,317	0,450	1,453
6300	0,494	0,797	-0,140	0,397	-0,341	0,792	-0,227	1,321	0,010	1,324	0,502	1,462
6500	0,663	0,800	-0,170	0,397	-0,382	0,793	-0,298	1,323	0,006	1,326	0,609	1,466
7000	0,561	0,804	-0,189	0,400	-0,315	0,799	-0,292	1,332	0,038	1,335	0,620	1,475
7500	0,348	0,810	-0,356	0,403	-0,600	0,804	-0,462	1,342	-0,132	1,345	0,636	1,488
8000	0,520	0,812	-0,035	0,404	-0,477	0,806	-0,138	1,346	-0,079	1,347	1,058	1,494
8500	0,054	0,815	0,034	0,408	-0,818	0,810	-1,178	1,347	-0,145	1,357	0,444	1,499
9000	0,789	0,821	-0,249	0,407	-0,389	0,814	-1,105	1,349	-0,270	1,357	1,182	1,509
9500	0,592	0,830	-0,275	0,412	-0,280	0,824	-0,811	1,369	-0,191	1,375	1,688	1,533
10000	0,619	0,838	-0,185	0,416	-0,552	0,831	-0,187	1,388	-0,225	1,388	1,372	1,544

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
[Hz]	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)
10500	0,553	1,410	-0,175	0,701	0,104	1,125	-0,233	2,805	0,483	2,819		
11000	0,521	1,427	-0,177	0,710	0,035	1,138	-0,351	2,837	0,620	2,857		
11500	0,298	1,442	-0,139	0,719	0,046	1,152	-0,680	2,865	0,667	2,892		
12000	0,196	1,457	-0,117	0,727	-0,116	1,163	-0,927	2,892	0,242	2,916		
12500	0,304	1,772	-0,141	0,736	0,091	1,179	-0,917	2,928	0,406	2,955		
13000	0,272	1,793	-0,141	0,745	-0,032	1,193	-0,952	2,964	0,352	2,990		
13500	0,195	1,817	-0,156	0,755	0,008	1,210	-0,998	3,004	0,437	3,033		
14000	-0,012	1,841	-0,145	0,767	0,021	1,228	-1,017	3,049	0,489	3,079		
14500	-0,225	1,860	-0,096	0,775	0,029	1,242	-1,121	3,081	0,548	3,115		
15000	-0,117	1,886	-0,178	0,785	0,421	1,261	-0,628	3,132	0,950	3,164		
15500	-0,461	1,910	-0,130	1,595	0,316	1,600	-0,763	3,972	0,707	4,009		
16000	-0,684	3,235	-0,260	1,621	0,200	1,626	-0,866	4,039	0,746	4,079		
16500	-1,004	3,291	-0,252	1,653	0,323	1,659	-0,790	4,119	0,847	4,160		
17000	-1,330	3,346	-0,249	1,684	0,265	1,689	-0,746	4,198	0,941	4,240		
17500	-1,712	3,399	-0,181	1,715	0,114	1,718	-0,866	4,269	0,741	4,310		
18000	-2,543	3,453	-0,088	1,751	0,269	1,754	-0,597	4,364	1,053	4,406		
18500	-2,989	3,518	-0,079	1,788	0,334	1,792	-0,338	4,464	1,227	4,503		
19000	-2,420	3,607	-0,235	1,825	0,260	1,830	-0,263	4,562	1,192	4,599		
19500	-1,533	3,716	-0,435	1,869	0,099	1,875	0,097	4,686	1,124	4,712		
20000	-0,947	3,824	-0,554	1,916	0,242	1,924	-0,375	4,795	1,157	4,833		

(continued) Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the BB

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE		CCAUV/ EURAMET	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	r	$u(r)$
[Hz]	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	fC/(m/s²)	Abs.	%
10,0	-0,278	0,641	-0,288	0,383	0,088	0,769	0,006	0,294	0,006	0,513	1,050	0,06
12,5	-0,119	0,640	-0,192	0,383	0,124	0,769	0,007	0,294	0,007	0,512	1,050	0,06
16,0	0,052	0,641	-0,200	0,383	0,094	0,769	0,000	0,294	0,000	0,512	1,049	0,06
20,0	-0,036	0,385	-0,141	0,384	0,133	0,641	0,006	0,256	0,006	0,512	1,049	0,06
25,0	-0,067	0,384	-0,120	0,384	0,124	0,641	0,006	0,256	0,006	0,512	1,049	0,06
31,5	0,272	0,385	-0,022	0,384	0,181	0,641	-0,012	0,256	-0,012	0,512	1,050	0,06
40,0	0,092	0,384	-0,002	0,384	0,202	0,641	-0,002	0,256	-0,002	0,512	1,050	0,06
63,0	0,060	0,384	-0,055	0,384	0,166	0,641	-0,003	0,256	-0,003	0,512	1,050	0,06
80,0	0,092	0,384	-0,013	0,384	0,117	0,640	-0,002	0,256	-0,002	0,512	1,049	0,06
100	-0,072	0,384	0,002	0,384	0,149	0,641	0,002	0,256	0,002	0,512	1,050	0,06
125	0,159	0,384	0,012	0,384	0,129	0,640	-0,009	0,256	-0,009	0,512	1,050	0,06
160	0,410	0,384	0,022	0,384	0,227	0,641	-0,020	0,256	-0,020	0,512	1,049	0,06
200	0,199	0,384	0,063	0,384	0,143	0,640	-0,011	0,256	-0,011	0,512	1,049	0,06
250	0,180	0,384	-0,030	0,384	0,144	0,641	-0,009	0,281	-0,009	0,512	1,049	0,06
315	0,168	0,384	0,021	0,384	0,152	0,641	-0,011	0,269	-0,011	0,512	1,050	0,06
400	0,147	0,384	0,000	0,384	0,143	0,641	-0,010	0,256	-0,010	0,512	1,050	0,06
500	0,177	0,384	0,020	0,384	0,152	0,641	-0,012	0,269	-0,012	0,512	1,049	0,06
630	0,168	0,384	0,000	0,384	0,150	0,641	-0,011	0,256	-0,011	0,513	1,050	0,06
800	0,155	0,384	0,040	0,384	0,162	0,641	-0,013	0,269	-0,013	0,513	1,050	0,06

1000	0,114	0,384	0,020	0,384	0,117	0,641	-0,011	0,295	-0,011	0,513	1,050	0,06
1250	0,166	0,641	0,051	0,385	0,095	0,769	-0,012	0,295	-0,012	0,513	1,049	0,06
1500	0,117	0,641	0,054	0,385	0,095	0,770	-0,009	0,295	-0,009	0,513	1,049	0,06
1600	0,235	0,642	0,067	0,385	0,126	0,770	-0,017	0,308	-0,017	0,513	1,050	0,06
2000	0,148	0,642	0,085	0,385	0,097	0,771	-0,010	0,308	-0,010	0,514	1,049	0,06
2500	0,085	0,643	0,117	0,386	0,133	0,772	-0,009	0,296	-0,009	0,644	1,049	0,06
3000	0,193	0,644	0,120	0,387	0,098	0,774	-0,017	0,309	-0,017	0,645	1,049	0,06
3150	0,151	0,644	0,130	0,387	0,085	0,775	-0,017	0,310	-0,017	0,646	1,050	0,06
3500	0,147	0,645	0,115	0,388	0,020	0,775	-0,021	0,310	-0,021	0,647	1,049	0,06
4000	0,242	0,647	0,211	0,389	0,131	0,778	-0,010	0,337	-0,010	0,649	1,049	0,06
4500	0,186	0,651	0,196	0,391	0,106	0,782	-0,003	0,352	-0,003	0,782	1,051	0,08
5000	0,200	0,652	0,158	0,785	0,045	0,784	-0,052	0,406	-0,052	0,784	1,051	0,08
5500	0,103	1,309	0,061	0,787	0,013	1,573	-0,149	0,958	-0,149	0,917	1,049	0,15
6000	0,219	1,314	0,229	0,791	-0,057	1,579	-0,149	1,014	-0,149	0,919	1,050	0,15
6300	0,270	1,321	0,281	0,796	-0,044	1,588	-0,140	1,060	-0,140	0,928	1,053	0,15
6500	0,209	1,323	0,041	0,796	-0,080	1,591	-0,170	1,075	-0,170	1,194	1,053	0,15
7000	0,515	1,332	0,305	1,338	-0,030	1,601	-0,189	1,201	-0,189	1,200	1,052	0,16
7500	2,271*	1,342	0,267	1,349	-0,133	1,615	-0,356	1,240	-0,356	1,211	1,055	0,17
8000	-0,635	1,346	0,207	1,349	0,323	1,621	-0,035	1,285	-0,035	1,220	1,052	0,16
8500	-0,355	1,347	0,066	1,359	-0,494	1,624	0,034	1,463	0,034	1,636	1,052	0,17
9000	0,566	1,349	-0,270	1,357	-0,473	1,627	-0,249	1,306	-0,249	1,640	1,044	0,19
9500	0,964	1,369	-0,506	1,372	-3,520*	1,610	-0,275	3,270	-0,275	1,667	1,050	0,20
10000	0,246	1,388	-0,805	1,382	4,732*	1,725	-0,185	3,417	-0,185	1,679	1,052	0,18
10500	0,427	2,805			0,637	2,822	-0,175	3,111			1,055	0,27
11000	0,543	2,837			0,433	2,853	-0,177	2,792			1,059	0,27
11500	0,688	2,865			-0,025	2,879	-0,139	2,635			1,061	0,27
12000	0,711	2,892			-0,029	2,910	-0,117	2,514			1,061	0,27
12500	0,923	2,928			0,245	2,951	-0,141	2,501			1,064	0,27
13000	0,968	2,964			0,193	2,987	-0,141	2,518			1,065	0,27
13500	1,244	3,004			0,270	3,029	-0,156	2,568			1,068	0,28
14000	1,462	3,049			0,331	3,076	-0,145	2,634			1,071	0,28
14500	1,316	3,081			0,346	3,111	-0,096	2,647			1,070	0,29
15000	1,977	3,132			0,846	3,162	-0,178	2,675			1,072	0,28
15500	2,038	3,972			0,786	4,011	-0,130	2,712			1,073	0,41
16000	2,147	4,039			0,819	4,081	-0,260	2,773			1,075	0,45
16500	2,447	4,119			1,046	4,165	-0,252	2,828			1,080	0,45
17000	2,781	4,198			1,192	4,246	-0,249	2,879			1,082	0,45
17500	2,806	4,269			1,266	4,323	-0,181	2,940			1,082	0,46
18000	3,204	4,364			1,662	4,421	-0,088	2,987			1,086	0,46
18500	3,660	4,464			2,092	4,525	-0,079	3,051			1,090	0,48
19000	3,913	4,562			2,282	4,626	-0,235	3,115			1,092	0,48
19500	4,080	4,686			2,506	4,747	-0,435	3,185			1,096	0,48
20000	4,123	4,795			2,898	4,877	-0,554	3,263			1,100	0,47

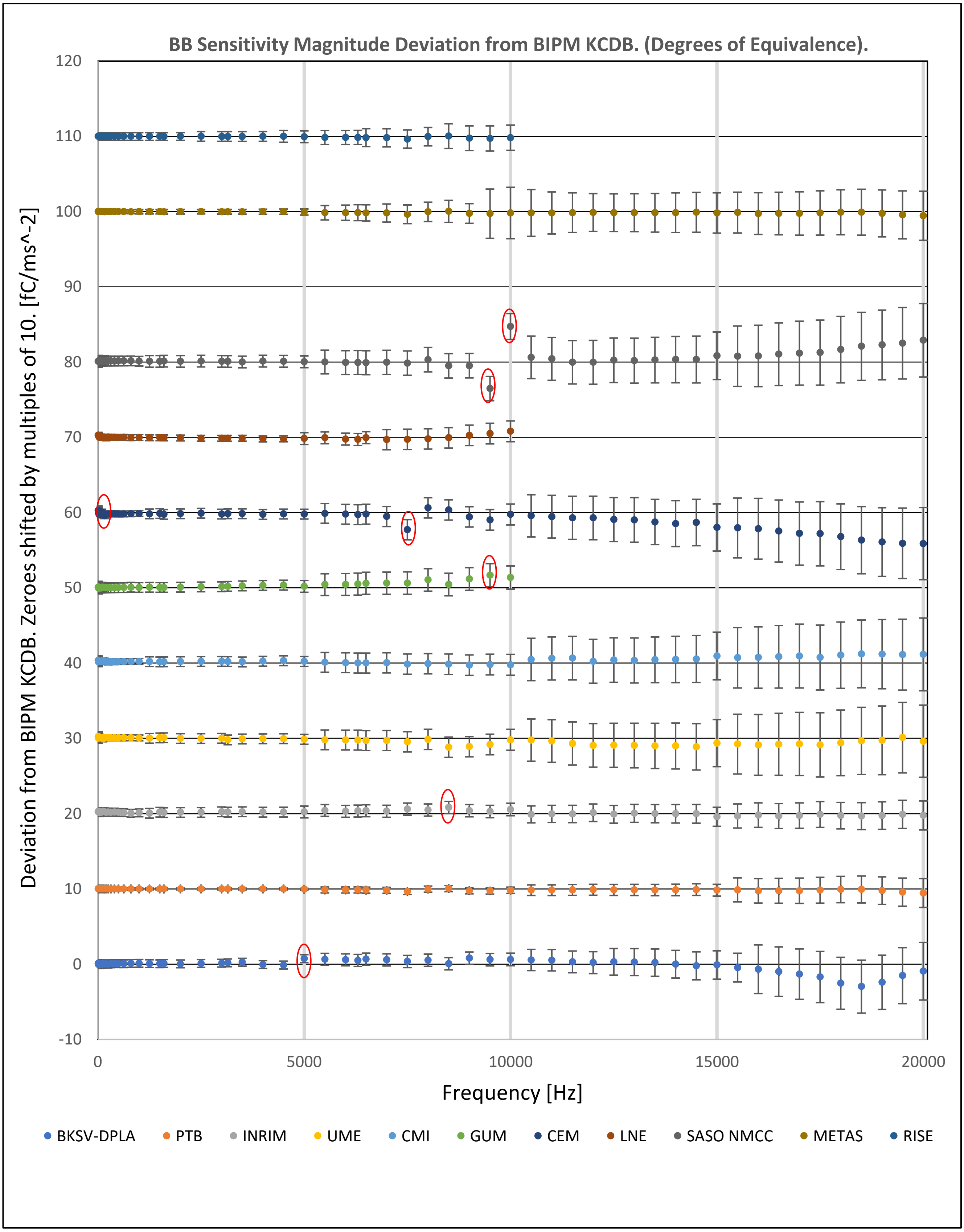

Figure 17 Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the BB sensitivity. The points inside the red ovals are not proving equivalence.

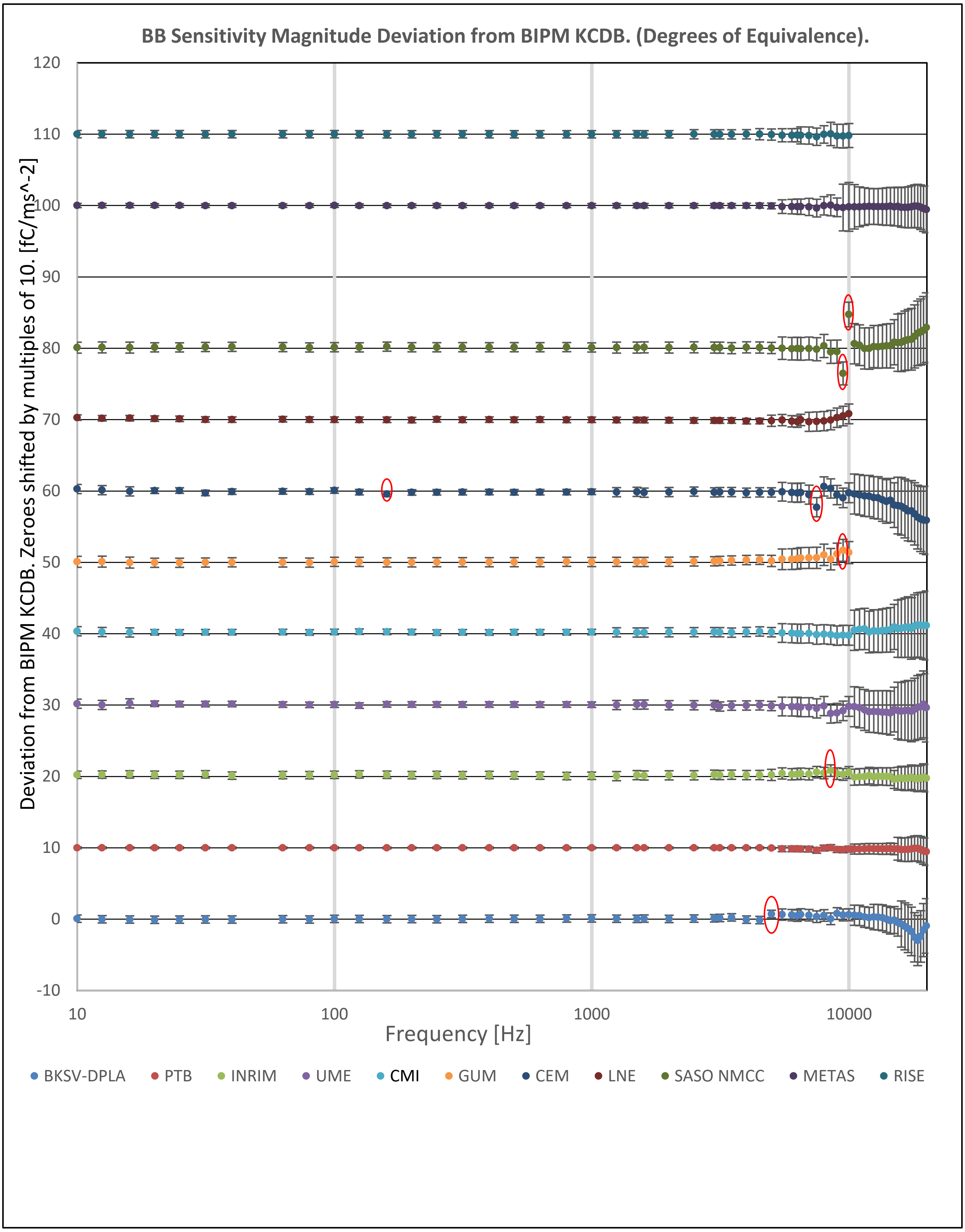

Figure 18. Degrees of equivalence to the CCAUV.V-K5 KCRV for the magnitude of the BB sensitivity. The points inside the red ovals are not proving equivalence. Logarithmic frequency scale to show details in the low frequency area.

8.8. Phase of the Complex Sensitivity of the SE

Table 8.8. Degrees of equivalence to the CCAUV.V-K5 KCRV for the phase shift of the SE

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	°	°	°	°	°	°	°	°	°	°	°	°
10,0	-0,01	0,227	-0,01	0,091			-0,05	0,521	-0,03	0,521	-0,01	0,715
12,5	-0,02	0,227	0,01	0,091			-0,08	0,521	-0,05	0,521	-0,01	0,715
16,0	0,00	0,227	0,00	0,091			-0,04	0,521	-0,07	0,521	-0,02	0,715
20,0	0,02	0,229	-0,01	0,093			-0,02	0,521	0,02	0,521	-0,02	0,618
25,0	0,02	0,229	-0,01	0,093			-0,01	0,521	-0,05	0,521	-0,03	0,618
31,5	0,02	0,229	-0,02	0,093			0,01	0,521	0,02	0,521	-0,03	0,618
40,0	0,00	0,229	0,00	0,093			0,01	0,521	0,02	0,521	-0,04	0,618
63,0	0,00	0,229	0,00	0,093			0,01	0,521	0,00	0,521	-0,05	0,618
80,0	0,02	0,229	-0,01	0,093			0,02	0,521	0,01	0,521	-0,03	0,618
100	0,01	0,229	-0,01	0,093			0,07	0,521	0,00	0,521	-0,03	0,618
125	0,06	0,229	0,03	0,093			0,08	0,521	0,06	0,521	0,04	0,618
160	0,00	0,229	0,00	0,093			0,01	0,521	0,00	0,521	-0,01	0,618
200	0,00	0,228	0,00	0,093			0,01	0,521	0,01	0,521	-0,02	0,618
250	0,00	0,228	0,01	0,093			0,03	0,521	0,01	0,521	0,00	0,618
315	-0,03	0,229	0,01	0,093			0,03	0,521	0,02	0,521	0,01	0,618
400	-0,01	0,229	0,00	0,093			0,02	0,521	0,02	0,521	0,01	0,618
500	-0,01	0,229	0,01	0,093			0,03	0,521	0,01	0,521	0,04	0,618
630	-0,03	0,229	0,02	0,093			0,02	0,521	-0,01	0,521	0,04	0,618
800	-0,02	0,229	0,01	0,093			0,03	0,521	0,01	0,521	0,05	0,618
1000	-0,03	0,225	0,01	0,088			0,04	0,522	0,01	0,522	0,04	0,618
1250	-0,01	0,137	0,01	0,402			0,05	0,547	0,02	0,547	0,06	0,639
1500	0,00	0,137	-0,01	0,402			0,03	0,547	-0,01	0,547	0,04	0,639
1600	0,00	0,137	0,01	0,402			0,04	0,547	0,00	0,547	0,08	0,639
2000	-0,05	0,137	0,03	0,402			0,08	0,547	0,04	0,547	0,11	0,639
2500	-0,03	0,137	0,05	0,402			0,11	0,547	0,04	0,547	0,16	0,639
3000	-0,04	0,137	0,06	0,402			0,14	0,547	0,04	0,547	0,19	0,639
3150	-0,04	0,137	0,05	0,402			0,10	0,547	0,04	0,547	0,19	0,639
3500	-0,04	0,137	0,05	0,402			0,14	0,547	0,04	0,547	0,19	0,639
4000	-0,06	0,134	0,07	0,401			0,19	0,547	0,07	0,547	0,26	0,640
4500	-0,07	0,136	0,09	0,401			0,23	0,547	0,11	0,547	0,29	0,640
5000	-0,06	0,136	0,10	0,401			0,26	0,547	0,10	0,547	0,26	0,830
5500	-0,12	0,306	0,09	0,306			0,27	1,047	0,08	1,047	0,31	1,047
6000	-0,12	0,304	0,08	0,304			0,29	1,048	0,08	1,048	0,35	1,048
6300	-0,18	0,306	0,11	0,306			0,30	1,047	0,10	1,047	0,37	1,047
6500	-0,11	0,306	0,07	0,306			0,34	1,047	0,10	1,047	0,30	1,047
7000	-0,16	0,306	0,10	0,306			0,38	1,047	0,11	1,047	0,32	1,047
7500	-0,22	0,863	0,05	0,227			0,34	1,066	0,05	1,066	0,29	1,066
8000	-0,18	0,863	0,06	0,227			0,41	1,066	0,15	1,066	0,43	1,066
8500	-0,16	0,863	-0,02	0,227			0,61	1,066	0,33	1,066	0,55	1,066
9000	-0,40	0,863	-0,07	0,227			0,00	1,066	-0,07	1,066	0,21	1,066
9500	-0,28	0,863	0,06	0,227			0,45	1,066	0,03	1,066	0,42	1,066
10000	-0,39	0,863	0,08	0,227			0,52	1,066	0,04	1,066	0,48	1,066
10500	-0,36	1,743	0,06	0,486			0,52	2,125	0,02	2,125		

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	°	°	°	°	°	°	°	°	°	°	°	°
11000	-0,36	1,743	0,07	0,486			0,54	2,125	-0,01	2,125		
11500	-0,33	1,743	0,09	0,486			0,62	2,125	0,03	2,125		
12000	-0,37	1,743	0,10	0,486			0,63	2,125	0,02	2,125		
12500	-0,46	1,743	0,06	0,486			0,61	2,125	-0,07	2,125		
13000	-0,33	1,743	0,19	0,486			0,73	2,125	-0,01	2,125		
13500	-0,39	1,743	0,11	0,486			0,71	2,125	-0,18	2,125		
14000	-0,50	1,743	0,15	0,486			0,85	2,125	-0,07	2,125		
14500	-0,42	1,743	0,12	0,486			0,91	2,125	-0,03	2,125		
15000	-0,38	1,743	0,08	0,486			0,96	2,125	0,02	2,125		
15500	-0,36	1,714	0,09	0,429			1,10	3,094	0,13	3,094		
16000	-0,53	2,793	0,04	0,379			1,17	3,102	0,20	3,102		
16500	-0,77	2,793	0,18	0,379			0,96	3,102	-0,04	3,102		
17000	-0,17	2,793	0,08	0,379			1,23	3,102	0,04	3,102		
17500	-0,41	2,793	0,19	0,379			1,08	3,102	0,05	3,102		
18000	-0,52	2,793	0,19	0,379			0,89	3,102	0,05	3,102		
18500	-0,39	2,793	0,15	0,379			0,98	3,102	0,03	3,102		
19000	-0,30	2,793	0,05	0,379			1,28	3,102	0,15	3,102		
19500	-0,32	2,793	0,08	0,379			1,27	3,102	0,04	3,102		
20000	-0,37	2,793	0,10	0,379			1,23	3,102	-0,03	3,102		

(continued) Degrees of equivalence to the CCAUV.V-K5 KCRV for the phase shift of the SE

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
[Hz]	°	°	°	°	°	°	°	°	°	°
10,0	-0,01	0,467	-0,39	2,005	-0,02	0,521	0,05	0,357		
12,5	-0,01	0,467	-0,18	2,005	-0,02	0,521	0,03	0,357		
16,0	-0,04	0,467	-0,23	2,005	-0,02	0,521	0,01	0,357		
20,0	-0,01	0,468	-0,21	2,005	0,01	0,521	0,02	0,324		
25,0	0,00	0,468	-0,18	2,005	0,01	0,521	0,02	0,324		
31,5	0,01	0,468	1,14	2,005	0,02	0,521	0,02	0,324		
40,0	0,00	0,468	-0,09	2,005	0,03	0,521	0,02	0,324		
63,0	-0,02	0,468	0,06	2,005	0,02	0,521	0,01	0,324		
80,0	0,00	0,468	0,13	2,005	0,02	0,521	0,01	0,324		
100	-0,02	0,468	0,05	2,005	0,03	0,521	0,01	0,324		
125	-0,44	0,468	0,09	2,005	0,10	0,521	0,06	0,324		
160	0,00	0,468	0,08	2,005	0,05	0,521	0,01	0,324		
200	-0,02	0,468	0,08	2,005	0,02	0,521	-0,01	0,335		
250	0,00	0,468	0,03	2,005	0,03	0,521	-0,01	0,335		
315	0,00	0,468	0,10	2,005	0,03	0,521	0,01	0,324		
400	-0,02	0,468	0,07	2,005	0,02	0,521	0,00	0,324		
500	-0,02	0,468	0,08	2,005	0,02	0,521	0,00	0,324		
630	0,00	0,468	0,09	2,005	0,01	0,521	-0,01	0,324		
800	0,02	0,468	0,15	2,005	0,02	0,521	0,00	0,324		
1000	0,02	0,466	0,18	2,006	0,01	0,522	0,00	0,422		
1250	0,02	0,951	0,26	2,012	0,03	0,547	0,01	0,378		
1500	0,00	0,951	0,30	2,012	0,01	0,547	-0,01	0,378		
1600	0,02	0,951	0,38	2,012	0,02	0,547	0,00	0,378		
2000	0,04	0,951	0,42	5,005	0,04	0,547	0,08	0,378		
2500	0,07	0,951	0,55	5,005	0,04	0,547	0,02	0,378		

Frequen-cy	CEM		LNE		SASO NMCC		METAS		RISE	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
[Hz]	°	°	°	°	°	°	°	°	°	°
3000	0,09	0,951	0,68	5,005	0,07	0,547	0,04	0,378		
3150	0,09	0,951	0,71	5,005	0,06	0,547	0,05	0,378		
3500	0,08	0,951	0,78	5,005	0,05	0,547	0,05	0,378		
4000	0,11	0,950	0,88	5,005	0,06	0,547	0,06	0,401		
4500	0,15	0,951	1,03	5,005	0,11	0,547	0,08	0,389		
5000	0,15	0,951	1,12	5,005	0,09	0,547	0,01	0,389		
5500	0,06	0,903	1,21	5,010	0,09	1,047	0,04	0,770		
6000	0,16	0,902	1,34	5,010	0,09	1,048	0,02	0,802		
6300	0,19	0,903	1,44	5,010	0,12	1,047	0,04	0,770		
6500	0,16	0,903	1,47	5,010	0,12	1,047	0,01	0,770		
7000	0,25	0,903	1,55	5,010	0,14	1,047	0,00	0,759		
7500	0,15	0,863	1,56	5,014	0,05	1,066	-0,09	0,713		
8000	0,15	0,863	1,81	5,014	-0,02	1,066	-0,17	0,713		
8500	0,34	0,863	2,09	5,014	-0,20	1,066	-0,06	0,713		
9000	-0,06	0,863	1,77	5,014	-0,07	1,066	0,58	0,713		
9500	0,10	0,863	2,14	5,014	0,14	1,066	-0,03	0,713		
10000	0,15	0,863	2,27	5,014	0,13	1,066	-0,04	0,713		
10500	0,15	1,157			0,13	2,125	-0,13	1,743		
11000	0,15	1,157			0,14	2,125	-0,16	1,743		
11500	0,09	1,157			0,20	2,125	-0,21	1,743		
12000	0,10	1,157			0,21	2,125	-0,22	1,743		
12500	0,27	1,157			0,18	2,125	-0,26	1,743		
13000	-0,19	1,157			0,32	2,125	-0,13	1,743		
13500	0,15	1,157			0,27	2,125	-0,30	1,743		
14000	0,15	1,157			0,37	2,125	-0,36	1,743		
14500	0,04	1,157			0,31	2,125	-0,12	1,743		
15000	0,07	1,157			0,32	2,125	-0,05	1,743		
15500	0,13	1,714			0,52	3,094	-0,11	1,714		
16000	0,19	1,690			0,54	3,102	-0,10	1,690		
16500	-0,14	1,690			0,22	3,102	-0,26	1,690		
17000	0,04	1,690			0,38	3,102	-0,28	1,690		
17500	-0,04	1,690			0,36	3,102	-0,51	1,690		
18000	-0,22	1,690			0,36	3,102	-0,29	1,690		
18500	-0,10	1,690			0,44	3,102	-0,34	1,690		
19000	0,04	1,690			0,49	3,102	-0,12	1,690		
19500	0,06	1,690			0,46	3,102	-0,21	1,690		
20000	-0,04	1,690			0,41	3,102	-0,20	1,690		

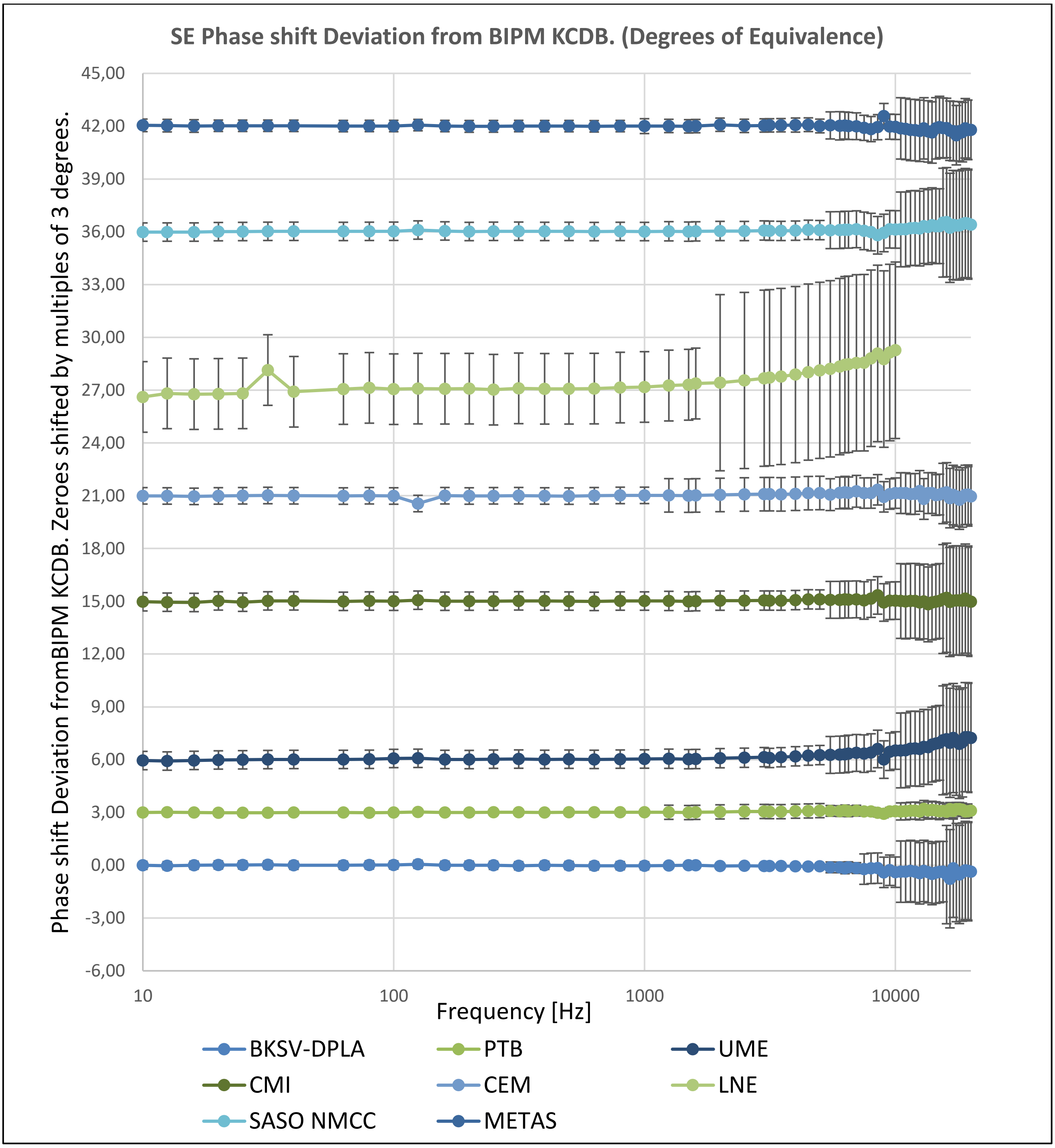

Figure 19. SE Phase shift Deviation from BIPM KCDB. (Degrees of Equivalence). All included.

8.9. Phase of the Complex Sensitivity of the BB

Table 8.9. Degrees of equivalence to the CCAUV.V-K5 KCRV for the phase shift of the BB

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	°	°	°	°	°	°	°	°	°	°	°	°
10,0	0,03	0,227	0,01	0,091			0,05	0,521	0,03	0,521	0,03	0,715
12,5	-0,01	0,227	0,01	0,091			0,08	0,521	-0,02	0,521	0,00	0,715
16,0	0,02	0,227	-0,03	0,091			0,08	0,521	0,03	0,521	-0,01	0,715
20,0	0,01	0,229	-0,01	0,093			0,03	0,521	0,01	0,521	-0,03	0,618
25,0	0,01	0,229	-0,02	0,093			0,03	0,521	0,01	0,521	-0,03	0,618
31,5	0,02	0,229	-0,02	0,093			0,04	0,521	0,01	0,521	-0,02	0,618
40,0	0,01	0,229	-0,01	0,093			0,03	0,521	0,01	0,521	-0,03	0,618
63,0	0,01	0,229	-0,02	0,093			0,01	0,521	0,00	0,521	-0,04	0,618
80,0	0,02	0,229	-0,03	0,093			0,04	0,521	0,01	0,521	-0,04	0,618
100	-0,01	0,229	-0,01	0,093			0,02	0,521	-0,02	0,521	-0,05	0,618
125	0,00	0,229	0,00	0,093			0,07	0,521	-0,02	0,521	-0,03	0,618
160	-0,01	0,229	-0,01	0,093			0,01	0,521	-0,02	0,521	-0,05	0,618
200	0,01	0,229	0,00	0,093			0,04	0,521	-0,01	0,521	-0,01	0,618
250	0,00	0,228	-0,01	0,093			0,03	0,521	-0,02	0,521	-0,01	0,618
315	0,01	0,229	-0,01	0,093			0,02	0,521	-0,03	0,521	0,00	0,618
400	-0,01	0,229	-0,01	0,093			0,02	0,521	-0,03	0,521	0,00	0,618
500	0,00	0,229	0,00	0,093			0,03	0,521	-0,03	0,521	0,04	0,618
630	-0,03	0,229	0,01	0,093			0,02	0,521	-0,04	0,521	0,04	0,618
800	-0,02	0,229	0,00	0,093			0,04	0,521	-0,01	0,521	0,03	0,618
1000	-0,03	0,225	0,01	0,088			0,05	0,522	-0,02	0,522	0,05	0,618
1250	-0,03	0,138	0,02	0,403			0,08	0,546	0,03	0,546	0,09	0,639
1500	-0,03	0,138	0,02	0,403			0,08	0,546	0,03	0,546	0,09	0,639
1600	-0,03	0,138	0,02	0,403			0,06	0,546	0,03	0,546	0,10	0,639
2000	-0,04	0,138	0,03	0,403			0,10	0,546	0,03	0,546	0,13	0,639
2500	-0,05	0,138	0,06	0,403			0,16	0,546	0,06	0,546	0,19	0,639
3000	-0,05	0,138	0,06	0,403			0,17	0,546	0,06	0,546	0,22	0,639
3150	-0,05	0,138	0,07	0,403			0,25	0,546	0,05	0,546	0,25	0,639
3500	-0,11	0,138	0,14	0,403			0,25	0,546	0,13	0,546	0,29	0,639
4000	-0,08	0,137	0,09	0,402			0,22	0,547	0,10	0,547	0,30	0,639
4500	-0,03	0,137	0,04	0,402			0,17	0,547	0,04	0,547	0,27	0,639
5000	0,00	0,137	0,05	0,402			0,18	0,547	0,01	0,547	0,23	0,830
5500	-0,13	0,306	0,07	0,306			0,20	1,047	0,05	1,047	0,33	1,047
6000	-0,14	0,306	0,08	0,306			0,21	1,047	0,04	1,047	0,39	1,047
6300	-0,14	0,306	0,08	0,306			0,18	1,047	0,03	1,047	0,41	1,047
6500	-0,13	0,306	0,06	0,306			0,22	1,047	0,04	1,047	0,38	1,047
7000	-0,21	0,304	0,10	0,304			0,20	1,048	0,03	1,048	0,49	1,048
7500	-0,18	0,859	0,13	0,219			0,17	1,068	0,07	1,068	0,56	1,068
8000	-0,28	0,852	0,01	0,205			-0,07	1,071	-0,06	1,071	0,35	1,071
8500	-0,25	0,849	-0,09	0,198			-0,05	1,073	-0,41	1,073	0,33	1,073
9000	-0,68	0,844	-0,15	0,188			0,00	1,075	-0,35	1,075	0,43	1,075
9500	-0,29	0,846	0,17	0,191			0,33	1,074	0,02	1,074	0,77	1,074
10000	-0,67	0,861	0,15	0,223			0,70	1,067	0,03	1,067	0,61	1,067
10500	-0,32	1,743	0,13	0,486			0,32	2,125	-0,05	2,125		
11000	-0,48	1,743	0,15	0,486			0,22	2,125	-0,07	2,125		
11500	-0,44	1,743	0,13	0,486			0,19	2,125	-0,15	2,125		
12000	-0,42	1,743	0,13	0,486			0,13	2,125	-0,07	2,125		

Frequency	BKSV-DPLA		PTB		INRIM		UME		CMI		GUM	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	°	°	°	°	°	°	°	°	°	°	°	°
12500	-0,40	1,743	0,11	0,486			0,22	2,125	-0,05	2,125		
13000	-0,41	1,743	0,13	0,486			0,16	2,125	-0,07	2,125		
13500	-0,44	1,743	0,11	0,486			0,16	2,125	-0,06	2,125		
14000	-0,50	1,743	0,12	0,486			0,13	2,125	-0,06	2,125		
14500	-0,47	1,743	0,12	0,486			0,15	2,125	-0,08	2,125		
15000	-0,49	1,743	0,13	0,486			0,20	2,125	-0,12	2,125		
15500	-0,55	1,714	0,15	0,429			0,21	3,094	-0,12	3,094		
16000	-0,62	2,793	0,10	0,379			0,14	3,102	-0,19	3,102		
16500	-0,64	2,793	0,11	0,379			0,14	3,102	-0,22	3,102		
17000	-0,70	2,793	0,14	0,379			0,09	3,102	-0,27	3,102		
17500	-0,76	2,793	0,15	0,379			0,14	3,102	-0,27	3,102		
18000	-0,69	2,793	0,14	0,379			0,17	3,102	-0,27	3,102		
18500	-0,38	2,793	0,12	0,379			0,15	3,102	-0,33	3,102		
19000	-0,13	2,793	0,12	0,379			0,15	3,102	-0,34	3,102		
19500	-0,18	2,793	0,13	0,379			0,15	3,102	-0,35	3,102		
20000	-0,57	2,793	0,15	0,379			0,16	3,102	-0,36	3,102		

(continued) Degrees of equivalence to the CCAUV.V-K5 KCRV for the phase shift of the BB

Frequency	CEM		LNE		SASO NMCC		METAS		RISE	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	°	°	°	°	°	°	°	°	°	°
10,0	-0,17	0,467	0,29	2,005	0,01	0,521	0,01	0,357		
12,5	0,01	0,467	0,34	2,005	-0,01	0,521	-0,01	0,357		
16,0	0,05	0,467	0,22	2,005	0,03	0,521	0,03	0,357		
20,0	0,01	0,468	0,11	2,005	0,01	0,521	0,01	0,324		
25,0	0,06	0,468	0,07	2,005	0,02	0,521	0,02	0,324		
31,5	0,06	0,468	1,31	2,005	0,02	0,521	0,03	0,324		
40,0	0,02	0,468	0,06	2,005	0,01	0,521	0,02	0,324		
63,0	0,03	0,468	0,17	2,005	0,00	0,521	0,03	0,324		
80,0	0,05	0,468	0,23	2,005	0,01	0,521	0,04	0,324		
100	0,02	0,468	0,13	2,005	-0,02	0,521	0,01	0,324		
125	0,01	0,468	0,09	2,005	-0,03	0,521	0,01	0,324		
160	0,10	0,468	0,13	2,005	-0,05	0,521	-0,02	0,324		
200	0,02	0,468	0,08	2,005	-0,01	0,521	-0,05	0,324		
250	0,00	0,468	0,06	2,005	-0,03	0,521	0,02	0,335		
315	0,00	0,468	0,10	2,005	-0,03	0,521	0,02	0,324		
400	-0,01	0,468	0,09	2,005	-0,04	0,521	0,04	0,324		
500	0,00	0,468	0,08	2,005	-0,02	0,521	0,02	0,324		
630	0,00	0,468	0,13	2,005	-0,04	0,521	0,00	0,324		
800	0,02	0,468	0,15	2,005	-0,02	0,521	0,02	0,324		
1000	0,04	0,466	0,19	2,006	-0,02	0,522	0,01	0,422		
1250	0,03	0,952	0,28	2,012	0,01	0,546	0,04	0,367		
1500	0,03	0,952	0,33	2,012	0,03	0,546	0,03	0,367		
1600	0,03	0,952	0,35	2,012	0,02	0,546	0,03	0,367		
2000	0,04	0,952	0,41	5,005	0,02	0,546	0,08	0,367		
2500	0,07	0,952	0,55	5,005	0,06	0,546	0,05	0,367		
3000	0,08	0,952	0,64	5,005	0,08	0,546	0,04	0,367		

Frequency	CEM		LNE		SASO NMCC		METAS		RISE	
	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l	d_l	U_l
Hz	°	°	°	°	°	°	°	°	°	°
3150	0,09	0,952	0,69	5,005	0,07	0,546	0,06	0,367		
3500	0,16	0,952	0,82	5,005	0,15	0,546	0,12	0,367		
4000	0,12	0,951	0,87	5,005	0,10	0,547	0,09	0,378		
4500	0,08	0,951	0,93	5,005	0,04	0,547	0,02	0,378		
5000	0,09	0,951	1,02	5,005	0,03	0,547	-0,06	0,378		
5500	0,12	0,903	1,09	5,010	0,05	1,047	0,08	0,759		
6000	0,12	0,903	1,21	5,010	0,06	1,047	0,06	0,770		
6300	0,13	0,903	1,23	5,010	0,04	1,047	0,08	0,770		
6500	0,19	0,903	1,31	5,010	0,05	1,047	0,08	0,770		
7000	0,23	0,902	1,52	5,010	0,06	1,048	0,15	0,813		
7500	-0,52	0,859	1,73	5,014	0,05	1,068	0,16	0,802		
8000	0,17	0,852	1,93	5,015	-0,13	1,071	0,06	1,010		
8500	0,43	0,849	1,76	5,015	-0,43	1,073	0,28	1,151		
9000	1,19	0,844	1,97	5,016	-0,64	1,075	0,21	1,481		
9500	-0,65	0,846	2,44	5,015	-0,75	1,074	0,49	1,333		
10000	-0,23	0,861	2,80	5,014	-0,10	1,067	0,27	0,758		
10500	-0,11	1,157			-0,17	2,125	0,02	1,743		
11000	-0,06	1,157			-0,18	2,125	0,00	1,743		
11500	-0,03	1,157			-0,09	2,125	0,00	1,743		
12000	-0,03	1,157			-0,14	2,125	-0,02	1,743		
12500	0,02	1,157			-0,12	2,125	-0,09	1,743		
13000	-0,08	1,157			-0,19	2,125	0,05	1,743		
13500	-0,06	1,157			-0,21	2,125	0,08	1,743		
14000	-0,07	1,157			-0,25	2,125	0,11	1,743		
14500	-0,05	1,157			-0,27	2,125	0,05	1,743		
15000	-0,03	1,157			-0,29	2,125	0,00	1,743		
15500	-0,04	1,714			-0,33	3,094	-0,01	1,714		
16000	-0,10	1,690			-0,38	3,102	-0,05	1,690		
16500	-0,10	1,690			-0,40	3,102	-0,06	1,690		
17000	-0,13	1,690			-0,47	3,102	-0,13	1,690		
17500	-0,10	1,690			-0,45	3,102	-0,16	1,690		
18000	-0,07	1,690			-0,44	3,102	-0,16	1,690		
18500	-0,09	1,690			-0,46	3,102	-0,21	1,690		
19000	-0,18	1,690			-0,46	3,102	-0,23	1,690		
19500	-0,16	1,690			-0,45	3,102	-0,29	1,690		
20000	-0,04	1,690			-0,44	3,102	-0,30	1,690		

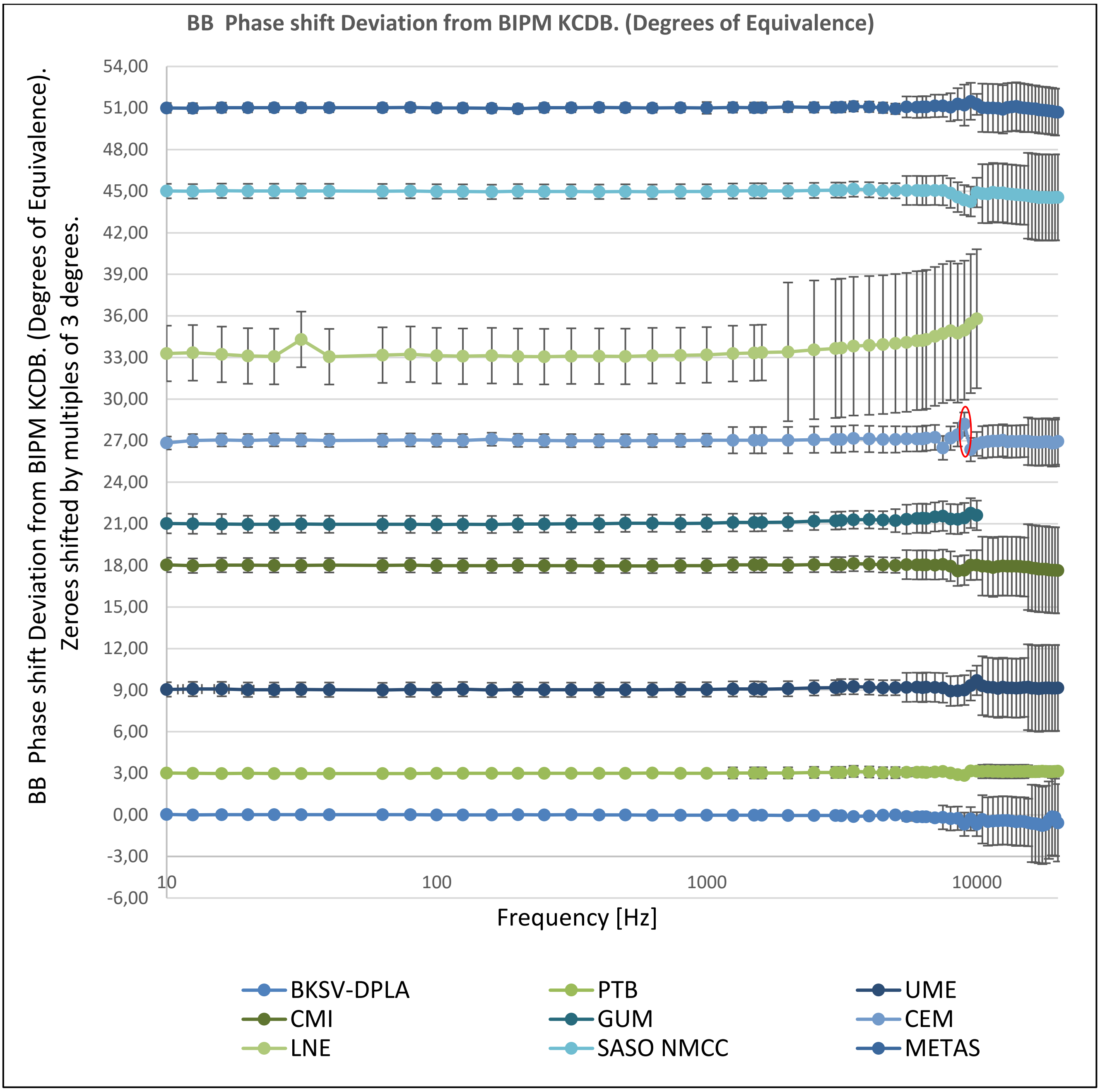

Figure 20. BB Phase shift Deviation from BIPM KCDB. (Degrees of Equivalence). Only one point is outside the DoE bounds.That is indicated by the red oval...

9 Conclusion

In the field of vibration and shock, this fifth regional key comparison (EURAMET.AUV.V-K5) was organized to compare measurement capabilities of regional national metrology laboratories for primary calibration of accelerometers by Laser-interferometry. It followed practically the same procedure as the CCAUV.V-K5 and started shortly after. The CCAUV.V-K5 final report [6] was not available before the end of this comparison. With its scope of calibration of magnitude and phase response in the frequency range from 10 Hz to 20 kHz it challenged the technical boundaries of the field. The artifacts used were the same models as used in the CCAUV.V-K5 comparison, but the individual units were different. To some extend the problems of CCAUV.V-K5 were seen again, but with much reduced influence on the results.

To ensure identical mounting conditions for all participants the adaptor type used in the CCAUV.V-K5 for the single-ended artifact was used again to ensure identical mounting conditions for all participants. This did contribute to improve the level of comparability between results at high frequencies.

It turned out however, as in CCAUV.V-K5, that owing to the geometry of the adapter and the (limited) freedom to position the target points of the laser interferometer measurements individually, the measurement showed two groups of results. This resulted in the exclusion from MoCS of the results from 3 laboratories for the frequency range 17 to 20 kHz because this was the only way a consistent dataset could be obtained.
The explanation is probably simple. Examining the somewhat limited information given about the position of the points and the actual numbers used it turns out that the 3 laboratories had all chosen to use 4 equally spaced points on a circle. This gives a rather large diameter of the circle and two of the points will be at the “ears” of the adaptor. Recent modelling of the adaptor shows rather large deformations of the “ears” at the highest frequencies. Therefore, the discrepancies can not be considered to be exclusively due to the capabilities of the laboratories, because there is a possible influence from the lack of stringent definition of the measuring points combined with the adaptor shape.This should be considered in future high frequency comparison calibrations.
The transducers are known to have a transverse resonance between approximately 7 kHz and 11 kHz. This, combined with structural transverse motion in the combined shaker armature and transducer, is known to lead to an increased spread of the results for different laser positions and deteriorated repeatability in this sub-range of frequencies. The effect is most pronounced on the BB transducer, maybe because of the increased distance from the motions “rocking point”. However, this effect was less pronounced in this comparison than the results in CCAUV.V-K5. Only 3 points were excluded from the MoCS.

The phase shift results exhibited a large amount of consistency between the participants over the whole scope. Only one point for one participant does not lie within the limits, and this is clearly due to the transverse resonance. This demonstrates that phase calibration has reached the state of being a well-established standard service on the level of national metrology institutes. However, it should be noted, that the stated uncertainties at high frequencies are rather high for most laboratories, probably reflecting the limited experience and a conservative approach!

Despite the challenges the Regional Key Comparison EURAMET.AUV.V-K5 can be considered successful for the represented RMOs. It establishes many new consistent degrees of equivalence and will certainly help to improve the quality of vibration and shock metrology on the regional scale.

Draft B may be used to underpin new CMC submissions of participating laboratories.

It should be noted that normal calibrations carried out by the participants use different shakers and adaptors, which are prone to exhibit higher mounting differences. The mounting conditions used at the calibration laboratories and by customers applications might present even larger measurement differences. Therefore, estimated uncertainties at high frequencies shall consider the effect of mounting conditions with care.

The results of this comparison provide the basis for the comparability currently achievable by NMIs under very well controlled conditions.

Bibliography

[1] ISO 16063-1:1998 Methods for the calibration of vibration and shock transducers – Part 1: Basic concepts

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[3] Elster C., Link A., Wöger W., Proposal for linking the results of CIPM and RMO key comparisons, 2003, Metrologia, 40, 189-194.

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[5] M. G. Cox, The evaluation of key comparison data: determining the largest consistent subset, Metrologia 44, 2007, 187, http://iopscience.iop.org/0026-1394/44/3/005

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Appendix A: Technical Protocol

Technical Protocol of the EURAMET Comparison EURAMET.AUV.V-K5

2019-05-04

Task and Purpose of the Comparison

According to the rules set up by the CIPM MRA the consultative committees of the CIPM have the responsibility to establish "degrees of equivalence" (DoE) between the different measurement standards operated by the NMIs. This is done by conducting key comparisons (KC) on different levels of the international metrological infrastructure.

The CCAUV.V-K5 is under progress to form the new basis for DoE. It will be then derived in subsequent RMO key comparisons and therefore be the foundation for the registration of "calibration and measurement capabilities" (CMC) in the framework of the CIPM MRA.

The specific task of this RMO comparison is to measure the complex charge sensitivity of two different accelerometers at specified frequencies with primary means *i.e.* according to [1] and [2].

The reported sensitivities and associated uncertainties are then supposed to be used for the calculation of the DoE between the participating NMI and the key comparison reference value (through a linking procedure based on the results of the linking laboratories).

Pilot Laboratory

Pilot laboratory for this RMO Comparison is:

DPLA, Bruel & Kjaer (BKSV-DPLA)
Jacob Holm Winther
Skodsborgvej 307
2850 NAERUM Denmark

Email: jacobholm.winther@bksv.com

Terms of participation

As the number of participants to the KC CCAUV.V-K5 was limited to four NMIs for EURAMET, all laboratories from EURAMET (and other RMOs) can participate to this RMO comparison.
Following this recommendation, this technical protocol is distributed to the chair of the technical committees of Acoustics, Ultrasound and Vibration (AUV) of GULFMET and AFRIMET and of course EURAMET.

Devices under Test and Measurement Conditions

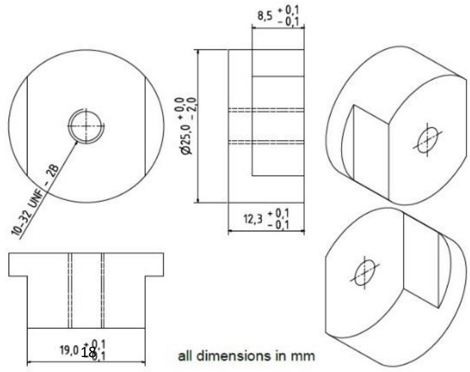
For the calibration task of this KC a set of two piezoelectric accelerometers will be circulated among the participating laboratories. The individual transducers being :

- a BK 8305-001 (SN: 2381734)“single ended” (SE) type, supplied by DPLA

- a BK 8305 (SN: 606545) “back to back” (BB) type supplied by DPLA

Brüel & Kjær 8305-001

Brüel & Kjær 8305 S



A special adapter for the SE-type transducer developed (supplied by DPLA) and used during the CCAUV Key Comparison will also be used during this comparison. The adapter is made of stainless steel1.4404 (AISI 316L) and has a weight (calculated) of 41 g. Its hardened top surface is polished in order to provide mirror-like reflectivity for the laser.

We are aware that it doesn’t correspond to the usual way of calibration of the participants; but this is the only way to reduce or avoid the material dependency to the moving element described in [3] and [4].

The accelerometers are to be calibrated for magnitude and phase of their complex charge sensitivity according to those procedures and conditions implemented by the NMI in conformance with ISO 16063-11 which provide magnitude and phase information of the artefact.

The sensitivities reported shall be for the accelerometers alone, excluding any effects from the charge amplifier. The frequency range of the measurements was agreed to be from 10 Hz to 10 kHz, optionally up to 20 kHz. Specifically, the laboratories are supposed to measure at the following frequencies (all values in Hz).

10, 12.5, 16, 20, 25, 31.5, 40, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800,
1 000, 1 250, 1 500, 1 600, 2 000, 2 500, 3 000, 3 150, 3 500, 4 000, 4 500, 5 000, 5 500,
6 000, 6 300, 6 500, 7 000, 7 500, 8 000, 8 500, 9 000, 9 500, 10 000,

Optionally: 10 500 11 000, 11 500, 12 000, 12 500, 13 000, 13 500, 14 000, 14 500, 15 000,

15 500, 16 000, 16 500, 17 000, 17 500, 18 000, 18 500, 19 000, 19 500, 20 000. Note: this

set does deviate from the standard frequencies of ISO 266, however, it coincides with the frequencies of the CCAUV.V-K5 comparison.

The participating laboratories will provide magnitude (mandatory) and phase (optionally) results at least for the range from 10 Hz to 10 kHz. Laboratories with existing CMCs registered in the KC DB of BIPM in the scope of this comparison shall provide results covering their CMCs.

The charge amplifier (CA) used for the calibration is not provided within the set of the artefacts, it must therefore be provided by the individual participant. By this measure, the capability of the participating laboratory to calibrate charge amplifiers is implicitly verified.

The measurement condition should be kept according to the laboratory's standard conditions for calibration of customer accelerometers for claiming their best measurement capability or CMC where applicable. This presumes that these conditions comply with those defined by the applicable ISO documentary standards [2,3,5], simultaneously.

Specific conditions for the measurements of this comparison are:

- Acceleration amplitudes: preferably 50 m/s² to 100 m/s², a range of 2 m/s² to 200 m/s² is admissible.
- Ambient temperature and accelerometer temperature during the calibration: (23 ± 2) ºC (actual values to be stated within tolerances of ± 0.3 ºC).
  The accelerometer temperature should be measured and reported.
- Relative humidity: max. 75 %RH
- Mounting torque of the accelerometer: (2.0 ± 0.1) N·m

Circulation Type, Schedule and Transportation

The transducers are circulated in a flower type fashion with a measurement period of two weeks provided for each participant. In between three subsequent measurements at any participant’s laboratory, the transducers are measured at the pilot lab in order to monitor the long-term stability. The schedule is planned as follows (the full delivery address for each participant is given in annex):

The cost of transportation to the next participating laboratory shall be covered by the participating laboratory. The accelerometers have to be sent by an international logistic service providing a tracking system. The transportation has to include an insurance covering a total value of 12 000€ in case the set of accelerometers gets damaged or lost during transportation. As an alternative the artefact may be hand carried by a member of the participating laboratory.

Participant	ISO country code	Duration in weeks (measurement + transportation)	Week number
Monitoring	DK	11 + 1	24-35
PTB	DE	2 + 1	36-38
-	-	2 + 1	39-41
INRIM	IT	2 + 1	42-44
Monitoring	DK	1 + 1	45-46
UME	TR	3 + 1	47-50
CMI	CZ	3 + 1	51-02
Monitoring	DK	1 + 1	03-04
GUM	PL	2 + 1	05-07
CEM	ES	2 + 1	08-10
METAS	CH	2 + 1	11-13
Monitoring	DK	1 + 1	14-15
LNE	FR	2 + 1	16-18
RISE	SE	2 + 1	19-21
SASO-NMCC	SA	3 + 1	22-25
Monitoring	DK	1 + 1	26-27

Handling, Measurement and Analysis Instructions

The participating laboratories must observe the following instructions:

- The charge amplifier used for the measurement of the accelerometer's response has to be calibrated with equipment traceable to national measurement standards.
- The motion of the BB accelerometer should be measured with the laser directly on the (polished) reference surface of the transducer without any additional reflector or dummy mass (c.f. picture on page 2).
- The SE accelerometer shall be mounted together with the mounting adapter, that comes attached to it. The combined SE accelerometer with adapter shall be handled as a single mechanical unit for mounting. The mounting adapter must *not* be adjusted, loosened or removed. The mounting or dismounting torque between the adapter and the shaker shall be applied only to the mounting adapter. An appropriate crowfoot wrench with 3/8” square drive adaptation and 18 mm span is provided within the set.
- The motion of the SE accelerometers shall be measured on the top surface of the polished mounting adapter that comes attached to each, close to the accelerometer's housing (c.f. picture on page 2) and at the same distance for all the measurement points.

- The mounting surface of the BB accelerometer or the adapters in case of the SE accelerometers and the moving part of the exciter must be slightly lubricated before mounting.
- The cable between accelerometer and charge amplifier should be taken from the set of DUT delivered to the laboratory. It is a B&K, 10-32 UNF (M) to 10-32 UNF (M), 1,2 m cable.
- In order to reduce the influence of non-rectilinear motion, the measurements (on both BB and SE accelerometers) should be performed for at least three different laser positions which are symmetrically distributed over the respective measurement surface.
- It is advised that the measurement results should be compiled from complete measurement series carried out at different days under nominally the same conditions, except that the BB accelerometer or adapter in case of an SE accelerometer is remounted and the cable reattached. The standard deviation of the subsequent measurements should be included in the report.
- For acceleration signals a(t) of the form

$$a(t)=\hat{a}\cdot\cos(\omega t+\varphi_a) \quad (1)$$

and the respective charge output of signal of the transducer q (t) of the form

$$q(t)=\hat{q}\cdot\cos(\omega t+\varphi_q) \quad (2)$$

-

- The phase is defined according to ISO 16063-1 as

$$\Delta\varphi = \varphi_q-\varphi_a \quad (3)$$

- For the measurement of the phase of the sensitivity the delay or phase characteristics of the interferometer channel(s) has to be taken into account, since the photo-diode-amplifier-system typically has a non-negligible influence on the results. The used delay and the type of interferometer system should be reported.

Communication of the Results to the Pilot Laboratory

Each participating laboratory will submit one printed and signed calibration report (sent by post-mail or email to Jacob Winther) for each accelerometer including the following:

- a description of the calibration systems used and the mounting techniques for the accelerometer,
- a description of the calibration methods used, including information about the demodulation scheme,
- a record of the ambient conditions during measurements,
- the calibration results, including the relative expanded measurement uncertainty, and the applied coverage factor for each value,
- a detailed uncertainty budget for the system covering all components of measurement uncertainty (calculated according to GUM, [6, 7]). Including among others information on the type of uncertainty (A or B), assumed distribution function and repeatability

component. (This information is necessary for the evaluation and linking of subsequent RMO KC).

In addition, each participating laboratory will receive two electronic spreadsheets prepared by the pilot laboratory, where the calibration results have to be filled in following the structure given in the files. The use of the electronic spreadsheets for reporting is mandatory. The consistency between the results in electronic form and the printed and signed calibration report is the responsibility of the participating laboratory. The data submitted in the electronic spreadsheet shall be deemed the official results submitted for the comparison.

The results have to be submitted to the pilot laboratory within six weeks after the measurements. The pilot laboratory will submit it's set of results to the executive secretary of CCAUV in advance to the first measurement of a participating laboratory.

Remarks on the Post Processing

- The results of the participants will be scaled to the level of KC RV of CCAUV.V-K5 once the results of both comparisons will be available. The scaling factor will be determined via the results of the linking laboratories which are taking part in both comparisons.
- The report will include the results of all the participants and their degrees of equivalence respectively to the KC RV of the CCAUV.V-K5.
- In case of damage or loss of any of the artefacts the KC will be evaluated as far in the schedule as possible, all further action concerning continuation will be decided in coordination with the participants.

References

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Appendix B: Measurement Uncertainty Budgets of the Participants

DPLA

Uncertainty budget for magnitude

i	Quantity	Description	Unc. Contribution	Relative expanded uncertainty or bounds of estimated error components [%]	Probability distribution model	Factor x_i	f	160	10 Hz to 20 Hz	> 20 Hz to 2 kHz	> 2 kHz to 4 kHz	> 4 kHz to 5 kHz	> 5 kHz to 10 kHz	> 10 kHz to 12 kHz	> 12 kHz to 15,5 kHz	> 15,5 kHz to 20 kHz
		Budget of Uncertainties **Quadrature system with WQ-2914-–**														
	Notes:															
	All values except the last line are 1sigma values															
	Budget of uncertainty for a piezoelectric accelerometer at 50-100 m/s(^2) at the higher frequencies.															
	Temperature influence on accelerometer not included.															
								Relative contribution $u_{rel,i}(y)$ %	%	%						
1	$u(\hat{u}_V)$	Output voltage Measurement	$u_1(S)$	0,124	Normal (k = 2)	0,5		0,062	0,062	0,062	0,062	0,062	0,062	0,062	0,062	0,062
2	$u(\hat{u}_F)$	Voltage filtering effect on accelerometer output amplitude measurement (frequency band limitati	$u_2(S)$	0,010	Rectangular	0,577		0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006
3	$u(\hat{u}_D)$	Effect of voltage disturbance on accelerometer output voltage measurement (e.g. hum and nois	$u_3(S)$	0,010	Rectangular	0,577		0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006
4	$u(\hat{u}_T)$	Effect of transverse, rocking and bending acceleration on accelerometer output voltage measur	$u_4(S)$	0,100	Special	0,2357		0,024	0,024	0,024	0,024	0,047	0,071	0,118	0,118	0,118
4a	$u(S_Q)$	Calibration factor for Reference charge amplifier	$u_{4a}(S)$	0,176	Normal (k = 2)	0,5		0,088	0,089	0,088	0,088	0,088	0,088	0,088	0,088	0,088
5	$u(\hat{\varphi}_{M,Q})$	Effect of interferometer quadrature output signal disturbance on phase amplitude measurement	$u_5(S)$	0,050	Rectangular	0,577		0,029	0,029	0,029	0,058	0,058	0,058	0,058	0,058	0,058
6	$u(\hat{\varphi}_{M,F})$	Interferometer signal filtering effect on phase amplitude measurement (frequency band limitation	$u_6(S)$	**Included in 5**												
7	$u(\hat{\varphi}_{M,VD})$	Effect of voltage disturbance on phase amplitude measurement (e.g. random noise in the photo	$u_7(S)$	**Included in 5**												
8	$u(\hat{\varphi}_{M,MD})$	Effect of motion disturbance on phase amplitude measurement (e.g. drift; relative motion betwe	$u_8(S)$	0,100	Rectangular	0,236		0,024	0,024	0,024	0,025	0,037	0,059	0,047	0,071	0,094
9	$u(\hat{\varphi}_{M,PD})$	Effect of phase disturbance on phase amplitude measurement (e.g. phase noise of the interferor	$u_9(S)$	**Included in 5**												
10	$u(\hat{\varphi}_{M,RE})$	Residual interferometric effects on phase amplitude measurement (interferometer function)	$u_{10}(S)$	**Included in 5**												
11	$u(f_{FG})$	Vibration frequency measurement (frequency generator and indicator)	$u_{11}(S)$	0,0025	Rectangular	1,1547		0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
12	$u(S_{RE})$	Residual effects on sensitivity measurement (e.g. random effect in repeat measurements; experi	$u_{12}(S)$	0,089	Rectangular	0,577		0,047	0,052	0,052	0,074	0,074	0,124	0,236	0,349	0,579
	$u_{rel}(S_2)$	**Uncertainty for accelerometer sensitivity S_2**		**Standard uncertainty (k = 1)**				**0,147**	**0,150**	**0,149**	**0,171**	**0,188**	**0,248**	**0,338**	**0,459**	**0,698**
		Uncertainty for accelerometer sensitivity S_2		**95% conf.level uncertainty (k = 2)**				**0,294**	**0,300**	**0,299**	**0,341**	**0,375**	**0,495**	**0,675**	**0,919**	**1,396**

Uncertainty budget for phase

Budget of Uncertainties — **Quadrature system with air-bearing shaker**

Phase

Notes:

All values are 1sigma values
Budget of uncertainty for a piezoelectric accelerometer at 30-100 m/s(^2) at the higher frequencies.
Temperature influence on accelerometer not included.

Charge

I	Quantity Numbering following ISO 16063-11 Table A.4 φ_s	Description	Unc. Contribution	Relative expanded uncertainty or bounds of estimated error components [degrees]	Probability distribution model	Factor x_i
1	$u(\varphi_V, V)$	Accelerometer output phase measurement (waveform recorder, e.g. ADC resolution)	u_1 (S)	0,200	Rectangular	0,577
2	$u(\varphi_V, F)$	Voltage filtering effect on accelerometer output phase measurement (frequency band limitation)	u_2 (S)	**Included in 1**	Rectangular	0,577
3	$u(\varphi_V, D)$	Effect of voltage disturbance on accelerometer output voltage phase measurement (e.g. hum or	u_3 (S)	0,010	Rectangular	0,577
4	$u(\varphi_V, T)$	Effect of transverse, rocking and bending acceleration on accelerometer output voltage phase m	u_4 (S)	0,060	Special	0,2357
4a	$u(\varphi_V, Q)$	Calibration factor for Reference charge amplifier phase response	u_{4a} (S)	0,020	Rectangular	0,577
5	$u(\varphi_D, [illegible])$	Effect of interferometer quadrature output signal disturbance on displacement phase amplitude	u_5 (S)	0,010	Rectangular	0,577
6	$u(\varphi_D, [illegible])$	Interferometer signal filtering effect on displacement phase amplitude measurement (frequency b	u_6 (S)	**Included in 5**		
7	$u(\varphi_D, VD)$	Effect of voltage disturbance on displacement phase amplitude measurement (e.g. random nois	u_7 (S)	**Included in 5**		
8	$u(\varphi_D, MD)$	Effect of motion disturbance on displacement phase amplitude measurement (e.g. drift; relative	u_8 (S)	0,057	Rectangular	0,577
9	$u(\varphi_D, PD)$	Effect of phase disturbance on displacement phase amplitude measurement (e.g. phase noise o	u_9 (S)	**Included in 5**		
10	$u(\varphi_D, RE)$	Residual interferometric effects on displacement phase amplitude measurement (interferometer	u_{10} (S)	0,010	Rectangular	0,577
11	$u(\Delta\varphi, RE)$	Residual effects on phase shift measurement (e.g. random effect in repeat measurements; exper	u_{12} (S)	0,050	Rectangular	0,577
	$u(\Delta\varphi)$	**Uncertainty for accelerometer sensitivity** $\Delta\varphi$		**Standard uncertainty (k = 1)**		
		Uncertainty for accelerometer sensitivity $\Delta\varphi$		**95% conf.level uncertainty (k = 2)**		

I	f: 160 Relative contribution u rel.U (y) [degrees]	> 10 Hz to 20 Hz [degrees]	> 20 Hz to 40 Hz [degrees]	> 40 Hz to 500 Hz [degrees]	> 500 Hz to 1,25 kHz [degrees]	> 1,25 kHz to 2 kHz [degrees]	> 2 kHz to 4 kHz [degrees]	> 4 kHz to 5 kHz [degrees]	> 5 kHz to 6.4 kHz [degrees]	> 6.4 kHz to 7.5 kHz [degrees]	> 7.5 kHz to 10 kHz [degrees]	> 10 kHz to 15.5 [degrees]	> 15.5 kHz to 20 kHz [degrees]
1	0,115	0,115	0,115	0,115	0,115	0,115	0,115	0,115	0,173	0,173	0,404	0,866	1,037
2													
3	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006
4	0,014	0,014	0,014	0,014	0,014	0,014	0,014	0,028	0,028	0,028	0,042	0,071	0,071
4a	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,012	0,014	0,040	0,110	0,110
5	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006	0,006
6													
7													
8	0,033	0,033	0,033	0,033	0,033	0,033	0,033	0,033	0,033	0,033	0,033	0,033	0,033
9													
10	0,006	0,006	0,006	0,006	0,006	0,006	0,023	0,023	0,052	0,052	0,115	0,173	0,231
11	0,029	0,029	0,029	0,029	0,029	0,029	0,029	0,029	0,115	0,115	0,115	0,231	0,231
Standard uncertainty (k = 1)	**0,125**	**0,125**	**0,125**	**0,125**	**0,125**	**0,125**	**0,127**	**0,130**	**0,219**	**0,220**	**0,441**	**0,923**	**1,152**
95% conf.level uncertainty (k = 2)	**0,250**	**0,250**	**0,250**	**0,250**	**0,250**	**0,250**	**0,254**	**0,259**	**0,439**	**0,439**	**0,882**	**1,846**	**2,305**

PTB

Measurement uncertainty for magnitude

DUT	B&K 8305 or 8305-001	+ B&K 2650						
acceleration:	100 m/s²							
Voltage	typic. 1V							
Sample rate	10 MS/s	@ 12 Bit						
					combined frequency ranges			
Disturbing Component	**comment**	**95% value**	**distribution**	**factor**	**500 Hz to 5 kHz**	**to 10 kHz**	**to 15 kHz**	**to 20 kHz**
frequency of SAM	deviation of sample clock from generator clock		rectangular	1,73205081	5,77E-05	5,77E-05	5,77E-05	5,77E-05
Accelerometer Voltage	sampling of NI PXI-5922 or HP3458A	5,00E-04	rectangular	1,73205081	2,89E-04	2,89E-04	2,89E-04	2,89E-04
Velocity amplitude	wave length, optical adjustment, deviation between the two beams	1,16E-05	normal	2	5,80E-06	5,80E-06	5,80E-06	5,80E-06
harmon. Distortion	mainly 1st harmonic		Steiner	1	7,84E-06	7,84E-06	7,84E-06	7,84E-06
Humm on Voltage	typical 1mV	5,00E-07	Steiner	1,00	5,00E-07	5,00E-07	5,00E-07	5,00E-07
Noise on Voltage	MC on influence to SAM duration 20ms, Un=1,0mV		normal	1	3,30E-06	3,30E-06	3,30E-06	3,30E-06
Transverse Motion	S(transv) = 0,7% a(transv) < 4%		u-type	1,41421356	1,98E-04	1,98E-04	1,98E-04	1,98E-04
Base strain sensitivity	S = 0,005m/s² / µ€ € < 0,1 µm/m	0,000005	rectangular	1,73	2,89E-06	2,89E-06	2,89E-06	2,89E-06
mounting	S = 6e-4/Nm; dM = 0,2 Nm	0,00012	rectangular	1,73205081	6,93E-05	6,93E-05	6,93E-05	6,93E-05
Temperature	S=2,5e-4 /K dT = 0,3 K	0,000075	rectangular	1,73	4,33E-05	4,33E-05	4,33E-05	4,33E-05
Magnetic field	S=1/a *(m/s²)/T B < 0,03mT	0,0000003	rectangular	1,73	1,73E-07	1,73E-07	1,73E-07	1,73E-07
Airborne acoustics	S=0,008 m/s² at 154 dB max sound level 88 dB	8,00E-08	rectangular	1,73	4,62E-08	4,62E-08	4,62E-08	4,62E-08
Noise on Interferom.	noise level equiv. of 2 nm after demodulation, Monte Carlo		normal	1	1,10E-04	3,00E-04	6,20E-04	1,10E-03
a-synchronous Measurement	voltage/acceleration/voltage	1,00E-04	rectangular	1,73	5,77E-05	5,77E-05	5,77E-05	5,77E-05
charge ampl. calibration					2,12E-04	2,12E-04	2,12E-04	2,12E-04
resid. influences		1,00E-04	normal	1,41421356	7,07E-05	7,07E-05	7,07E-05	7,07E-05
exp. std. dev					2,30E-04	1,60E-04	4,40E-04	6,60E-04
rel. std. uncertainty	**in %**				**0,0501**	**0,0549**	**0,0874**	**0,1353**
rel. comb. exp. Uncertainty (k=2)	**in %**				**0,1002**	**0,1098**	**0,1748**	**0,2707**
stated rel. comb. exp. Uncertainty	**in %**				**0,1000**	**0,3000**	**0,5000**	**1,0000**

Measurement uncertainty for phase shift

DUT	B&K 8305 or 8305-001	+ B&K 2650					
acceleration:	100 m/s²						
Voltage	typic. 1V						
Sample rate	10 MS/s	@ 12 Bit					
					combined frequency ranges		
Disturbing Component	**comment**	**95% value**	**distribution**	**factor**	**10 Hz to 1 kHz**	**to 10 kHz**	**to 20 kHz**
Channel a-synchronisity	all frequencies	< 10 ns	normal	2	1,80E-03	1,80E-02	3,60E-02
Humm (50 Hz)	Monte Carlo, multiples of 20ms are evaluated	equivalent displacement amp. 4 µm	normal	1	8,00E-03	1,00E-03	1,00E-03
Noise on accelerometer Voltage output	Monte Carlo, SNR=500	< 2mV @ 1V	normal	1	4,00E-04	4,00E-04	4,00E-04
Transverse/Rocking motion	1 % transv. Sensitivity @ 10% transv. Excitation	rel. Phase 0 … 2pi	U-type (by MC)	1	7,00E-04	7,00E-04	7,00E-04
delay of Laser Vibrom. + Mixer + Filter	absolute correction 1,54µs applied	uncert. of correction 60 ns	rectang.	1,73	1,25E-02	1,25E-01	2,49E-01
Calibration Charge Amplifier B&K 2650	including Stability, reproducibility, methode (black box)	<0,02°	normal	2	2,00E-02	2,00E-02	2,00E-02
Noise on heterodyne interferometer channel	noise level equiv. of 2 nm after demodulation, Monte Carlo	< 2nm	normal	1	1,43E-04	1,43E-02	5,73E-02
Motion disturbance	drift, relative motion evaluation as velocity and period by period	estimated < 0,02°	normal	2	1,00E-02	1,00E-02	1,00E-02
exp. Std. deviation		typical < 0,02°	normal	2	1,00E-02	1,50E-02	2,00E-02
std. uncertainty	**in 1°**				**0,029**	**0,130**	**0,260**
exp. Uncertainty (k=2)	**in 1°**				**0,057**	**0,259**	**0,520**
stated exp. Uncertainty	**in 1°**				**0,200**	**0,500**	**1,000**

5. THE CALIBRATION RESULTS WITH THE RELATIVE EXPANDED MEASUREMENT UNCERTAINTIES AND COVERAGE FACTOR

The relative expanded uncertainty of the charge sensitivity at the calibration frequencies and acceleration amplitudes given in Table 1 have been calculated in accordance with ISO 16063-1, by adding the component of the uncertainty budget (standard uncertainties) listed in Table 2 in quadrature.

The uncertainty of the laser interferometer includes wavelength uncertainty (refraction index of air included), cosine error, Abbe's error, and diffraction.

Repeatability and reproducibility include data statistics and random effect in repeated calibrations.

Table 2: Uncertainty budget 0.5 Hz to 1 kHz

Uncertainty	description	Type	distibution	factor	degrees of freedom	Standard uncertainty (%)
u_{ri}	repeatability	A	normal	1	20	0.05
u_{rp}	reproducibility	A	normal	1	20	0.12
u_{mt}	accelerations transverse	B	rectangular	$1/\sqrt{3}$	30	0.1
u_{d}	distorsion	A	normal	1	30	0.06
u_{sc}	Stability conditionator	B	rectangular	$1/\sqrt{3}$	30	0.06
u_{v}	velocity error	A	normal	1	100	0.03
u_{mv}	tension error	A	normal	1	100	0.05
u_{amp}	amplifier noise	A	normal	1	30	0.05
u_{te}	temperature	A	normal	1	50	0.06

$$u_S = \sqrt{u_{ri}^2 + u_{rp}^2 + u_{mt}^2 + u_d^2 + u_{sc}^2 + u_v^2 + u_{mv}^2 + u_{te}^2 + u_{amp}^2}$$

$$u_S = 0.2\ \%$$

The total degrees of freedom are calculated using the Welch-Satterthwaite formula's:

$$\nu = \frac{u_S^4}{\sum_i^7 \frac{u_i^4}{\nu_i}}$$

and are

$$\nu_{eff} = 96$$

Using the *t*-student distribution, a coverage factor, k=2 has been evaluated.

So, the expanded uncertainty, calculated as $U_S = k \cdot u_S$ expressed as the standard uncertainty multiplied by the coverage factor $k = 2$, corresponds to a probability of coverage of about 95%.

$$U_{S\,(95\%)} = 0.4\ \%$$

Table 3: Uncertainty budget 1.25 kHz to 4 kHz

Uncertainty	description	Type	distibution	factor	degrees of freedom	Standard uncertainty (%)
u_{ri}	repeatability	A	normal	1	20	0,05
u_{rp}	reproducibility	A	normal	1	20	0,15
u_{mt}	accelerations transverse	B	rectangular	$1/\sqrt{3}$	30	0,15
u_{d}	distorsion	A	normal	1	30	0,06
u_{sc}	Stability conditionator	B	rectangular	$1/\sqrt{3}$	30	0,06
u_{v}	velocity error	A	normal	1	100	0,1
u_{mv}	tension error	A	normal	1	100	0,05
u_{amp}	amplifier noise	A	normal	1	30	0,05
u_{te}	temperature	A	normal	1	50	0,06

$$u_S = \sqrt{u_{ri}^2 + u_{rp}^2 + u_{mt}^2 + u_d^2 + u_{sc}^2 + u_v^2 + u_{mv}^2 + u_{te}^2 + u_{amp}^2}$$

$$u_S = 0.25\ \%$$

The total degrees of freedom are calculated using the Welch-Satterthwaite formula's:

$$\nu = \frac{u_S^4}{\sum_i^7 \frac{u_i^4}{\nu_i}}$$

and are

$$\nu_{eff} = 107$$

Using the *t*-student distribution, a coverage factor, k=2 has been evaluated.

So, the expanded uncertainty, calculated as $U_S = k \cdot u_S$ expressed as the standard uncertainty multiplied by the coverage factor $k = 2$, corresponds to a probability of coverage of about 95%.

$$U_{S\,(95\%)} = 0.5\ \%$$

Table 4: Uncertainty budget 5 kHz to 10 kHz

Uncertainty	description	Type	distibution	factor	degrees of freedom	Standard uncertainty (%)
u_{ri}	repeatability	A	normal	1	20	0,05
u_{rp}	reproducibility	A	normal	1	20	0,2
u_{mt}	accelerations transverse	B	rectangular	$1/\sqrt{3}$	30	0,15
u_{d}	distorsion	A	normal	1	30	0,06
u_{sc}	Stability conditionator	B	rectangular	$1/\sqrt{3}$	30	0,06
u_{v}	velocity error	A	normal	1	100	0,15
u_{mv}	tension error	A	normal	1	100	0,04
u_{amp}	amplifier noise	A	normal	1	30	0,1
u_{te}	temperature	A	normal	1	50	0,06

$$u_S = \sqrt{u_{ri}^2 + u_{rp}^2 + u_{mt}^2 + u_d^2 + u_{sc}^2 + u_v^2 + u_{mv}^2 + u_{te}^2 + u_{amp}^2}$$

$$u_S = 0.3\ \%$$

The total degrees of freedom are calculated using the Welch-Satterthwaite formula's:

$$\nu = \frac{u_S^4}{\sum_i^7 \frac{u_i^4}{\nu_i}}$$

and are

$$\nu_{eff} = 99$$

Using the *t*-student distribution, a coverage factor, k=2 has been evaluated.

So, the expanded uncertainty, calculated as $U_S = k \cdot u_S$ expressed as the standard uncertainty multiplied by the coverage factor $k = 2$, corresponds to a probability of coverage of about 95%.

$$U_{S\,(95\%)} = 0.6\ \%$$

Table 5: INRIM CMCs

Charge sensitivity (magnitude)	Accelerometer	Comparison, ISO 16063-11	$C/(m/s^2)$	Frequency	0.5 Hz to 1 kHz	0.4	%	2	PT-AUV.21.4-01
Charge sensitivity (magnitude)	Accelerometer	Comparison, ISO 16063-11	$C/(m/s^2)$	Frequency	1.25 kHz to 4 kHz	0.5	%	2	PT-AUV.21.4-01
Charge sensitivity (magnitude)	Accelerometer	Comparison, ISO 16063-11	$C/(m/s^2)$	Frequency	5 kHz to 10 kHz	0.8	%	2	PT-AUV.21.4-01
Voltage sensitivity (magnitude)	Acceleration measuring chain	Comparison, ISO 16063-11	$V/(m/s^2)$	Frequency	5 Hz to 1 kHz	0.4	%	2	PT-AUV.21.4-01
Voltage sensitivity (magnitude)	Acceleration measuring chain	Comparison, ISO 16063-11	$V/(m/s^2)$	Frequency	1.25 kHz to 4 kHz	0.5	%	2	PT-AUV.21.4-01
Voltage sensitivity (magnitude)	Acceleration measuring chain	Comparison, ISO 16063-11	$V/(m/s^2)$	Frequency	5 kHz to 10 kHz	0.8	%	2	PT-AUV.21.4-01

UME

Uncertainty Budged for Magnitude of Complex Sensitivity

i	Source of uncertainty	Standard uncertainty component $u(x_i)$	Probability Distribution	Uncertainty contribution $u_i(y)$, %					
				10 Hz ≤ f < 20	20 Hz ≤ f ≤ 1 kHz	1 kHz < f ≤ 5 kHz	5 kHz < f ≤ 10 kHz	10 kHz < f ≤ 15 kHz	15 kHz < f ≤ 20 kHz
1	Uncertainty of standard v_S	$U(S_S)$	Normal	7.50E-04	7.50E-04	7.50E-04	7,50E-04	7,50E-04	7,50E-04
2	Angular frequency of v	u(w)	Rectangular	1.00E-05	1.00E-05	1.00E-05	1,00E-05	1,00E-05	1,00E-05
3	Voltage U	u(R)	Normal	2.00E-04	2.00E-04	2.00E-04	2,00E-04	5,00E-04	5,00E-04
4	Amplifier gain G	u(G)	Normal	2.00E-04	2.00E-04	2.00E-04	2,00E-04	2,00E-04	2,00E-04
5	Frequency response of G	$u(K_F)$	Normal	5.00E-04	5.00E-04	5.00E-04	8,00E-04	2,50E-03	5,00E-03
6	Transverse motion	$u(K_T)$	Rectangular	8.70E-05	4.30E-04	6.10E-04	2,20E-04	6,50E-04	6,50E-04
7	Harmonics	$u(K_D)$	Rectangular	1.00E-04	1.00E-04	1.00E-04	1,00E-04	1,00E-04	1,00E-04
8	Hum	$u(K_H)$	Rectangular	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
9	Noise	$u(K_N)$	Normal	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
10	Dependence of location	$u(K_{GL})$	Rectangular	1.00E-04	2.00E-04	5.00E-04	5.00E-04	2.00E-03	3.00E-03
11	Sensor mounting	$u(K_{MT})$	Rectangular	2.00E-05	5.00E-04	5.00E-04	5.00E-04	1.00E-03	3.00E-03
12	Cable layout	$u(K_{MC})$	Rectangular	1.00E-03	3.00E-04	2.50E-04	0.00E+00	0.00E+00	0.00E+00
13	Relative motion	$u(K_{REL})$	Rectangular	1.00E-04	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
14	Temperature change	$u(K_{TK})$	Rectangular	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05	1.50E-05
15	Linearity	$u(K_L)$	Rectangular	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
16	Long-term stability of v_S	$u(K_I)$	Rectangular	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05	1.00E-05
17	Influence of magnetic field	$u(K_M)$	Rectangular	1.00E-03	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
18	Residual effects	$u(K_{RES})$	Rectangular	7.00E-04	5.00E-04	1.00E-03	3.74E-03	5.00E-03	6.92E-03
Relative Measurement Uncertainty				3.70E-03	2.64E-03	3.38E-03	7.97E-03	1.23E-02	1.92E-02
Expanded Uncertainty, % (k=2.0)				0.37	0.26	0.34	0.80	1.23	1.92
Declared Expanded Uncertainty, % (k=2.0)				**0.50**	**0.30**	**0.50**	**1.00**	**2.00**	**2.50**

Uncertainty Budged for Phase Shift of Complex Sensitivity

i	Source of uncertainty	Standard uncertainty component $u(x_i)$	Probability Distribution	Uncertainty contribution $u_i(y)$. Degree					
				10 Hz ≤ f < 20	20 Hz ≤ f ≤ 1 kHz	1 kHz < f ≤ 5 kHz	5 kHz < f ≤ 10 kHz	10 kHz < f ≤ 15 kHz	15 kHz < f ≤ 20 kHz
1	Uncertainty of standard $\varphi(v_S)$	$u(\varphi_S)$	Normal	0,050	0,050	0,050	0,050	0,050	0,050
2	Angular frequency of v	$u(\varphi_R)$	Rectangular	0,000	0,000	0,000	0,000	0,000	0,000
3	Voltage U	$u(\varphi_U)$	Normal	0,050	0,050	0,050	0,050	0,050	0,050
4	Amplifier gain G	$u(\varphi_w)$	Normal	0,100	0,100	0,100	0,100	0,100	0,100
5	Frequency response of G	$u(\varphi_G)$	Normal	0,050	0,050	0,050	0,100	0,200	0,200
6	Transverse motion	$u(\varphi_F)$	Rectangular	0,070	0,070	0,140	0,200	0,200	0,200
7	Harmonics	$u(\varphi_T)$	Rectangular	0,000	0,000	0,000	0,000	0,000	0,000
8	Hum	$u(\varphi_D)$	Rectangular	0,010	0,010	0,010	0,010	0,010	0,010
9	Noise	$u(\varphi_H)$	Rectangular	0,010	0,010	0,010	0,010	0,010	0,010
10	Dependence of location	$u(\varphi_N)$	Rectangular	0,010	0,100	0,100	0,150	0,150	0,150
11	Sensor mounting	$u(\varphi_{GL})$	Rectangular	0,000	0,000	0,100	0,200	0,200	0,200
12	Cable layout	$u(\varphi_{MT})$	Rectangular	0,100	0,050	0,000	0,000	0,000	0,000
13	Relative motion	$u(\varphi_{MC})$	Rectangular	0,050	0,050	0,050	0,050	0,050	0,050
14	Temperature change	$u(\varphi_{REL})$	Rectangular	0,010	0,010	0,010	0,010	0,010	0,010
15	Linearity	$u(\varphi_{TK})$	Rectangular	0,010	0,010	0,010	0,010	0,010	0,010
16	Long-term stability of v_S	$u(\varphi_L)$	Rectangular	0,000	0,000	0,050	0,100	0,100	0,100
17	Influence of magnetic fields	$u(\varphi_I)$	Rectangular	0,100	0,000	0,000	0,000	0,000	0,000
18	Residual effects	$u(\varphi_{RES})$	Rectangular	0,050	0,050	0,050	0,214	0,200	0,200
Absolute Measurement Uncertainty, Degree				0,219	0,201	0,255	0,431	0,459	0,459
Expanded Absolute Uncertainty, Degree (k=2.0)				0,438	0,401	0,510	0,863	0,917	0,917
Declared Expanded Uncertainty, Degree (k=2.0)				**0.50**	**0.50**	**0.50**	**1.00**	**2.00**	**3.00**

CMI

Calculation of expanded uncertainty of measurement the magnitude of sensitivity U_{rel} (S) for Method 3 "Sine-approximation method" according to ISO 16063-11:1999			Czech metrology institute			EURAMET AUV.V-K5		
			Frequency [Hz]					
Description - relative uncertainty contribution			10 to <20	20 to 1k	>1k to 5k	>5k to 10k	>10k to 15k	>15k to 10k
Uncertainty on the output signal measurement of the accelerometer			%	%	%	%	%	%
1	$u(\hat{u}_V)$	accelerometer output voltage measurement (waveform recorder; ADC-resolution)	0,1	0,09	0,1	0,25	0,6	0,7
2	$u(\hat{u}_F)$	voltage filtering effect on accelerometer output amplitude measurement (frequency band limitation)	0,01	0,01	0,01	0,02	0,09	0,1
3	$u(\hat{u}_D)$	effect of voltage disturbance on accelerometer outout voltage measurement (hum and noise)	0,01	0,01	0,01	0,03	0,08	0,1
4	$u(\hat{u}_T)$	effect of transverse, rocking and bending acceleration on accelerometer output voltage measurement	0,2	0,1	0,2	0,4	0,7	0,9
Uncertainty on the displacement measurement through the interferometric phase								
5	$u(\varphi_{M,Q})$	effect of interferometer quadrature output signal disturbance on phase amplitude measurement (offsets, voltage amplitude deviation, deviation from 90° nominal angle difference)	0,05	0,05	0,06	0,09	0,25	0,4
6	$u(\varphi_{M,MD})$	effect of motion disturbance on phase amplitude measurement (drift; relative motion between the accelerometer reference surface and the spot sensed by the interferometer)	0,03	0,03	0,04	0,07	0,1	0,15
7	$u(f_{FG})$	vibration frequency measurement (frequency generator and indicator)	0,003	0,003	0,003	0,003	0,003	0,003
8	$u(S_{RE})$	residual effects on sensitivity measurement (e.g. random effect in repeat measurements; experimental standard deviation of arithmetic mean)	0,05	0,05	0,05	0,06	0,09	0,09
Expanded relative uncertainty of measurement the magnitude of sensitivity (k=2) [%]			**0,47**	**0,31**	**0,48**	**0,98**	**1,94**	**2,46**
Reported relative uncertainty of measurement the magnitude of sensitivity (k=2) [%]			**0,50**	**0,30**	**0,50**	**1,00**	**2,00**	**2,50**

Calculation of expanded uncertainty of measurement the phase shift of sensitivity U (Δφ) for Method 3 "Sine-approximation method" according to ISO 16063-11:1999

Czech metrology institute EURAMET AUV.V-K5

	Description - relative uncertainty contribution	Frequency [Hz]					
		10 to <20	20 to 1k	>1k to 5k	>5k to 10k	>10k to 15k	>15k to 10k
		[°]	[°]	[°]	[°]	[°]	[°]
1	accelerometer output phase measurement (waveform recorder; ADC-resolution)	0,2	0,2	0,2	0,25	0,6	0,7
2	effect of voltage disturbance on accelerometer output phase measurement (hum and noise)	0,01	0,01	0,01	0,03	0,08	0,1
3	effect of transverse, rocking and bending acceleration on accelerometer output phase measurement (transverse sensitivity)	0,04	0,04	0,04	0,4	0,7	1,2
4	effect of interferometer quadrature output signal disturbance on displacement phase measurement (offsets, voltage amplitude deviation, deviation from 90° nominal angle difference)	0,01	0,05	0,06	0,09	0,25	0,4
5	effect of motion distubance on displacement phase measurement (drift; relative motion between the accelerometer reference surface and the spot sensed by the interferometer)	0,003	0,003	0,003	0,003	0,003	0,003
6	residual interferometric effects on displacement phase measurement (interferometric function)	0,01	0,01	0,01	0,01	0,01	0,01
7	residual effects on phase shift measurement (random effect in repeat measurements; experimental standard deviation of arithmetic mean)	0,05	0,05	0,05	0,06	0,09	0,09
Expanded relative uncertainty of measurement the phase of sensitivity (k=2)	[°]	**0,42**	**0,43**	**0,44**	**0,97**	**1,93**	**2,90**
Reported relative uncertainty of measurement the phase of sensitivity (k=2)	[°]	**0,5**	**0,5**	**0,5**	**1,0**	**2,0**	**3,0**

10. **Uncertainty budget**

10.1. **Uncertainty budget for sensitivity**

i	Source of uncertainty	Distribution (type of uncertainty)	Uncertainty contribution					
			10 Hz to 16 Hz	20 Hz to < 5 kHz	5 kHz	> 5 kHz to 8 kHz	>8 kHz to < 10 kHz	10 kHz
1	Accelerometer output voltage measurement	normal (B)	0,00045	0,00045	0,00045	0,00045	0,00045	0,00045
2	Frequency of vibration signal	rectangular (B)	0,00001	0,00001	0,00001	0,00001	0,00001	0,00001
3	Vibration velocity	normal (B)	0,00010	0,00010	0,00010	0,00010	0,00010	0,00015
4	Amplifier transfer coefficient (gain)	normal (B)	0,00040	0,00040	0,00040	0,00040	0,00040	0,00040
5	Frequency response	normal (B)	0,00050	0,00050	0,00050	0,00400	0,00400	0,00400
6	Transverse motion	rectangular (B)	0,00010	0,00010	0,00010	0,00100	0,00100	0,00100
7	Harmonics	rectangular (B)	0,00001	0,00001	0,00001	0,00001	0,00001	0,00001
8	Hum	rectangular (B)	0,00010	0,00010	0,00010	0,00010	0,00010	0,00010
9	Noise	normal (B)	0,00001	0,00001	0,00001	0,00001	0,00001	0,00001
10	Base strain	rectangular (B)	0,00001	0,00001	0,00001	0,00001	0,00001	0,00001
11	Geometrical dependence on measurement location	normal (B)	0,00150	0,00150	0,00200	0,00200	0,00200	0,00200
12	Transducer mounting	rectangular (B)	0,00140	0,00140	0,00140	0,00280	0,00280	0,00280
13	Cable mounting	rectangular (B)	0,00200	0,00100	0,00100	0,00100	0,00100	0,00100
14	Relative motion	rectangular (B)	0,00001	0,00001	0,00001	0,00001	0,00001	0,00001
15	Temperature change	rectangular (B)	0,000015	0,000015	0,000015	0,000015	0,000015	0,000015
16	Linearity	rectangular (B)	0,00001	0,00001	0,00001	0,00001	0,00001	0,00001
17	Instability of vibration signal with time	rectangular (B)	0,00001	0,00001	0,00001	0,00001	0,00001	0,00001
18	Magnetic fields	rectangular (B)	0,00050	0,00050	0,00050	0,00050	0,00050	0,00050
19	Residual interferometric effects on measurement	rectangular (B)	0,00050	0,00050	0,00050	0,00050	0,00050	0,00050
20	Standard deviation of arithmetic mean	normal (A)	0,00025	0,00029	0,00017	0,00091	0,00141	0,00059
Total relative measurement uncertainty			0,00307	0,00254	0,00285	0,00562	0,00572	0,00557
Expanded measurement uncertainty ($k = 2$), rounded			0,6 %	0,5 %	0,6 %	1,1 %	1,1 %	1,1 %

10.2 Uncertainty budget for phase

i	Source of uncertainty	Distribution (type of uncertainty)	Uncertainty contribution in °					
			10 Hz	12,5 Hz to 16 Hz	20 Hz to < 5 kHz	5 kHz	>5 kHz to < 10 kHz	10 kHz
1	Accelerometer output voltage measurement	normal (B)	0,1	0,1	0,1	0,1	0,1	0,1
2	Frequency of vibration signal	rectangular (B)	0	0	0	0	0	0
3	Vibration velocity	normal (B)	0,01	0,01	0,01	0,01	0,01	0,01
4	Amplifier transfer coefficient (gain)	normal (B)	0,1	0,1	0,1	0,1	0,1	0,1
5	Frequency response	normal (B)	0,1	0,1	0,1	0,1	0,2	0,2
6	Transverse motion	rectangular (B)	0,1	0,1	0,1	0,1	0,2	0,2
7	Harmonics	rectangular (B)	0	0	0	0	0	0
8	Hum	rectangular (B)	0,01	0,01	0,01	0,01	0,01	0,01
9	Noise	normal (B)	0,01	0,01	0,01	0,01	0,01	0,01
10	Base strain	rectangular (B)	0,01	0,01	0,01	0,01	0,01	0,01
11	Geometrical dependence on measurement location	rectangular (B)	0,1	0,1	0,1	0,25	0,25	0,25
12	Transducer mounting	rectangular (B)	0,1	0,1	0,1	0,1	0,2	0,2
13	Cable mounting	rectangular (B)	0,2	0,2	0,1	0,1	0,1	0,1
14	Relative motion	rectangular (B)	0,1	0,05	0,05	0,05	0,05	0,05
15	Temperature change	rectangular (B)	0,01	0,01	0,01	0,01	0,01	0,01
16	Linearity	rectangular (B)	0,01	0,01	0,01	0,01	0,01	0,01
17	Instability of vibration signal with time	rectangular (B)	0,01	0,01	0,01	0,01	0,01	0,01
18	Magnetic fields	rectangular (B)	0,05	0,05	0,05	0,05	0,05	0,05
19	Residual interferometric effects on measurement	rectangular (B)	0,1	0,1	0,1	0,1	0,1	0,1
20	Standard deviation of arithmetic mean	normal (A)	0,002	0,009	0,040	0,009	0,077	0,014
	Total relative measurement uncertainty		0,35 °	0,34 °	0,29 °	0,37 °	0,48 °	0,48 °
	Expanded measurement uncertainty ($k = 2$), rounded		0,70 °	0,70 °	0,60 °	0,80 °	1,00 °	1,00 °

CEM

Uncertainty Budget

Magnitude

Description	Frequency range (Hz)	Relative expanded uncertainty (%)	Probability distribution	Factor	Uncertainty type	Uncertainty contribution
Laser	0,4 - 20 000	0,26	normal	2	B	0,130
Voltage	0,4 - 20 000	0,06	normal	1	B	0,060
Hum and noise	0,4 - 20 000	0,02	rectangular	1,732	B	0,012
Mounting	0,4 - 20 000	0,1	rectangular	1,732	B	0,058
Transverse motion	0,4 - 20 000	0,12	special	1	B	0,120
Reproducibility and repeatibility	0,4-< 10	0,1	normal	1	B	0,10
	10 - 5 000	0,05				0,05
	>5 000 - 10 000	0,4				0,35
	>10 000 - 15 000	0,5				0,70
	>15 000 - 20 000	1,0				1,00
Temperature response	0,4 - 20 000	0,1	rectangular	1,732	B	0,058
Relative Motion, inestability, geometric location of the laser beam	0,4 - 20 000	0,1	rectangular	1,732	B	0,058
Influence on voltage from magnetic field from exciter	0,4 - 20 000	0,05	rectangular	1,732	B	0,029
Temperature influence on sensor	0,4 - 20 000	0,04	rectangular	1,732	B	0,023
		Expanded uncertainty (0,4 Hz - < 10 Hz)				0,5
		Expanded uncertainty (10 Hz - 5 kHz)				0,4
		Expanded uncertainty (>5 kHz -10 kHz)				0,8
		Expanded uncertainty (>10 kHz -15 kHz)				1,5
		Expanded uncertainty (>15 kHz -20 kHz)				2,0

Phase

Description	Frequency range (Hz)	Expanded uncertainty (1°)	Probability distribution	Factor	Uncertainty type	Uncertainty contribution
Laser	0,4 - 20 000	0,1	normal	2	B	0,05
Voltage	0,4 - 20 000	0,5	normal	2	B	0,25
Hum and noise	0,4 - 20 000	0,02	rectangular	1,732	B	0,012
Mounting	0,4 - 20 000	0,1	rectangular	1,732	B	0,058
Reproducibility and repeatibility	0,4 - 1000	0,05	rectangular	1,732	B	0,03
	>1000 - 10 000	0,5				0,29
	>10 000 - 15 000	1,1				0,64
	>15 000 - 20 000	1,6				0,92
Temperature response	0,4 - 20 000	0,01	rectangular	1,732	B	0,006
Influence on voltage from magnetic field from exciter	0,4 - 20 000	0,0	rectangular	1,7	B	0,012
Relative Motion, inestability, geometric location of the laser beam	0,4 - 1 000	0,05	rectangular	1,732	B	0,03
	>1 000 - 20 000	0,5				0,29
		Expanded uncertainty (0,4 Hz - 1 kHz)				0,5
		Expanded uncertainty (>1 kHz -10 kHz)				1,0
		Expanded uncertainty (>10 kHz -15 kHz)				1,5
		Expanded uncertainty (>15 kHz -20 kHz)				2,0

LNE

Magnitude SE

i		Description	type	Contribution Incertitude	10 Hz to 40 Hz	> 40 Hz to 2 kHz	> 2 kHz to 5 kHz	> 5 kHz to 7 kHz	> 7 kHz to 10 kHz
					%	%	%	%	%
uncertainty on the measurement of the output of the accelerometer signal									
1	u(ûV)	output voltage measurement	B	u1 (S)	0,054	0,052	0,053	0,053	0,053
1a	u(sA)	conditionner gain	B	u1a (SA)	0,060	0,060	0,060	0,060	0,060
2	u(ûF)	voltage filtering effects on the amplitude output	B	u2 (S)	0,006	0,006	0,006	0,006	0,006
3	u(ûD)	voltage perturbation on the measure of the ouput voltage	B	u3 (S)	0,006	0,006	0,006	0,006	0,006
4	u(ûT)	effect of transverse acceleration on the output voltage	B	u4 (S)	0,033	0,033	0,033	0,067	0,133
5	u(STE)	effect of temperature sensitivity of the accelerometer on the output voltage	B	u12 (S)	0,030	0,030	0,030	0,030	0,030
uncertainty on the measurement of the amplitude									
6	u(φ̂M,Q)	effects of the interferometric quadrature output signal disturbance on the amplitude measurement	B	u5 (S)	0,029	0,029	0,029	0,058	0,058
7	u(φ̂M,F)	effect of the interferometric signal filtering on the phase amplitude measurement (limitation of the frequency band)		u6 (S)	included in i6				
8	u(φ̂M,VD)φ̂	effect of voltage disturbance on the amplitude measurement		u7 (S)	included in i6				
9	u(φ̂M,MD)	effect of motion of the vibration disturbance on the amplitude measurement	B	u8 (S)	0,017	0,017	0,017	0,101	0,267
10	u(φ̂M,PD)	residual interferometrics effects on the amplitude measurement		u9 (S)	included in i6				
11	u(φ̂M,RE)	longitudinal and transverse motion of the insulated table of the laser	B	u10 (S)	0,041	0,041	0,041	0,041	0,041
11b	u(φ̂M,LD)	wavelenght of the laser effect	B	u10b (S)	0,001	0,001	0,001	0,001	0,001
12	u(fFG)	vibration frequency measurement	B	u11 (S)	0,002	0,002	0,002	0,002	0,002
13		repeatability on the 3 measurements	A	u13(S)	0,060	0,030	0,025	0,025	0,025
		Relative standard uncertainty on accelerometer magnitude sensitivity (k=1)			**0,14**	**0,13**	**0,12**	**0,23**	**0,44**
		Relative expanded uncertainty on accelerometer magnitude sensitivity (k=2)			**0,30%**			**0,60%**	**1,0%**

Phase SE

i		Description	type	Contribution Incertitude	10 Hz to 40 Hz	> 40 Hz to 2 kHz	> 2 kHz to 5 kHz	> 5 kHz to 7 kHz	> 7 kHz to 10 kHz
i					degrees	degrees	degrees	degrees	degrees
uncertainty on the measurement of the output of the accelerometer signal									
1	$u(\hat{\varphi}_{u,V})$	output phase measurement	B	$u1\ (\Delta\varphi)$	0,50	0,50	1,00	1,00	1,00
1a	$u(sA)$	conditionner gain	B	$u1a\ (\Delta\varphi)$	0,50	0,10	0,10	0,10	0,10
2	$u(\hat{\varphi}_{u,F})$	voltage filtering effects on the output phase	B	$u2\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
3	$u(\hat{\varphi}_{u,D})$	voltage perturbation on the measure of the ouput phase	B	$u3\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
4	$u(\hat{\varphi}_{u,T})$	effect of transverse acceleration on the output voltage	B	$u4\ (\Delta\varphi)$	0,50	0,50	1,00	2,00	2,00
uncertainty on the measurement of the phase									
5	$u(\hat{\varphi}_{S,Q})$	effects of the interferometric quadrature output signal disturbance on the phase measurement	B	$u5\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
6	$u(\hat{\varphi}_{S,F})$	effect of the interferometric signal filtering on the phase phase measurement (limitation of the frequency band)		$u6\ (\Delta\varphi)$			included in i6		
7	$u(\hat{\varphi}_{S,VD})$	effect of voltage disturbance on the phase measurement		$u7\ (\Delta\varphi)$			included in i6		
8	$u(\hat{\varphi}_{S,MD})$	effect of motion of the vibration disturbance on the phase measurement	B	$u8\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
9	$u(\hat{\varphi}_{S,PD})$	residual interferometrics effects on the phase measurement		$u9\ (\Delta\varphi)$			included in i6		
10	$u(\hat{\varphi}_{S,RE})$	longitudinal and transverse motion of the insulated table of the laser	B	$u10\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
11b	$u(\hat{\varphi}_{S,LD})$	wavelenght of the laser effect	B	$u10b\ (\Delta\varphi)$	0,00	0,00	0,00	0,00	0,00
11	$u(fFG)$	vibration frequency measurement	B	$u11\ (\Delta\varphi)$	0,10	0,10	0,10	0,50	0,50
12	$u(R)$	repetability on the 3 measurements	A	$u12(\Delta\varphi)$	0,32	0,10	0,01	0,15	0,30
		Absolute standard uncertainty on accelerometer phase shift (k=1)			**1,0**	**0,9**	**1,5**	**2,4**	**2,4**
		Absolute expanded uncertainty on accelerometer phase shift (k=2)			**2°**			**5°**	

Magnitude BB

i		Description	type	Contribution Incertitude	10 Hz to 40 Hz	> 40 Hz to 2 kHz	> 2 kHz to 5 kHz	> 5 kHz to 7 kHz	> 7 kHz to 10 kHz
i					%	%	%	%	%
		uncertainty on the measurement of the output of the accelerometer signal							
1	$u(\hat{u}V)$	output voltage measurement	B	*u1 (S)*	0,054	0,052	0,053	0,053	0,053
1a	$u(sA)$	conditionner gain	B	*u1a (SA)*	0,060	0,060	0,060	0,060	0,060
2	$u(\hat{u}F)$	voltage filtering effects on the amplitude output	B	*u2 (S)*	0,006	0,006	0,006	0,006	0,006
3	$u(\hat{u}D)$	voltage perturbation on the measure of the ouput voltage	B	*u3 (S)*	0,006	0,006	0,006	0,006	0,006
4	$u(\hat{u}T)$	effect of transverse acceleration on the output voltage	B	*u4 (S)*	0,033	0,033	0,033	0,067	0,133
5	$u(STE)$	effect of temperature sensitivity of the accelerometer on the output voltage	B	*u12 (S)*	0,030	0,030	0,030	0,030	0,030
		uncertainty on the measurement of the amplitude							
6	$u(\hat{\varphi}M,Q)$	effects of the interferometric quadrature output signal disturbance on the amplitude measurement	B	*u5 (S)*	0,029	0,029	0,029	0,058	0,058
7	$u(\hat{\varphi}M,F)$	effect of the interferometric signal filtering on the phase amplitude measurement (limitation of the frequency band)		*u6 (S)*			included in i6		
8	$u(\hat{\varphi}M,VD)\hat{\varphi}$	effect of voltage disturbance on the amplitude measurement		*u7 (S)*			included in i6		
9	$u(\hat{\varphi}M,MD)$	effect of motion of the vibration disturbance on the amplitude measurement	B	*u8 (S)*	0,017	0,017	0,017	0,101	0,267
10	$u(\hat{\varphi}M,PD)$	residual interferometrics effects on the amplitude measurement		*u9 (S)*			included in i6		
11	$u(\hat{\varphi}M,RE)$	longitudinal and transverse motion of the insulated table of the laser	B	*u10 (S)*	0,041	0,041	0,041	0,041	0,041
11b	$u(\hat{\varphi}M,LD)$	wavelenght of the laser effect	B	*u10b (S)*	0,001	0,001	0,001	0,001	0,001
12	$u(fFG)$	vibration frequency measurement	B	*u11 (S)*	0,002	0,002	0,002	0,002	0,002
13		repeatability on the 3 measurements	A	*u13(S)*	0,027	0,028	0,054	0,100	0,100
		Relative standard uncertainty on accelerometer magnitude sensitivity (k=1)			**0,13**	**0,13**	**0,13**	**0,27**	**0,47**
		Relative expanded uncertainty on accelerometer magnitude sensitivity (k=2)				**0,30%**		**0,60%**	**1,0%**

Phase BB

i		Description	type	Contribution Incertitude	10 Hz to 40 Hz	> 40 Hz to 2 kHz	> 2 kHz to 5 kHz	> 5 kHz to 7 kHz	> 7 kHz to 10 kHz
					degrees	degrees	degrees	degrees	degrees
		uncertainty on the measurement of the output of the accelerometer signal							
1	$u(\hat{\varphi}_{u,V})$	output phase measurement	B	$u1\ (\Delta\varphi)$	0,50	0,50	1,00	1,00	1,00
1a	$u(sA)$	conditionner gain	B	$u1a\ (\Delta\varphi)$	0,50	0,10	0,10	0,10	0,10
2	$u(\hat{\varphi}_{u,F})$	voltage filtering effects on the output phase	B	$u2\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
3	$u(\hat{\varphi}_{u,D})$	voltage perturbation on the measure of the ouput phase	B	$u3\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
4	$u(\hat{\varphi}_{u,T})$	effect of transverse acceleration on the output voltage	B	$u4\ (\Delta\varphi)$	0,50	0,50	1,00	2,00	2,00
		uncertainty on the measurement of the phase							
5	$u(\hat{\varphi}_{S,Q})$	effects of the interferometric quadrature output signal disturbance on the phase measurement	B	$u5\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
6	$u(\hat{\varphi}_{S,F})$	effect of the interferometric signal filtering on the phase phase measurement (limitation of the frequency band)		$u6\ (\Delta\varphi)$			included in i6		
7	$u(\hat{\varphi}_{S,VD})$	effect of voltage disturbance on the phase measurement		$u7\ (\Delta\varphi)$			included in i6		
8	$u(\hat{\varphi}_{S,MD})$	effect of motion of the vibration disturbance on the phase measurement	B	$u8\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
9	$u(\hat{\varphi}_{S,PD})$	residual interferometrics effects on the phase measurement		$u9\ (\Delta\varphi)$			included in i6		
10	$u(\hat{\varphi}_{S,RE})$	longitudinal and transverse motion of the insulated table of the laser	B	$u10\ (\Delta\varphi)$	0,10	0,10	0,10	0,10	0,10
11b	$u(\hat{\varphi}_{S,LD})$	wavelenght of the laser effect	B	$u10b\ (\Delta\varphi)$	0,00	0,00	0,00	0,00	0,00
11	$u(fFG)$	vibration frequency measurement	B	$u11\ (\Delta\varphi)$	0,10	0,10	0,10	0,50	0,50
12	$u(R)$	repetability on the 3 measurements	A	$u12(\Delta\varphi)$	0,07	0,02	0,08	0,09	0,10
		Absolute standard uncertainty on accelerometer phase shift (k=1)			**1,0**	**0,8**	**1,5**	**2,4**	**2,4**
		Absolute expanded uncertainty on accelerometer phase shift (k=2)			**2°**		**5°**		

RISE

Uncertainty budget

The uncertainty budget for the magnitude sensitivity determination given in table 2. The uncertainty components are numbered according to ISO 16063-11, table A.3, and brief descriptions of them are given in table 3. In the result table 1, the combined uncertainties are multiplied by k=2 and rounded up to "comfortable" stated uncertainties. For measurement frequencies between the 1/3-octave frequencies the measurement uncertainty of the upper 1/3- octave frequency are applied.

Freq.	Relative standard uncertainty component (%)												
(Hz)	1	2	3	4	5	6	7	8	9	10	11	12	Combined
10	0,11	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,07	0,15
12,5	0,11	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,05	0,14
16	0,11	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,02	0,14
20	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
25	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
31,5	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
40	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
63	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
80	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
100	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
125	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
160	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
200	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
250	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,12
315	0,09	0,01	0,01	0,04	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,03	0,12
400	0,09	0,01	0,01	0,08	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,04	0,14
500	0,09	0,01	0,01	0,12	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,16
630	0,09	0,01	0,01	0,08	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,03	0,14
800	0,09	0,01	0,01	0,08	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,14
1000	0,09	0,01	0,01	0,08	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,14
1250	0,09	0,01	0,01	0,08	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,01	0,14
1600	0,09	0,01	0,01	0,08	0,06	0,01	0,01	0,01	0,01	0,03	0,01	0,02	0,14
2000	0,09	0,01	0,01	0,08	0,12	0,01	0,01	0,01	0,01	0,03	0,01	0,03	0,17
2500	0,09	0,01	0,01	0,08	0,12	0,01	0,01	0,01	0,01	0,03	0,01	0,02	0,17
3150	0,09	0,01	0,01	0,08	0,17	0,01	0,01	0,02	0,01	0,03	0,01	0,02	0,21
4000	0,09	0,01	0,01	0,12	0,17	0,01	0,01	0,02	0,01	0,03	0,01	0,11	0,26
5000	0,09	0,01	0,01	0,12	0,29	0,01	0,01	0,02	0,01	0,03	0,01	0,12	0,35
6300	0,09	0,01	0,01	0,33	0,29	0,01	0,01	0,08	0,01	0,04	0,01	0,13	0,47
8000	0,09	0,01	0,01	0,29	0,29	0,01	0,01	0,07	0,01	0,04	0,01	0,45	0,62
10000	0,09	0,01	0,01	0,41	0,29	0,01	0,01	0,06	0,01	0,05	0,01	0,14	0,53

Table 2. Uncertainty budget for magnitude sensitivity determination.

Uncertainty source for magnitude sensitivity	Distribution
1 - Accelerometer charge measurement	Rectangular
2 - Accelerometer output filtering	Rectangular
3 - Voltage disturbance on accelerometer signal	Rectangular
4 – Transverse and rocking movements of accelerometer	Special (1/√6)
5 - Disturbance of quadrature output signal	Rectangular
6 - Interferometer signal filtering	Rectangular
7 - Voltage disturbance on phase amplitude measurement	Rectangular
8 - Motion disturbance on phase amplitude measurement	Rectangular
9 - Phase disturbance on phase amplitude measurement	Rectangular
10 - Residual interferometric effects on phase amplitude measurement	Rectangular
11 - Vibration frequency	Rectangular
12 - Type A uncertainty	$\sigma=1$

Table 3. Explanation of the magnitude sensitivity uncertainty component numbers and statement of their distributions.

SASO-NMCC

Section with calculation Magnitude / Phase

Calculation of frequency-dependent MU contributions / Magnitude

Pos.	Defining quantity / Influence variable X j	MU term w (x$_i$)	Primary calibration of **reference accelerometer** / Frequency range, Hz													
			5 - < 10		10 - < 20		20 - 1 k		> 1 k - 5 k		> 5 k - 10 k		> 10 k - 15 k		> 15 k - 20 k	
			Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance
1	Uncertainty of standard v_S	$w(S_S)$	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10
2	Angular frequency of v	$w(\omega)$	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10
3	Voltage U	$w(R)$	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08	5,00E-04	2,50E-07	5,00E-04	2,50E-07
4	Amplifier gain G	$w(G)$	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08	2,00E-04	4,00E-08
5	Frequency response of G	$w(K_F)$	5,00E-04	2,50E-07	5,00E-04	2,50E-07	5,00E-04	2,50E-07	5,00E-04	2,50E-07	8,00E-04	6,40E-07	2,50E-03	6,25E-06	5,00E-03	2,50E-05
6	Transverse motion	$w(K_T)$	1,00E-04	1,00E-08	1,00E-04	1,00E-08	5,00E-04	2,50E-07	5,00E-04	2,50E-07	5,00E-04	2,50E-07	1,00E-03	1,00E-06	1,00E-03	1,00E-06
7	Harmonics	$w(K_D)$	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08
8	Hum	$w(K_H)$	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08
9	Noise	$w(K_N)$	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10
10	Dependence of location	$w(K_{GL})$	1,00E-04	1,00E-08	1,00E-04	1,00E-08	2,00E-04	4,00E-08	5,00E-04	2,50E-07	5,00E-04	2,50E-07	2,00E-03	4,00E-06	3,00E-03	9,00E-06
11	Sensor mounting	$w(K_{MT})$	2,00E-05	4,00E-10	2,00E-05	4,00E-10	5,00E-04	2,50E-07	5,00E-04	2,50E-07	5,00E-04	2,50E-07	1,00E-03	1,00E-06	3,00E-03	9,00E-06
12	Cable layout	$w(K_{MC})$	1,00E-03	1,00E-06	1,00E-03	1,00E-06	3,00E-04	9,00E-08	2,50E-04	6,25E-08	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
13	Relative motion	$w(K_{REL})$	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10
14	Temperature change	$w(K_{TK})$	1,50E-05	2,25E-10	1,50E-05	2,25E-10	1,50E-05	2,25E-10	1,50E-05	2,25E-10	1,50E-05	2,25E-10	1,50E-05	2,25E-10	1,50E-05	2,25E-10
15	Linearity	$w(K_L)$	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10
16	Long-term stability of v_S	$w(K_I)$	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10	1,00E-05	1,00E-10
17	Influence of magnetic fields	$w(K_M)$	1,80E-03	3,24E-06	1,00E-03	1,00E-06	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08	1,00E-04	1,00E-08
18	Residual effects	$w(K_{RES})$	2,00E-04	4,00E-08	3,30E-04	1,09E-07	1,60E-04	2,56E-08	1,30E-04	1,69E-08	2,90E-04	8,41E-08	5,00E-03	2,50E-05	5,00E-03	2,50E-05
	Relative measurement uncertainty			2,16E-03		1,58E-03		1,01E-03		1,09E-03		1,26E-03		6,13E-03		8,33E-03
	Expanded relative uncertainty			4,32E-03		3,16E-03		2,02E-03		2,18E-03		2,52E-03		1,23E-02		1,67E-02
	Expanded uncertainty	%		**0,43**		**0,32**		**0,20**		**0,22**		**0,25**		**1,23**		**1,67**
	Maximum value 20 to 1 k	%														
	Target value	%		0,6		0,6		0,5		0,6		1,2		2,0		2,5
	Expanded Uncertainty to be declared	**%**		**0,6**		**0,6**		**0,5**		**0,6**		**1,2**		**2,0**		**2,5**

Calculation of frequency-dependent MU contributions / Phase

Pos.	Defining quantity / Influence variable Phi j	MU term u (Phi $_i$)	Primary calibration of **reference accelerometer** / Frequency range, Hz													
			5 - < 10		10 - < 20		20 - < 1 k		1 k - 5 k		5 k - 10 k		> 10 k - 15 k		> 15 k - 20 k	
			Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance	Contribution	Variance
1	Uncertainty of standard φ(v_S)	u (Phi $_S$)	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,150	0,023	0,150	0,023	0,150	0,023
2	Angular frequency of v	u (Phi $_R$)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
3	Voltage U	u (Phi $_U$)	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003
4	Amplifier gain G	u (Phi $_w$)	0,100	0,010	0,100	0,010	0,100	0,010	0,100	0,010	0,100	0,010	0,100	0,010	0,100	0,010
5	Frequency response of G	u (Phi $_G$)	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,100	0,010	0,200	0,040	0,200	0,040
6	Transverse motion	u (Phi $_F$)	0,000	0,000	0,070	0,005	0,070	0,005	0,140	0,020	0,200	0,040	0,200	0,040	0,200	0,040
7	Harmonics	u (Phi $_T$)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
8	Hum	u (Phi $_D$)	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000
9	Noise	u (Phi $_H$)	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000
10	Dependence of location	u (Phi $_N$)	0,010	0,000	0,010	0,000	0,100	0,010	0,100	0,010	0,150	0,023	0,150	0,023	0,150	0,023
11	Sensor mounting	u (Phi $_{GL}$)	0,000	0,000	0,000	0,000	0,000	0,000	0,100	0,010	0,200	0,040	0,200	0,040	0,200	0,040
12	Cable layout	u (Phi $_{MT}$)	0,150	0,023	0,100	0,010	0,050	0,003	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
13	Relative motion	u (Phi $_{MC}$)	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003
14	Temperature change	u (Phi $_{REL}$)	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000
15	Linearity	u (Phi $_{TK}$)	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000	0,010	0,000
16	Long-term stability of v_S	u (Phi $_L$)	0,000	0,000	0,000	0,000	0,000	0,000	0,050	0,003	0,100	0,010	0,100	0,010	0,100	0,010
17	Influence of magnetic fields	u (Phi $_I$)	0,100	0,010	0,100	0,010	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
18	Residual effects	u (Phi $_{RES}$)	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,050	0,003	0,200	0,040	0,200	0,040
	Absolute measurement uncertainty			0,230		0,213		0,194		0,255		0,375		0,456		0,456
	Expanded absolute uncertainty			0,460		0,426		0,389		0,510		0,749		0,912		0,912
	Expanded uncertainty	°		**0,46**		**0,43**		**0,39**		**0,51**		**0,75**		**0,91**		**0,91**
	Maximum value 20 to 1 k	°														
	Target value	°		0,5		0,5		0,5		0,5		1,0		2,0		3,0
	Expanded Uncertainty to be declared	°		**0,5**		**0,5**		**0,5**		**0,5**		**1,0**		**2,0**		**3,0**

METAS

Measurement uncertainty budget for the primary calibration of accelerometers (amplitude)

uncertainty contribution					frequency range / Hz						
					5 - < 20	20 - < 63	63 - < 1 k	1 k - < 5 k	5 k - 10 k	>10 k - 15 k	>15 k - 20 k
Component		Distribution	Factor	Evaluation Type	contribution	contribution	contribution	contribution	contribution	contribution	contribution
electrical measurement	including charge amplifier calibration	normal	2,00	Type B	3,00E-04	3,00E-04	3,00E-04	3,00E-04	3,00E-04	5,00E-04	5,00E-04
frequency	including the influence of speed to acceleration conversion	rectangular	1,73	Type B	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05
signal conditioner gain	including level non-linearity	normal	2,00	Type B	2,00E-04	2,00E-04	2,00E-04	2,00E-04	2,00E-04	2,00E-04	2,00E-04
signal conditioner frequency response	including frequency non-linearity	normal	2,00	Type B	5,00E-04	5,00E-04	5,00E-04	5,00E-04	2,00E-03	4,00E-03	4,00E-03
transverse motion	typical values for 8305-type of transducer	rectangular	1,73	Type B	1,40E-04	1,40E-04	1,40E-04	7,00E-04	2,50E-03	7,00E-03	7,00E-03
contribution of harmonics	nonlinearities affecting mechanical excitation	rectangular	1,73	Type B	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
hum	max. tolerated contribution of powerline hum	rectangular	1,73	Type B	1,00E-04	1,00E-04	1,00E-04	1,00E-04	1,00E-04	1,00E-04	1,00E-04
noise	broadband noise (including DUT, mechanical, electrical contributions)	normal	2,00	Type B	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05
position dependence	reproducibility and averaging from different measurement positions * (determined for each calibration)	rectangular	1,73	Type A*	2,10E-05	2,94E-05	5,22E-04	2,70E-04	4,30E-04	4,65E-04	1,96E-03
transducer mounting	including reproducibility of mounting torque	rectangular	1,73	Type A	7,00E-05	7,00E-05	1,40E-04	5,00E-04	1,00E-03	2,00E-03	2,00E-03
cable fixture	including connector strain and triboelectric effects	rectangular	1,73	Type B	9,00E-04	7,00E-04	7,00E-04	3,50E-04	0,00E+00	0,00E+00	0,00E+00
relative motion	including imperfections of the laser vibration isolation	rectangular	1,73	Type B	1,00E-04	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05
thermal stability	combinde effect on laser reference, signal acquisition and DUT	rectangular	1,73	Type B	1,50E-05	1,50E-05	1,50E-05	1,50E-05	1,50E-05	1,50E-05	1,50E-05
linearity	additional effects of non-linearity	rectangular	1,73	Type B	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05
reference signal	instabilities affecting the velocity signal after demodulation	rectangular	1,73	Type B	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05	1,00E-05
residual components		rectangular	1,73	Type B	1,00E-04	1,00E-04	1,00E-04	1,00E-04	1,00E-04	1,00E-04	1,00E-04
relative standard uncertainty					1,12E-03	9,57E-04	1,10E-03	1,16E-03	3,40E-03	8,34E-03	8,55E-03
expanded uncertainty					2,23E-03	1,91E-03	2,19E-03	2,31E-03	6,81E-03	1,67E-02	1,71E-02
expanded uncertainty (%)					**0,22**	**0,19**	**0,22**	**0,23**	**0,7**	**1,7**	**1,7**

Measurement uncertainty budget for the primary calibration of accelerometers, (phase)

uncertainty contribution					frequency range / Hz						
					5 - < 20	20 - < 63	63 - < 1 k	1 k - 5 k	5 k - 10 k	>10 k - 15 k	>15 k - 20 k
Component		Distribution	Factor	Evaluation Type	contribution	contribution	contribution	contribution	contribution	contribution	contribution
electrical measurement	including charge amplifier calibration	normal	2,00	Type B	5,00E-02	5,00E-02	5,00E-02	5,00E-02	5,00E-02	1,00E-01	1,00E-01
frequency	including the influence of speed to acceleration conversion	rectangular	1,73	Type B	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
signal conditioner gain	including level non-linearity	normal	2,00	Type B	1,00E-01	1,00E-01	1,00E-01	1,00E-01	1,00E-01	2,00E-01	2,00E-01
signal conditioner frequency response	including frequency non-linearity	normal	2,00	Type B	1,00E-01	1,00E-01	1,00E-01	1,00E-01	2,00E-01	4,00E-01	4,00E-01
transverse motion	typical values for 8305-type of transducer	rectangular	1,73	Type B	7,00E-02	7,00E-02	7,00E-02	1,40E-01	3,00E-01	6,00E-01	6,00E-01
contribution of harmonics	nonlinearities affecting mechanical excitation	rectangular	1,73	Type B	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
hum	max. tolerated contribution of powerline hum	rectangular	1,73	Type B	1,00E-02	1,00E-02	1,00E-02	1,00E-02	1,00E-02	2,00E-02	2,00E-02
noise	broadband noise (including DUT, mechanical, electrical contributions)	normal	2,00	Type B	1,00E-02	1,00E-02	1,00E-02	1,00E-02	1,00E-02	2,00E-02	2,00E-02
position dependence	reproducibility and averaging from different measurement positions * (determined for each calibration)	rectangular	1,73	Type A*	1,04E-03	4,96E-04	4,71E-02	3,67E-03	6,22E-03	4,19E-02	8,64E-02
transducer mounting	including reproducibility of mounting torque	rectangular	1,73	Type A	5,00E-02	5,00E-02	5,00E-02	1,00E-01	2,00E-01	4,00E-01	4,00E-01
cable fixture	including connector strain and triboelectric effects	rectangular	1,73	Type B	7,00E-02	5,00E-02	5,00E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00
relative motion	including imperfections of the laser vibration isolation	rectangular	1,73	Type B	5,00E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
thermal stability	combinde effect on laser reference, signal acquisition and DUT	rectangular	1,73	Type B	1,00E-02	1,00E-02	1,00E-02	1,00E-02	1,00E-02	2,00E-02	2,00E-02
linearity	additional effects of non-linearity	rectangular	1,73	Type B	1,00E-02	1,00E-02	1,00E-02	1,00E-02	1,00E-02	2,00E-02	2,00E-02
reference signal	instabilities affecting the velocity signal after demodulation	rectangular	1,73	Type B	1,00E-02	1,00E-02	1,00E-02	1,00E-02	1,00E-02	2,00E-02	2,00E-02
residual components		rectangular	1,73	Type B	5,00E-02	5,00E-02	5,00E-02	5,00E-02	5,00E-02	1,00E-01	1,00E-01
relative standard uncertainty					2,01E-01	1,88E-01	1,94E-01	2,35E-01	4,31E-01	8,62E-01	8,66E-01
expanded uncertainty (°)					**0,40**	**0,38**	**0,39**	**0,47**	**0,9**	**1,7**	**1,7**