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Bilateral Comparison

EURAMET.AUV.V-K1.2

(vibration acceleration)

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Abstract

This report describes the results obtained in a bilateral comparison of primary vibration calibration facilities. Two piezoelectric standard accelerometers (one single-ended as well one back-to-back type) were calibrated first at METAS, then at the PTB and again at METAS after their return.

The METAS and the PTB calibrations were found to be in excellent agreement, with a mean difference smaller than the expanded uncertainty (k = 2) of the comparison.

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1. Introduction

This report summarizes the results obtained in the bilateral comparison EURAMET.AUV.V-K1.2 carried out from October 2008 to April 2009.

2. Participants

The following two laboratories participated in the bilateral EURAMET comparison:

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3. Aim and task of the comparison

This bilateral EURAMET comparison of accelerometer calibration was intended as a follow-up to the EUROMET.AUV.V-K1 comparison to underpin the improved measurement capabilities of METAS in the vibration and acceleration field.

The EUROMET.AUV.V-K1 comparison was organized to disseminate the key comparison reference values, which were established earlier in the CIPM key comparison CCAUV.V-K1 within the RMO EURAMET. METAS did participate in EUROMET.AUV.V-K1 with calibration facilities on the secondary level. However, after this comparison, METAS put into service a new set-up for primary calibration. Its performance is validated with the comparison reported here.

The principal task of the comparison is to measure the charge sensitivity of two accelerometer standards (one of single-ended design and one of back-to-back design) at different frequencies and acceleration amplitudes specified in clause 4. The charge sensitivity is calculated as the ratio of the amplitude of the output charge of the accelerometer to the amplitude of the acceleration at its reference surface. The reference surface is the base or mounting surface of the accelerometer of single-ended design, and the top surface of the accelerometer of back-to-back design. The charge sensitivity is given in pico coulombs per metres per second squared: pC/(m/s^2).

To calibrate the two accelerometers, primary vibration calibration by laser interferometry in accordance with ISO 16063-11:1999 was used.

A calibrated charge amplifier was used to measure the output charge of the accelerometer standards.

The participating laboratories reported the measurement results of the charge sensitivity and the associated uncertainties individually as they were calculated for any specified measurement condition (in particular, for a given frequency), without applying any curve fitting procedure (as frequently used to suppress deviations from a "flat" frequency response).

4. Measurement Conditions

- frequencies: 40 Hz, 80 Hz, 160 Hz, 800 Hz, 2 kHz and 5 kHz (160 Hz is the reference frequency);
- optionally the laboratories can measure at other frequencies (such as frequencies included in the third-octave frequency series);
- amplitudes: preferred value 100 m/s^2**.** A range of 10 m/s^2 to 200 m/s^2 were complied with;
- tolerated ambient and accelerometer temperature during the calibration: 23°C ± 3 °C (actual values to be stated with an uncertainty of 0.5 °C);
- relative humidity: max. 75%;
- mounting torque of the accelerometer: (2 ± 0.1) N · m.

5. Transfer standards

Two types of piezoelectric standard accelerometers were used as transfer standards: one single-ended Brüel & Kjær type 8305 WH (**Accelerometer A**), and one back-to-back Brüel & Kjær type 8305 (**Accelerometer B**).

Specifications of Accelerometer A: single ended transfer standard accelerometer; Brüel & Kjær 8305 WH SN 2495771; weight: 26 grams; length: 22 mm; width over flats of hexagonal faces: 16 mm; mounting thread: 10-32 UNF-2B; electrical connector: coaxial 10-32 UNF-2A thread; accelerometer capacitance: ≈75 pF; sensitivity: ≈0.13 pC/(m/s^2); max. transverse sensitivity at 30 Hz: ≤ 1%.

Specifications of Accelerometer B: back-to-back reference standard accelerometer; Brüel & Kjær 8305 SN 2456549); weight: 40 grams; length: 29 mm; width over flats of hexagonal faces: 16 mm; mounting thread: 10 32 UNF-2B; electrical connector: coaxial 10- 32 UNF-2A thread; accelerometer capacitance: ≈75 pF; sensitivity: ≈0.13 pC/(m/s^2); max. transverse sensitivity at 30 Hz: ≤ 1%.

6. Measurement information

- The ***measurand*** was the magnitude of the complex charge sensitivity.
- Calibration of Accelerometer A by laser interferometry: the reference surface for acceleration measurement was by definition the base or mounting surface of the accelerometer. As this surface is covered during the calibration, the motion was sensed on the moving part close to the accelerometer. (Alternatively, the motion could have been sensed at the mounting surface of the accelerometer via longitudinal holes in the moving part of the vibration exciter. However, neither of the laboratories did this).
- Calibration of Accelerometer B by laser interferometry: the motion was sensed at the top surface without any dummy mass; no reflector (e.g. corner cube) was attached to the top surface.
- The **char*ge amplifier*** used in the laboratories was calibrated using a standard capacitor and standard voltmeter, both traceable to national standards. The calibration of the charge amplifier was carried out shortly before the calibration, using values of the electrical quantities similar to those occurring in the accelerometer calibration.
- In order to suppress the effect of any non-rectilinear motion, the displacement was measured at a minimum of three different points. These points were equally spaced on the top surface of the back-to-back accelerometer or on the mounting surface of the single-ended accelerometer.
- The mounting surfaces of the accelerometers and the moving part of the vibration exciter were slightly lubricated before mounting.
- The calibration of the accelerometers was carried out in accordance with the usual procedure of the corresponding laboratory.

7. Communication of the results

METAS performed an initial calibration of the standards and then submitted the calibration results to the CCAUV Executive Secretary (24 October 2008) before sending the artifacts to the PTB.

PTB performed the calibration of the artifacts (November 2008) and submitted its calibration report to the CCAUV Executive Secretary and to the pilot laboratory (March 2009)

The calibration reports contained detailed descriptions of:

- the calibration equipment;
- the calibration methods used;
- the ambient conditions;
- the mounting technique;
- the calibration results including the relative expanded uncertainty;
- For reporting the calibration results, clause 10 of ISO 16063-11:1999 was taken into account.

8. Circulation type

From METAS to PTB and back.

9. Transportation

The transfer standards were transported in a closed box by an international transportation agency.

10. Results

For the purpose of linking to the earlier determined CCAUV.V-K1 reference values, the participants of the EUROMET.AUV.V-K1 comparison were requested to provide measurement results for the following frequencies: 40 Hz, 80 Hz, 160 Hz, 800 Hz, 2 kHz and 5 kHz. The results communicated by the two participants are summarized in Table 1 and Table 2.

Table 1. Summary of the results obtained while calibrating the single ended reference transducer (SN 2495771).

	results obtained by the METAS		results obtained by the PTB	
frequency (Hz)	sensitivity (amplitude) (pC/(m/s^2))	expanded uncertainty (k=2) (%)	sensitivity (amplitude) (pC/(m/s^2))	expanded uncertainty (k=2) (%)
40	0.12906	0.4	0.12904	0.1
80	0.12906	0.4	0.12902	0.1
160	0.12904	0.4	0.12908	0.1
800	0.12912	0.4	0.12912	0.1
2000	0.12960	0.4	0.12953	0.1
5000	0.13261	0.4	0.13260	0.1

Table 2. Summary of the results obtained while calibrating the back to back reference transducer (SN 2456549).

	results obtained by the METAS		results obtained by the PTB	
frequency (Hz)	sensitivity (amplitude) (pC/(m/s^2))	expanded uncertainty (k=2) (%)	sensitivity (amplitude) (pC/(m/s^2))	expanded uncertainty (k=2) (%)
40	0.12619	0.4	0.12610	0.1
80	0.12612	0.4	0.12609	0.1
160	0.12611	0.4	0.12610	0.1
800	0.12622	0.4	0.12621	0.1
2000	0.12660	0.4	0.12662	0.1
5000	0.12861	0.4	0.12863	0.1

The results of these measurements appear to be in excellent agreement. The information of Tables 1 and 2 is represented graphically in Figures 1 to 4.

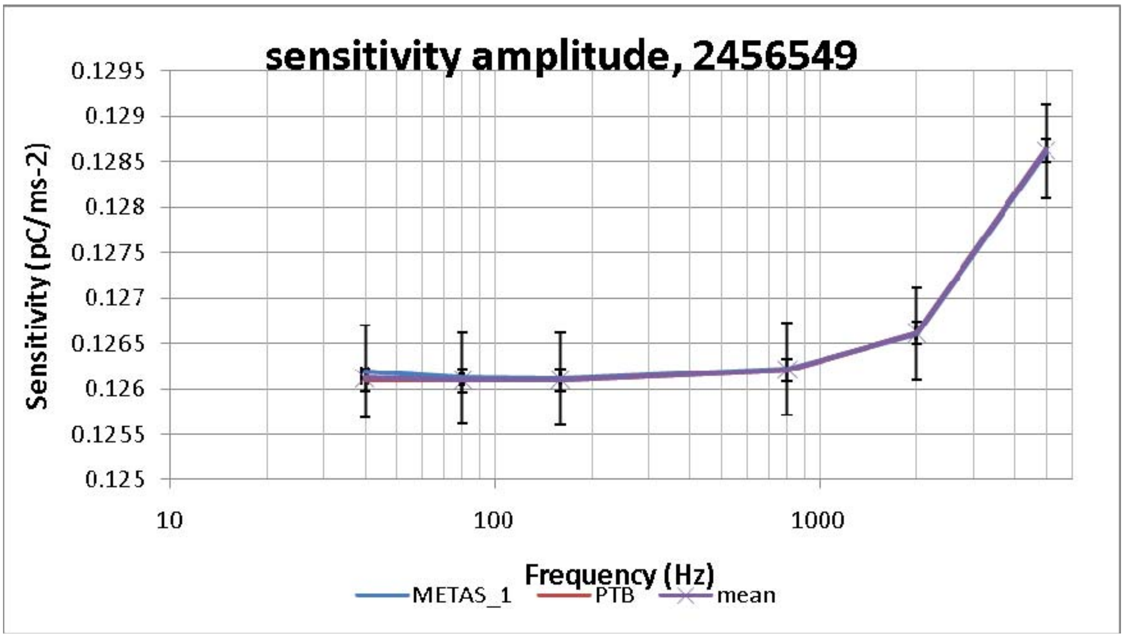

Figure 1. Sensitivity of the back-to-back reference transducer as measured by METAS in comparison with the determination by PTB - the results are virtually indistinguishable.

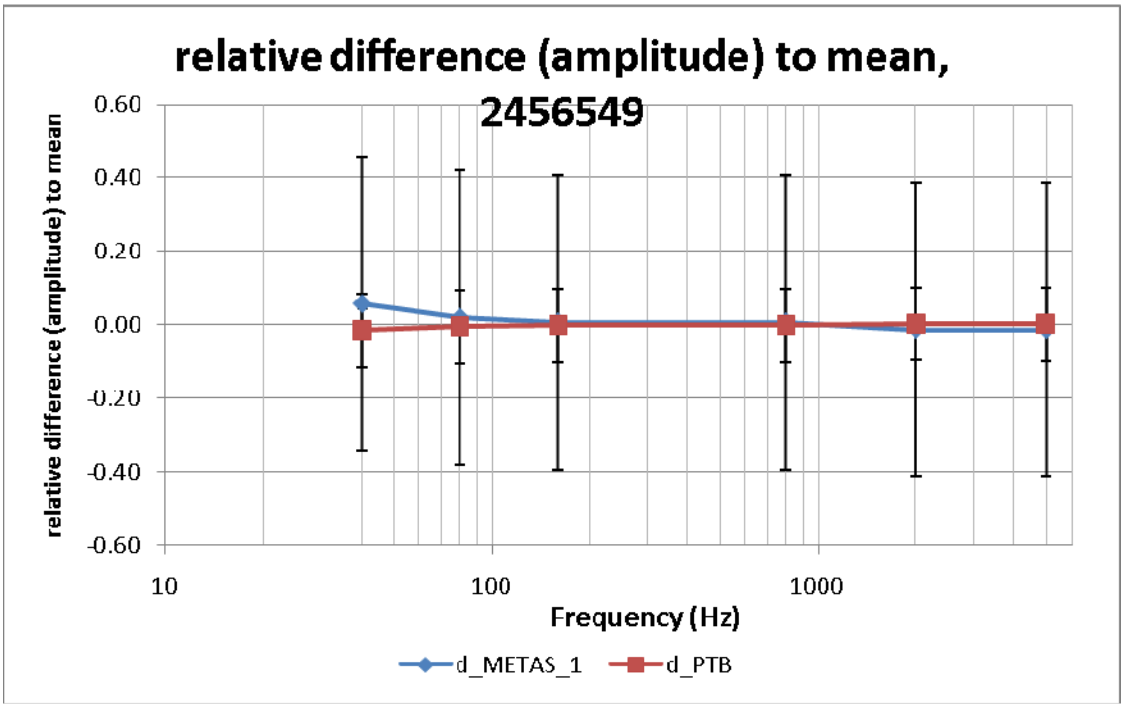

Figure 2. Relative deviation from the mean of the sensitivity of the back-to-back reference transducer as measured by METAS in comparison with the determination by PTB - the results are in excellent agreement.

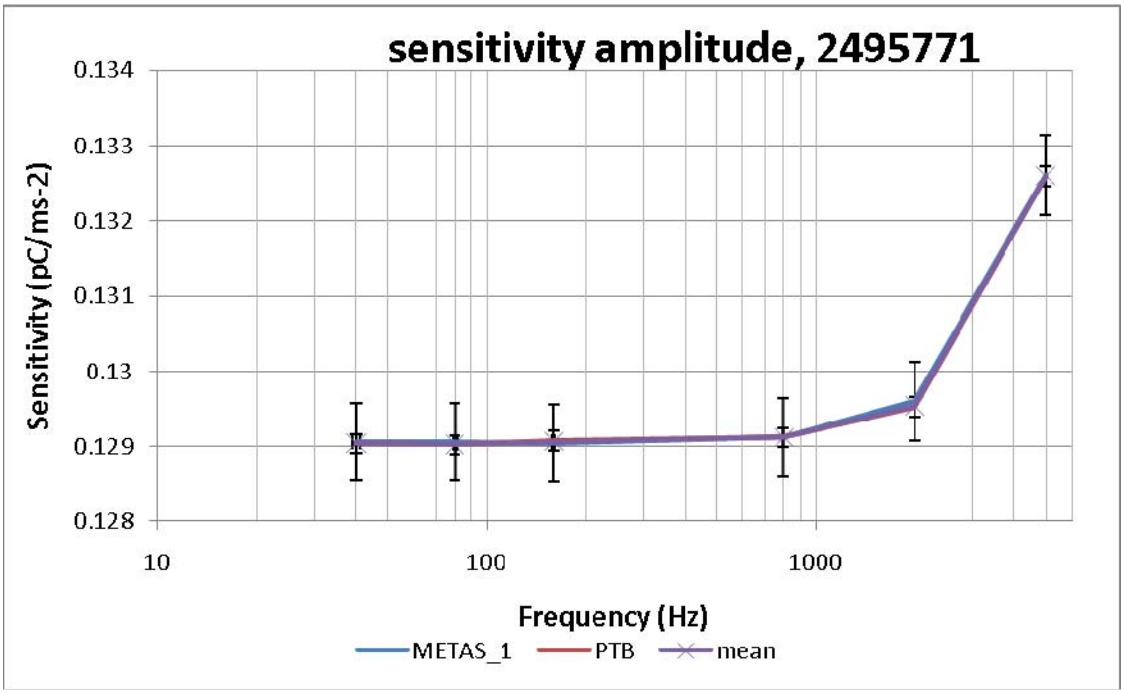

Figure 3. Sensitivity of the single-ended reference transducer as measured by METAS in comparison with the determination by PTB - the results are virtually indistinguishable.

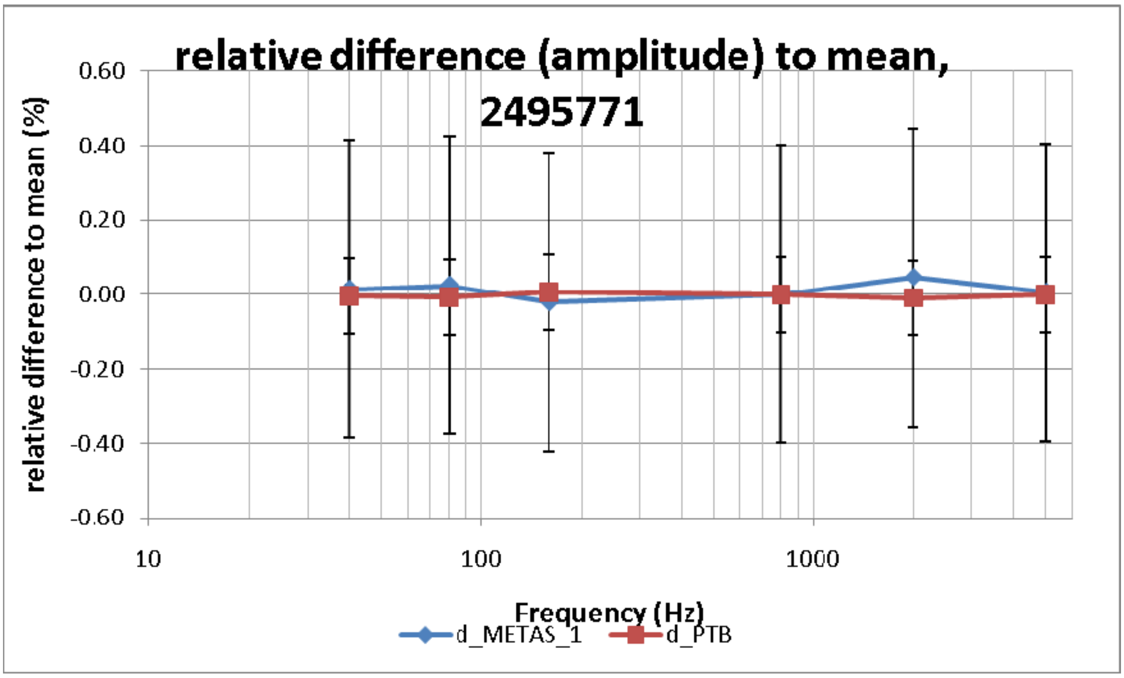

Figure 4. Relative deviation of the sensitivity of the single-ended reference transducer from the mean as measured by METAS in comparison with the determination by PTB - the results are in excellent agreement.

A more thorough mathematical analysis of these data allows to confirm in quantitative terms the actual consistency of the obtained results. Table 3 and Table 4 summarize the mean of the measurand at different frequencies for both transducers, the chi-squared values (*CHI_sq*), the deviations of the METAS-results from the mean (d_i), the deviations of the PTB-results from the mean (d_j), the corresponding uncertainties and the degrees of equivalence.

Table 3. Analysis of the results obtained during the calibration of the back-to-back reference transducer (SN 2456549) by METAS (*i*) and PTB (*j*).

frequency (Hz)	weighted mean	*SD* (mean)	*CHI_sq*	D_i*10^4 (pC/(m/s^2))	$U(D_i)$*10^4 (pC/(m/s^2))	D_j*10^4 (pC/(m/s^2))	$U(D_j)$*10^4 (pC/(m/s^2))	D_{ij}*10^4 (pC/(m/s^2))	$U(D_{ij})$*10^4 (pC/(m/s^2))
40	0.12611	0.00006	0.11970	0.84713	4.89710	-0.05287	0.30563	0.90000	5.20273
80	0.12609	0.00006	0.01331	0.28236	4.89424	-0.01764	0.30574	0.30000	5.19999
160	0.12610	0.00006	0.00148	0.09412	4.89381	-0.00588	0.30581	0.10000	5.19962
800	0.12621	0.00006	0.00148	0.09412	4.89808	-0.00588	0.30608	0.10000	5.20416
2000	0.12662	0.00006	0.00587	-0.18823	4.91276	0.01177	0.30714	-0.20000	5.21990
5000	0.12863	0.00006	0.00569	-0.18823	4.99076	0.01177	0.31202	-0.20000	5.30277

Table 4. Analysis of the results obtained during the calibration of the single-ended reference transducer (SN 2495771) by METAS (*i*) and PTB (*j*).

frequency (Hz)	weighted mean	*SD* (mean)	*CHI_sq*	D_i*10^4 (pC/(m/s^2))	$U(D_i)$*10^4 (pC/(m/s^2))	D_j*10^4 (pC/(m/s^2))	$U(D_j)$*10^4 (pC/(m/s^2))	D_{ij}*10^4 (pC/(m/s^2))	$U(D_{ij})$*10^4 (pC/(m/s^2))
40	0.12904	0.00006	0.00696	0.20891	5.00831	-0.01305	0.31291	0.22196	5.32123
80	0.12902	0.00006	0.02300	0.37979	5.00836	-0.02372	0.31283	0.40351	5.32118
160	0.12907	0.00006	0.01783	-0.33431	5.00741	0.02091	0.31314	-0.35522	5.32054
800	0.12912	0.00006	0.00001	0.00904	5.01059	-0.00056	0.31316	0.00960	5.32375
2000	0.12953	0.00006	0.07045	0.66745	5.02938	-0.04167	0.31399	0.70912	5.34337
5000	0.13260	0.00006	0.00117	0.08810	5.14605	-0.00551	0.32158	0.09360	5.46763

An excellent agreement between the measurement results was found for the calibration applying the primary method over the requested frequency range according to CCAUV.V-K1.

11. Conclusion

The reported comparison demonstrates a mutual equivalence of the calibration results obtained by the participating institutes within the declared uncertainty and over the considered frequency range.

It further allowed to investigate the uncertainty contributions in an enhanced frequency range, which and to improve the estimated uncertainty budget.