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

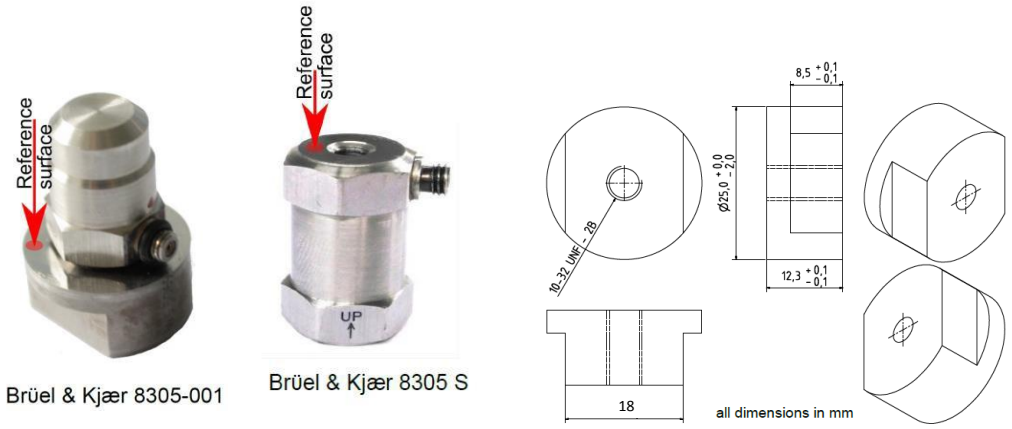
As the number of participants to the KC CCAUV.V-K5 was limited to four NMIs for EURAMET, all laboratories from EURAMET (and other RMOs) can participate to this RMO comparison.
Following this recommendation, this technical protocol is distributed to the chair of the technical committees of Acoustics, 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) °C (actual values to be stated within tolerances of ± 0.3 °C).
  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

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

[2] ISO 16063-11:1999 ‘‘Methods for the calibration of vibration and shock transducers Part 11: Primary vibration calibration by laser interferometry’’

[3] The influence of different vibration exciter systems on high frequency primary calibration of single-ended accelerometers, A. Täubner, H Schlaak, M Brucke and Th Bruns, Metrologia, Volume 47, Number 1

[4] The influence of different vibration exciter systems on high frequency primary calibration of single-ended accelerometers: II, Th Bruns, A Link and A Täubner, Metrologia, Volume 49, Number 1

[5] ISO/IEC 17025:2005/2017 “General requirements for the competence of testing and calibration laboratories”

[6] ISO/IEC Guide 98-3:2008 “Uncertainty of measurement Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)

[7] ISO/IEC Guide 98-3:2008/Suppl 1:2008 “Propagation of distributions using a Monte Carlo method”

Address List

BKSV-DPLA
Att.: Jacob Holm Winther
Skodborgvej 307
DK-2850 Nærum
Denmark

PTB
AG. 1.71
z.Hd. Dr. Thomas Bruns
Bundesallee 100
38116 Braunschweig
Germany

RISE Research Institutes of Sweden
Att. Håkan Andersson
Brinellgatan 4
SE-504 62 Borås
Sweden

INRIM
Att. Alessandro Schiavi
Mechanics - STALT
Str. delle Cacce, 91
10135 Torino
Italy

UME
Att. Eyup BILGIC
TÜBİTAK UME P.O. Box 54
41470 Gebze KOCAELI
Turkey

CMI
Att. Milan PRASIL & Stanislav Hynek
V Botanice 4/1504
150 72 Praha 5
Czech Republic

GUM
Att. Zbigniew Siejda
ul. Elektoralna 2
PL 00-139 Warszawa
Poland

CEM
Att. Salustiano Ruiz
C/Alfar,
2. 28760 Tres Cantos,
Madrid
Spain

METAS
Federal Institute of Metrology METAS
Att. Christian HOF
Laboratory Acoustics and Vibration
Lindenweg 50
3003 Bern-Wabern
Switzerland

LNE
Att. Adrien Canu
29 avenue Roger Hennequin
78197 TRAPPES Cedex
France

SASO-NMCC
Attention Fheed N. Alsubaey
Riyadh - Al Muhammadiyah – in front of
King Saud University
P.O. Box: 3437 Riyadh 11471 KINGDOM of
SAUDI ARABIA