Technical Protocol of the CIPM Key Comparison

CCAUV.V-K2

2009-07-09

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 national NMIs. This is done by conducting key comparisons (KC) on different levels of the international metrological infrastructure. The previous top level KC in the field of Vibration metrology, CCAUV.V-K1 was finished in the year 2001 and it's results have since been then the foundation of all subsequently established DoE in the field.

However, over the last years, developments in technology and improvements at the NMIs expanded the general range of the calibration capabilities currently available. Therefore during the meeting of CCAUV in 2008 the decision was taken to make preparations for a further KC with an appropriately extended measurement range.

The results of this KC will, after approval for equivalence, form the new basis for DoE 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 the KC is to measure the complex charge sensitivity of two different accelerometers at specified frequencies with primary means *I.e.* according to ISO 16063-11 “Methods for the calibration of vibration and shock transducers -- Part 11: Primary vibration calibration by laser interferometry”.

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.

Pilot Laboratory

Pilot laboratory for this Key Comparison is

Physikalisch-Technische Bundesanstalt (PTB)
Working Group Acceleration
Bundesallee 100
38116 Braunschweig
Germany

This is the delivery address for the set of artefacts and the written and signed reports. Contact Persons are

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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 “single ended” (SE) type, namely a Brüel & Kjær 8305-001 (SN: 2571390), and a “back to back” (BB) type, namely a Brüel & Kjær 8305 S (SN: 2602106).

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. 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, 1000, 1250, 1500, 1600, 2000, 2500, 3000, 3150, 3500, 4000, 4500, 5000, 5500, 6000, 6300, 6500, 7000, 7500, 8000, 8500, 9000, 9500, 10000.

Note: *this set does deviate from the standard frequencies of ISO 266.*

The participating laboratories should be able to provide magnitude results over the whole frequency range with their systems and to provide phase results for the majority of the specified frequencies.

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.

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 [1,2,3], simultaneously.

Specific conditions for the measurements of this KC 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 ± 0.3ºC). The accelerometer temperature should be measured and reported.
- relative humidity: max. 75 %
- mounting torque of the accelerometer: (2.0 ± 0.1) N·m

Circulation Type, Schedule and Transportation

The transducers are circulated in a star type fashion with a measurement period of two weeks provided for each participant. In between two subsequent measurements at any participants laboratory the transducers are measured at the pilot lab in order to monitor the long term stability.

The schedule is planned as follows:

Participant	Transportation to Participant (calendar week)	Measurement (calendar week)	Transportation to Pilot (calendar week)	Monitoring measurements (calendar week)
CMI	37/2009	38-39/2009	40/2009	41-45/2009
NMISA	43/2009	44-45/2009	46/2009	47-51/2009
DPLA	49/2009	50-51/2009	52-53/2009	03.07.10
CEM	04/2010	05-06/2010	07/2010	08-12/2010
GUM	10/2010	11-12/2010	13/2010	14-18/2010
UME	16/2010	17-18/2010	19/2010	20-24/2010
AIST/NMIJ	22/2010	23-24/2010	25/2010	26-30/2010
METAS	28/2010	29-30/2010	31/2010	32-36/2010
KRISS	34/2010	35-36/2010	37/2010	38-42/2010
LNE	40/2010	41-42/2010	43/2010	44-48/2010
NIM	46/2010	47-48/2010	49/2010	50-02/2011
CENAM	01/2011	02-03/2011	04/2011	05-09/2011
INMETRO	10/2011	11-12/2011	12/2011	13-17/2011
VNIIM	18-19/2011	20-21/2011	22-23/2011	24-28/2011

The cost of transportation to and from a participating laboratory shall be covered by the participating laboratory.
The accelerometers have to be send by an international logistic service providing a tracking system. The transportation has to include an insurance covering a value of 9 000,- € 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.

Measurement and Analysis Instructions

The participating laboratories have to 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) top surface of the transducer ***without any additional reflector or dummy mass***.
- The motion of the SE accelerometer should be measured on the moving part of the vibration exciter, close to the accelerometer's mounting surface, since the mounting (reference) surface is usually not directly accessible.
- The mounting surface of the accelerometer 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.
- In order to reduce the influence of non-rectilinear motion, the measurements 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 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
$$a(t)=\hat{a}\cdot\cos(\omega t+\varphi_a) \qquad (1)$$
and the respective charge output signal of the transducer $q(t)$ of the form
$$q(t)=\hat{q}\cdot\cos(\omega t+\varphi_q) \qquad (2)$$
the phase is defined according to ISO 16063-1 as
$$\Delta\varphi = \varphi_q-\varphi_a\,. \qquad (3)$$
- 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 result.

Communication of the Results to the Pilot Laboratory

Each participating laboratory will submit one printed and signed calibration report for each accelerometer to the pilot laboratory including the following:

- a description of the calibration systems used for the comparison and the mounting techniques for the accelerometer
- a description of the calibration methods used
- documented 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, [4, 5]). Including among others information on the type of uncertainty (A or B), assumed distribution function and repeatability component. (These information are 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

- Since it was generally agreed that the chosen accelerometers were not the optimal choice as “best device under test” (DUT) for the frequencies below 40 Hz, an additional uncertainty component, attributed to the DUT, will be added to the measurement uncertainties for those frequencies prior to the evaluation of comparison results. This is supposed to cover the influence of the possible electrostrictive or tribo-electric effect of cable motion. This processing will be performed by the pilot laboratory during data analysis, **this component is not to be included in the participant's uncertainty budget**.
- Presuming consistency of the results, the key comparison reference value and the degrees of equivalence will be calculated according to the established methods as a weighted mean as agreed upon already for CCAUV.V-K1.
- 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] ISO/IEC 17025:2005 “General requirements for the competence of testing and calibration laboratories”

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

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

Acknowledgement

The Artefacts were kindly committed by Brüel & Kjær to the pilot lab for the purpose of this comparison. They are especially selected from a larger production sample intended to provide the quality of “best measurement standards” in terms of the CIPM MRA.