Status report of INMETRO to the 11th CCAUV meeting

September, 2017

This report presents a brief synthesis of the current status and presents some activities developed by Inmetro in the fields of Acoustics, Ultrasound and Vibration since the last CCAUV meeting in 2015.

I) Organization structure

The Acoustics and Vibration Metrology Division (Diavi) is the organizational unit of the Directory of Scientific and Industrial Metrology of INMETRO in charge of the quantities related to Acoustics, Ultrasound and Vibration Metrology. Dr. Gustavo Ripper is the current head of Diavi, which includes four laboratories:

- Lavib – Vibration Laboratory, head: Ronaldo S. Dias
- Laeta – Electroacoustics Laboratory, head: Zemar M. Soares
- Laena – Acoustics testing Laboratory, head: Paulo M. Massarani
- Labus – Ultrasound Laboratory, head: Rodrigo P.B. Costa-Félix

The changes of management positions that occurred were motivated by the retirement of Mr. Gilmar Ximenes and Dr. Marco Nabuco, respectively former heads of Diavi and Laena.

II) Recent Publications

The list of technical publications from INMETRO was updated and is available at the CCAUV web site thought the following link: http://www.bipm.org/en/committees/cc/ccauv/publications-cc.html.

III) Participation of INMETRO in CCAUV and its WGs

INMETRO has participated in every CCAUV meeting since the 2nd meeting in 2001 and is member of the working groups for strategic planning and key comparisons. Its delegate, Dr. Gustavo Ripper, participates in the SPWG and the KCWG, of which he is the current chair. He also participates in the RMOWG as the chair of SIM MWG-9.

IV) Participation of INMETRO in key and supplementary interlaboratory comparisons:

During the period 2015-2017 there was no comparison organized by SIM.

INMETRO has participated in most interlaboratory key comparisons at CCAUV level and have also joined some key and supplementary comparisons organized by other regional metrology organizations. These comparisons are presented below:

IV.1 - Comparisons concluded:

- CCAUV.V-K3 (Metrologia, 2017, **54**, Tech. Suppl. 09001)
- CCAUV.U-K3.1 (Metrologia, 2016, **53**, Tech. Suppl. 09002)
- CCAUV.U-K4 (Metrologia, 2016, **53**, Tech. Suppl. 09004)
- AFRIMETS.AUV.A-S1 (Metrologia, 2016, **53**, Tech. Suppl. 09001)

IV.2 - Comparisons in progress:

- CCAUV.V-K4 Measurements concluded by Inmetro
- CCAUV.V-K5 Measurements are scheduled for April/2018
- EURAMET.AUV.A-S2 Measurements concluded by Inmetro
- CCAUV.W-K2 Measurements concluded by Inmetro

V) The participation of INMETRO in technical cooperation activities:

INMETRO has participated in cooperative activities developed between SIM members in order to disseminate technical knowledge and exchange experiences. Some recent initiatives are exemplified below:

2016 – Informal bilateral comparisons between INTI and INMETRO on calibration of pistonphones and LS1P microphones in pressure field – The results were published in the proceedings of ICA 2016, Buenos Aires:

SERRANO, F.A.; RIGANTI, J.M.; MILHOMEM, T.; SOARES, Z., **BI-LATERAL COMPARISON OF LS1P MICROPHONE CALIBRATION BETWEEN INTI AND INMETRO"**. In: Proceedings of the 22nd International Congress on Acoustics (ICA 2016), Buenos Aires, 2016.

RIGANTI, J.M.; SERRANO, F.A.; MILHOMEM, T.; SOARES, Z., **"Bilateral comparison of pistonphone calibration between INMETRO and INTI"**. In: Proceedings of the 22nd International Congress on Acoustics (ICA 2016), Buenos Aires, 2016.

2017 – Technical visit and training of one technician from INMETRO at CENAM.

2017 – Informal comparison between INMETRO and CENAM on low-frequency accelerometer calibration from 0,1 Hz up to 80 Hz.

2017 – Informal Comparison between NIST and INMETRO on primary interferometric accelerometer calibration from 10 Hz up to 20 kHz.

INMETRO and PTB have developed cooperation activities under the scope of the Bilateral Project stablished between Germany and Brazil entitled "Strengthening the Quality Infrastructure for Renewable Energies and Energy Efficiency in Brazil". The technical cooperation between PTB and Inmetro is focusing on improvement of measurement capabilities in Acoustics and Vibration at low frequencies to support the Wind Energy sector.

Some recent activities developed in acoustics were the following:

2017 – A two-month period stay of one person from INMETRO, Thiago Milhomem, as guest researcher at the PTB in Braunschweig.

2017 – Informal comparison between PTB and INMETRO on secondary calibration of microphones at low frequencies, from 2 Hz to 400 Hz.

VI) Recent improvements in measurement systems

Primary shock calibration system

The Vibration Laboratory concluded its low-intensity primary shock calibration system for the key comparison CCAUV.V-K4. The shock machine implemented by INMETRO is based on rigid body motion of an anvil which is impacted by a hammer, following the requirements of ISO standard 16063-13. Air bearings are used to guide the motion of both the stainless steel hammer and anvil while acceleration is measured by laser interferometry. The amplitude of the shock is controlled by adjustment of the pneumatic actuator settings. Different pulse-forming materials are used to obtain shock pulses with the desired shape and pulse durations. The shock machine and interferometer are placed on different tables to avoid excitation of the optical parts by the mechanical shocks generated, as shown in Fig.1. Typical shock pulses generated by the shock machine from 500 to 5000 m/s^2 are shown in Fig.2 and detailed views of the interferometric setups and of the accelerometer under test mounted to the anvil are given in Fig. 3.

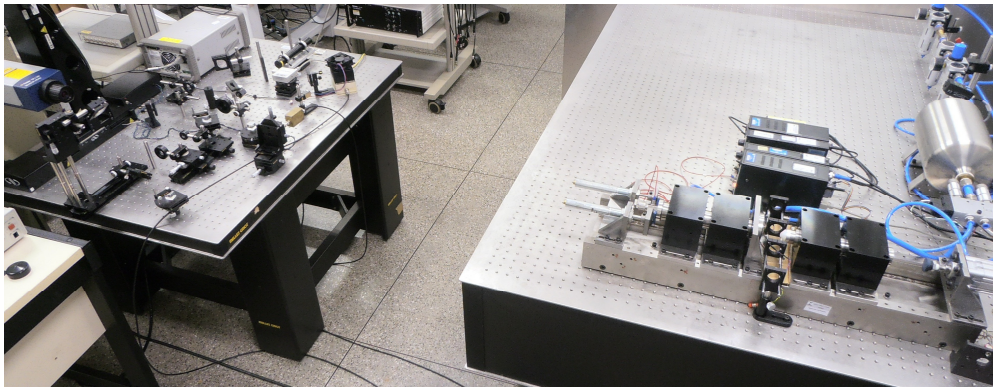


Fig 1 – Overview of the primary shock calibration system.

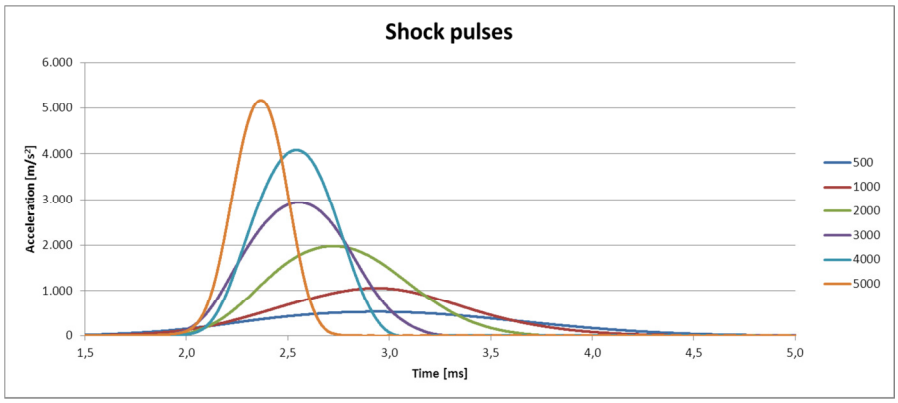
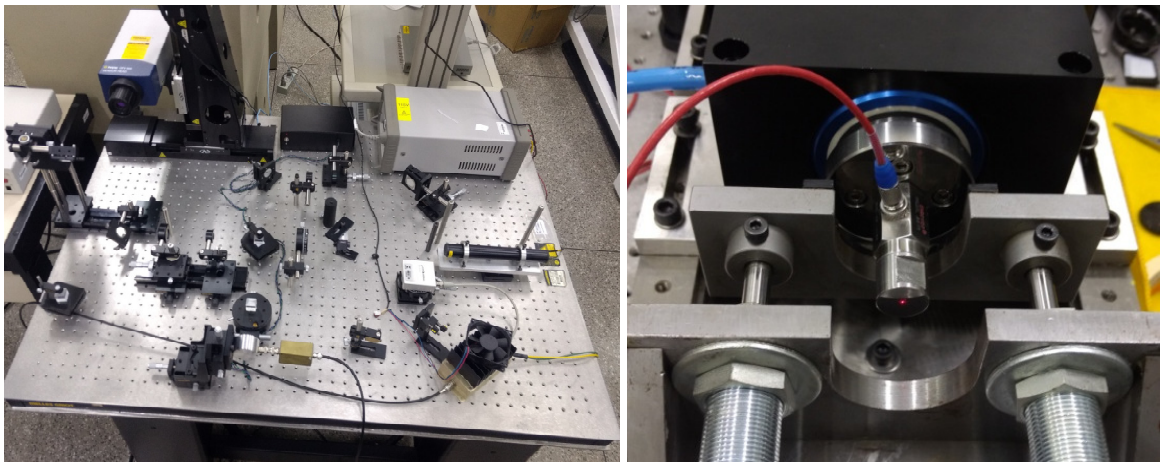


Fig 2 – Typical acceleration shock pulses generated by the shock machine.



(a) (b)

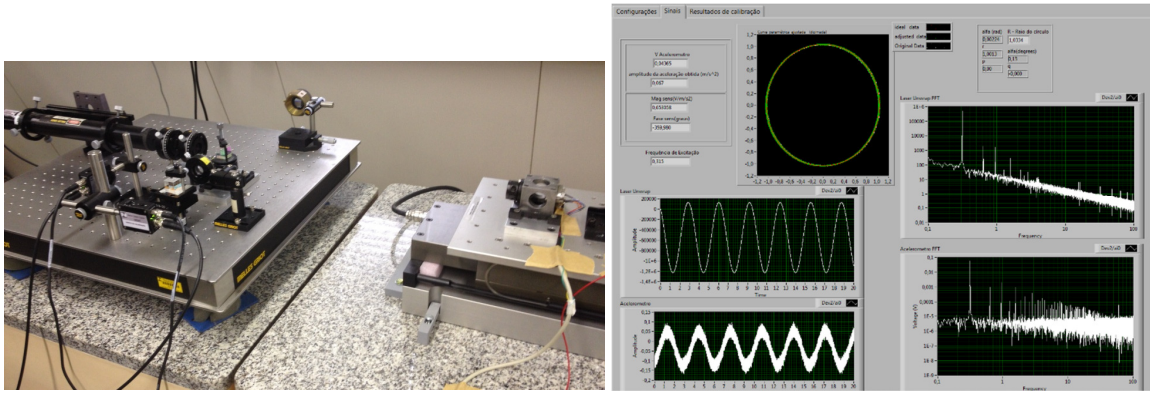
Fig 3 – (a) Interferometric set up and (b) detail of a BTB accelerometer with dummy loading mass mounted to the anvil.

Two different interferometric setups can be used:

1) SETUP 1 – this configuration uses a commercial Polytec Sensor Head OFV 505 which is mounted on a X-Y translation stage. The baseband I&Q signals are provided by a Polytec OFV-5000 vibrometer controller in conjunction with a customized junction box VDD-Z-011.
2) SETUP 2 – this configuration is based on a conventional heterodyne interferometer based on a 40 MHz optomodulator, which is mounted on an optical breadboard.

<u>Low-Frequency primary vibration calibration system</u>

The low-frequency accelerometer calibration system was upgraded in order to employ the Sine-Approximation Method, allowing the calibration of complex sensitivity of accelerometers and acceleration measuring chains. After the conclusion of the key comparison CCAUV.V-K3, for which INMETRO reported results from 0,2 Hz to 40 Hz, it was decided to try to extend the lowest frequency limit down to 0,1 Hz. The computational program used to control the calibration has been updated to include the additional frequencies and an informal bilateral comparison was started between CENAM and INMETRO to compare results obtained on accelerometer calibration at this lower frequency range. Figure 4 presents the low-frequency system and its calibration program. Fig. 5 presents the DoEs obtained in the key comparison CCAUV.V-K3.



(a) (b)

Fig 4 – Low-frequency primary calibration (a) system and the (b) program front panel.

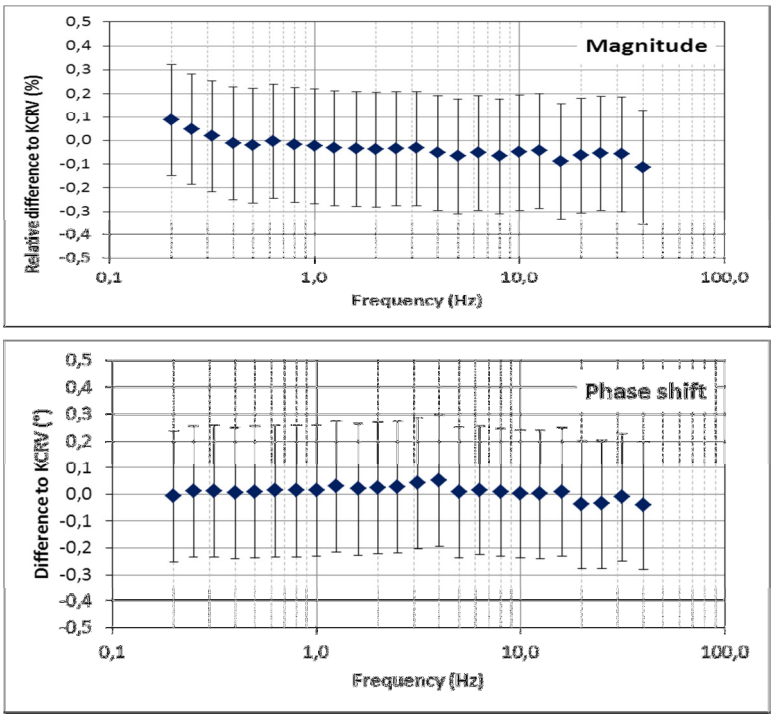


Fig 5 – Differences of INMETROs' results to the KCRV determined for the key comparison CCAUV.V-K3.

Reciprocity calibration of microphones in reverberant field

The Electroacoustics laboratory carried out a research focusing the reciprocity calibration of 1-inch and ½-inch microphones in diffuse field from 1 kHz to 20 kHz. A doctorate thesis based on this subject shall be concluded by the end of 2017. Some partial results of this research have been presented in the following publications:

MILHOMEM, T.; SOARES, Z.; MUSAFIR, R. **"An Investigation about the Effect of Diffusivity of Sound Field for Reciprocity Calibration of Measurement Microphones in Diffuse field"** In: internoise2016 - 45th International Congress and Exposition on Noise Control Engineering, 2016, Hamburg, Germany.

MILHOMEM, T.;MUSAFIR, R.E.; SOARES, Z.; **"An investigation on diffuse field calibration of measurement microphones by the reciprocity technique"** In: Proceedings of the 22nd International Congress on Acoustics, Buenos Aires, 2016.

Secondary calibration of microphones in low-frequencies

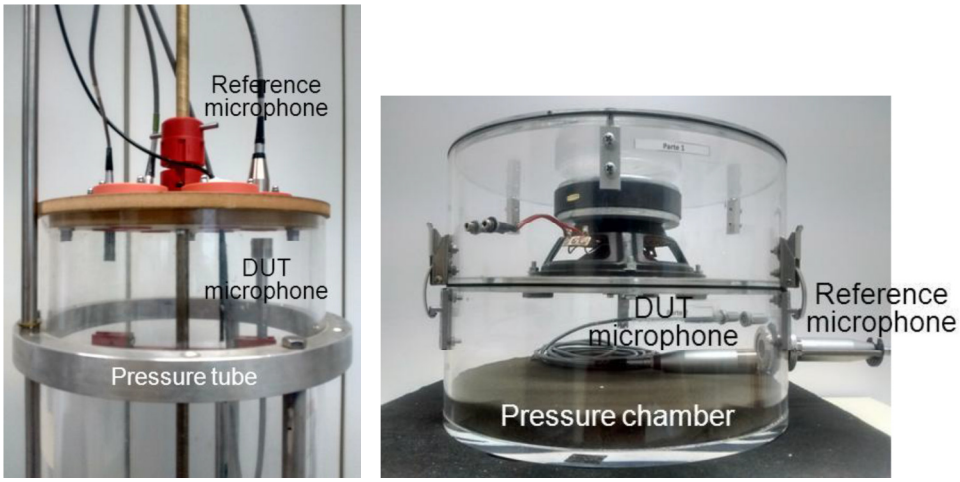
An investigation on microphone calibration at infrasound frequencies was performed by the INMETRO and by the Working Group 1.63 Noise Measuring Technology – WG 1.63 of the Physikalisch-Technische Bundesanstalt – PTB during March to May 2017 at WG 1.63 installations.

This investigation was performed in three steps: (1) a bilateral comparison on microphone calibration at infrasound frequencies when microphone's vent is exposed to the sound field and (2) when its vent is not exposed to the sound field; and (3) a study about the possible reasons for the different results found by each NMI.

Six measurement microphones were calibrated by comparison with a reference microphone. Results of the bilateral comparison were collected and the normalized error's modules ($|E_n|$) were calculated to evaluate the performance. This evaluation has shown that both NMIs obtained equivalent results and that it allows validation of the procedures and measuring systems against each other. Figures 6 and 7 show some details of the measurement setups of INMETRO and PTB. Results of this work have been presented in the following publications:

KLING, C.; FEDTKE, T.; SOARES, Z.; MILHOMEM, T.; **"Metrology for infrasound measurements"**. In: Proceedings of the 24th International Congress on Sound and Vibration - ICSV24, July 2017, London, UK.

KLING, C.; WIECZOREK, J.; MILHOMEM, T; SOARES, Z.; **"An Investigation on Microphone Calibration at Infrasound Frequencies"**. Internal Report - Bilateral Project for Strengthening the Quality Infrastructure for Renewable Energies and Energy Efficiency in Brazil, Technical cooperation between PTB and Inmetro, 2017.



(a) (b)

Fig. 6 - Arrangement in (a) PTB´s and in (b) Inmetro's pressure chambers for calibration (by simultaneous comparison) of a microphone with its vent exposed to the sound field

Fig 7 - Inmetro's setup used for calibration by simultaneous comparison of a microphone with its vent exposed to the sound field

VII) Inter-regional reviews of CMCs

INMETRO have participated actively in all the reviews of CMCs carried out by SIM MWG-9. The following CMC batches were reviewed by INMETRO in the period from Sept/2015 to Sept/2017:

- AFRIMETS.AUV.4.2016;
- AFRIMETS.AUV.5.2017;
- APMP.AUV.12.2016;
- APMP.AUV.13.2016;
- COOMET.AUV.8.2017.

VIII) Quality Management System in support of INMETROs' Acoustics and Vibration services

The Quality Management System supporting the capabilities of INMETRO in the fields of Acoustics and Vibration has been last reviewed in 2014, when onsite technical peer reviews were carried out by the experts Dr. Thomas Bruns from PTB/ Germany and Dr. Dominique Rodrigues from LNE/ France. The certificate of reapproval of the Quality Management System was issued by the Inter-American Metrology System on 05/November/2014, confirming compliance with the requirements of the CIPM MRA to operate a QMS based on ISO/IEC 17025.

Considering the upcoming changes in requirements after release of the new version of ISO standard 17025, a training of the staff is scheduled to start on October-November of 2017.

IX) Visits of international experts to INMETRO and of our staff to other NMIs

1) Visits of international experts to Inmetro
   - Dr. Qiao SUN from NIM/China – visit to INMETRO (2017)

2) Visits of Inmetro´s personnel to other NMIs
   - Thiago Milhomem – visit to PTB / Germany (2016)
   - Gustavo P. Ripper – visit MIKES / Finland (2017)
   - Caue Doval Ferreira – visit to CENAM / Mexico (2017)

X) Technical assessments carried out by INMETRO´s staff

The experts from Inmetro have participated in the following onsite technical assessments:

- Dr. Zemar Soares - onsite peer review of the acoustics calibration services at INTI/Argentina in October 2014.
- Dr. Gustavo Ripper - onsite the peer review of the vibration calibration services at INTI/Argentina in February 2015.
- Dr. Gustavo Ripper - technical assessment of the acoustics and vibration calibration services at NMISA/South Africa in May 2016.

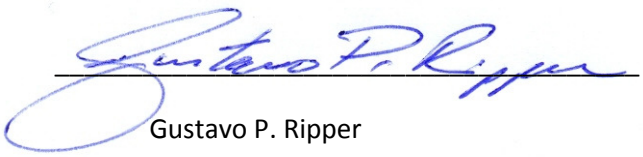
XI) Participation in Metrology Forums

Inmetro has participated in standardization and technical scientific forums related to measurements in AUV

- IMEKO – Dr. Gustavo Ripper is the current chairman of TC22 – Vibration measurement
- CGCRE CT12 – Dr. Zemar Soares is the chairman of the technical committee for acoustics ultrasound and vibration of the Brazilian Accreditation Board. Drs. Gustavo Ripper, Ronaldo S. Dias, Paulo Massarani, Rodrigo Costa-Félix and other experts of Diavi are members of this Technical Committee.

Note - An important project carried out within this TC, and with the support from Laeta, was an interlaboratory comparison between 12 Brazilian secondary accredited laboratories on calibration of microphones, sound calibrators and sound level meters

- IEC - Dr. Zemar Soares is the Brazilian delegate for TC29 – Electroacoustics and participates in WG 05, 10, 13 and 21.
- ABNT – Dr. Zemar Soares is the convenor of ABNT CE 26.120.03, mirror of IEC WG13 – Hearing Aids.
- IEC - Dr. Rodrigo P. B. Costa-Felix is the Brazilian delegate for TC87 WG 6, 8, 9, 14 and 15.
- ABNT - Dr. Rodrigo P. B. Costa-Felix is member of ABNT ONS 58, CB 26 and CB53.



Gustavo P. Ripper
12/September/2017