Joint Report of Activities from DFM and BKSV-DPLA

Joint Report of Activities, October 2012

11. juni 2012
Ref 1107-08 SBF
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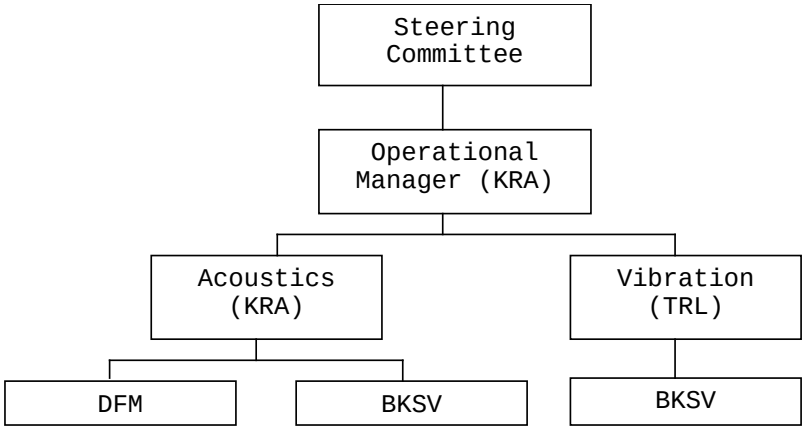
1. Introduction

The Danish Primary Laboratory of Acoustics (DPLA) is an entity co-operated by Brüel & Kjær S&V A/S (BKSV) and Danish Fundamental Metrology Ltd. (DFM). DPLA has been nominated as Danish Primary Laboratory in the field of Acoustics in gases and solids by the Department of Trade and Industry (EFS). In order to comply with the new structure required to participate in EURAMET the international status of the members of DPLA has changed accordingly. Now DPLA is represented by DFM as the Danish National Metrology Institute, and BKSV as a Designated Institute.

The activities of DPLA are supervised by a Steering Group formed by staff from DFM and BKSV: The operational manager of DPLA is Knud Rasmussen, and the members of the Steering Committee are Salvador Barrera-Figueroa, Michael Kjær, Erling Sandermann-Olsen, Torben R. Licht, and Finn Krygger Nielsen. The organisational structure is shown in the block diagram below.



Further cooperation on research in acoustic metrology is maintained between DPLA and the Acoustic Technology group of the Institute of Electrical Engineering, Technical University of Denmark, and the ITI institute of the University of Southern Denmark.

DFM and BKSV are members of DANIAmet. This is an umbrella organization that covers and coordinates multiple aspects of the decentralised Danish metrological infrastructure such as: fundamental metrology, legal metrology, and the network of primary and reference laboratories.

Acoustics is one of the four priority subject fields for Danish Metrology. This implies that acoustic metrology is undergoing a special effort for marketing and dissemination among the Danish acoustical community.

Responsibilities

It is the responsibility of DPLA to maintain and disseminate the basic units in the field of Acoustics in gasses and solids and through research in the field to develop and improve methods for primary as well as secondary calibration. This responsibility is partially undertaken by offering services of microphone and accelerometer calibration at primary and secondary level. DPLA's services are accredited by DANAK (accr. 255 and 277). Secondary calibrations by comparison methods, performance testing and verification of acoustical measuring instruments are also performed by other accredited calibration laboratories in Denmark.

2. Activities in 2010-2012

Calibration activities

The combined annual number of certificates issued to external costumers by DFM and BKSV in 2010-2012 on primary pressure reciprocity calibration of microphones is over 70 and over 100 on laser-calibration of accelerometers. In addition to the calibrations for customers a large number of internal microphone calibrations are performed to maintain the unit of sound pressure and for research and development activities. For this purpose DPLA holds a combined number of 19 B&K Type 4160 and 30 B&K Type 4180 microphones, which generally are calibrated each year. DPLA holds four sets of reference accelerometers, including the associated preamplifiers, which are maintained and used as transfer standards. The four sets are calibrated every month.

Research activities

The major research activities on Acoustics in air are related to calibration of microphones by improving the calibration methods, extending the frequency range and the dynamic range of calibrations. A new line of research has been recently started at DFM: opto-acoustic methods for Characterising sound fields.

The activities on acoustics in solids have mainly been focused on refining the ISO16063-11 method 3 using off the shelf FFT analysers and extending the frequency range.

Microphone calibration at DFM

Low-frequency calibration

Calibration of LS1 microphones to frequencies down to 2 Hz has been tested in the past, and DPLA participated in a Key Comparison (CCAUV-A.K2). No further calibrations at low frequencies were performed after the moving laboratory from DTU to DFM. Therefore, a new set of low-frequency calibrations was performed at DFM using the current set-up. The results are comparable to those obtained before. Additionally, the calibration of LS2 microphones was also tested. The results showed a similar

reproducibility to the one obtained with LS1 microphones. An additional task will be to test whether WS2 microphones can also be calibrated using this technique.

In order to calibrate microphones below 2 Hz, an alternative method must be investigated, probably a laser pistonphone.

High-Frequency calibration

Preliminary tests of free-field calibration of working standard microphones up to 100 kHz have been performed successfully. Additional calculations of several parameters of the microphones must be carried out. Testing of the frequency doubler necessary for measurements at frequencies above 100 kHz in the current set-up showed that the signal delivered after the double contains large remnants of the input frequency. This signal cannot be used as such, and further testing of the device must be carried out in order to test its suitability for this task. Furthermore, additional modifications of the existing instrumentation (designed to cover audio frequencies) may be needed.

Optical techniques for sound measurement

A calibration method based on the measurement of the displacement of the membrane of a microphone by means of laser-Doppler vibrometry has been successfully tested. The results are comparable to the results determined using traditional methods. This method has also been used to establish the relation between the radiation impedance of a microphone and its diffuse-field sensitivity.

An industrial PHD project has been awarded to DFM for the investigation of the application of the acousto-optic effect in the reconstruction of sound fields and other applications. Another subject of the study will be introductory steps into the measurement of acoustic particle velocity using LDA.

Secondary free-field calibration

Some refinements of the method for calibrating microphones in a free field using the comparison technique have been carried out. These refinements are related to the design of the sound source used in the calibration. The directivity of the sources was investigated in order to assess their suitability for simultaneous calibration.

A suitable source was especially designed in cooperation with the SENSE Institute of the University of Southern Denmark, the simultaneous comparison method was also tested. Due to inevitable non-symmetries in the sound field generated by the special source, the microphones must exchange positions in an additional measurement. The results are in good agreement with reciprocity and sequential comparison; however, this exchange eliminates the advantage of a fast measurement procedure. A potential application can be testing of many microphones simultaneously if a larger uncertainty is accepted.

A third method was also tested. It is a combination of the simultaneous and sequential methods. In the *hybrid* method the transfer function between a monitor microphone mounted on the sound source, and the test and reference microphones are measured in a sequential fashion. The measurement of the transfer function eliminates any temporal instability while keeping the simplicity of a sequential set-up.

Microphone calibration at B&K

Very low frequency calibration

A new method for measuring the frequency response of microphones at frequencies down to 0.1 Hz, was developed. This method is being refined in order to establish a calibration service. This further development includes establishing the uncertainty of measurement.

Vibration transducer calibration at B&K

ISO16063-11 method 3 has been implemented using quadrature output laser interferometers to cover low frequency vibration transducer calibration down to 0.1 Hz and high frequency calibration up to 100 kHz but limited by the mechanical properties of the exciters and transducers. During 2007 funding has been found to establish such a system at DPLA. This system is undergoing accreditation procedures.

Double beam laser calibration is another field of interest, but this has not been pursued further recently. This is especially of interest due to the non-perfect vibration generation possible with present vibration exciters.

Transverse motion in laser calibration setup

Transverse motion is one of the major error sources when performing laser calibrations off center. Therefore an investigation of actual transverse motion on transducers set up for laser calibration was performed on 3 different exciters. The results showed very high peaks of transverse motion in the range 5 to 10 kHz for all shakers. Using a mechanical filter between the shaker and accelerometer was proven to eliminate most of these problems.

Correction curves for back-to-back reference transducers

For the last twenty or more years a number of correction curves have been used for the back-to-back reference transducers. Recently some new, astonishing results were published by PTB. At BKSV a number of measurements were undertaken to verify or question these new results. The results seem to confirm the findings reported by PTB.

Joint development projects

A turnkey free-field reciprocity system has been developed under close collaboration between DFM and BKSV. The hardware and software is

based on the set-up investigated along several years first at DTU, and later at DFM. BKSV has provided modified instrumentation all along the process.

International cooperation

The two Institutes of DPLA are active players in the global cooperation in CCAUV and in the regional cooperation within EURAMET. A member of DFM holds the Chair of EURAMET's TCAUV.

Staff members of DPLA are active members of IEC TC29 and ISO 108/SC3 in which they act as specialists and project leaders for specific standards. A member of BKSV staff is chairman of ISO 108/SC3.

DFM is acting as co-pilot laboratory for the Supplementary Comparison EURAMET.AUV.A-S1, concerned with calibration of LS1 and LS2 microphones. The measurement round has finished, and DFM is preparing the draft B report.

BKSV is participating in the Key Comparison CCAUV.A-K5, dealing with calibration of LS1 microphones in both Modulus and Phase at frequencies down to 2 Hz.

BKSV participates in the EURAMET project 1056, Comparison of methods to determine corrections to obtain the free-field response of a sound level meter. The final report has been published in the EURAMET homepage.

BKSV has also participated in the Key Comparison CCAUV.V-K2.