Physikalisch-Technische Bundesanstalt
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# Calibration of sensors for airborne infrasound utilizing the hydrostatic pressure gradient

## Introduction

The reliable and comparable assessment of any physical quantity requires traceability to the international system of units (SI). Sound pressure is traditionally quantified using measurement microphones as transfer standards, for which the established primary calibration methods are currently limited to frequencies of 2 Hz and higher. These frequencies do not fully cover the range of interest for the International Monitoring System (IMS). For this reason, multiple calibration methods for airborne infrasound based on different physical principles are currently in development.
Two novel calibration techniques has been established at Physikalisch-Technische Bundesanstalt, the National Metrology Institute of Germany. A primary method developed is able to calibrate microphones and uses a completely different measurement principle than well-established techniques mainly used in the audible frequency range. Since it can only be applied to specific microphones a secondary technique was developed which is able to transfer the primary calibration results to nearly all practically relevant sensors.

## Primary calibration in the microphone carousel

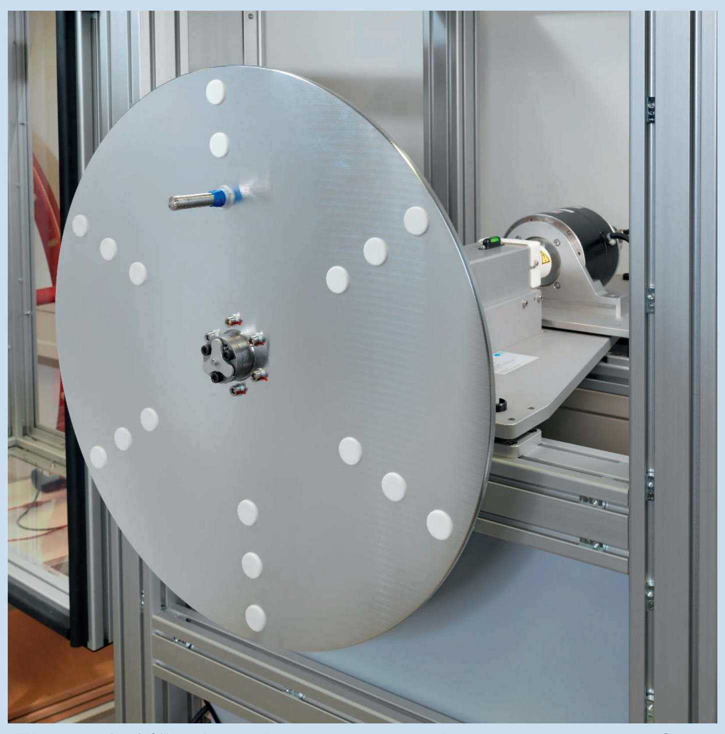

Figure 1: ½" microphone mounted on the carousel for primary calibration.

A microphone mounted on a vertically rotating disc is exposed to a periodically varying barometric pressure and thus subjected to a sinusoidal excitation signal. This dynamic pressure signal $\Delta p(t)$ approximately follows the relation

$$\Delta p(t) = -\rho \cdot g \cdot \Delta h(t)$$

with density of air $\rho$, gravity acceleration $g$ and variation in altitude $\Delta h(t)$. That allows to realise the unit Pascal only by measuring environmental conditions (temperature, humidity and static pressure of air) and the measurement of the altitude variation (a length).

Under laboratory conditions, a variation $\Delta h = \pm 15$ *cm* induces a calibration signal of $L_{Zeq} \approx 96$ dB which is more than is applied in a typical sound calibrator.
The mechanical construction is likewise challenging. The rotation axis has to be adjusted precisely horizontally and vibrations have to be mitigated by carefully balancing the complete system.

There are only minor restrictions to the microphone under test such as the weight and vent orientation. Reliable results can be obtained with an uncertainty better than 0.2 dB. To validate the novel method a first comparison was carried out with a pistonphone setup available at Laboratoire National de Métrologie et d'Essais (LNE). The agreement found was better than 0.03 dB in the frequency range between 0.1 Hz and 5 Hz.

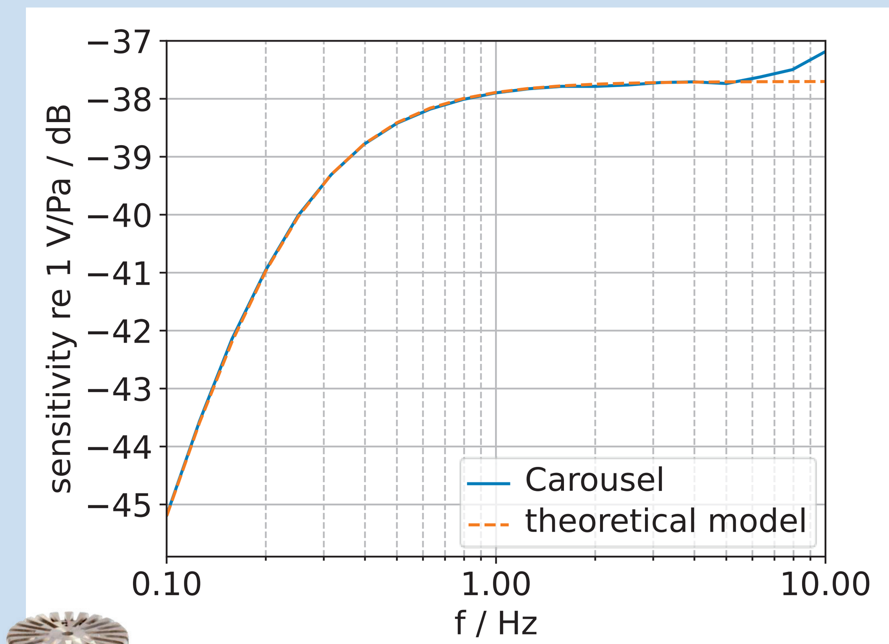


Figure 2: Calibration result determined on a ½" infrasound microphone B&K 4193 mounted on a preamplifier GRAS 26AI. (Source of photo: www.bksv.com)

## Secondary calibration by comparison

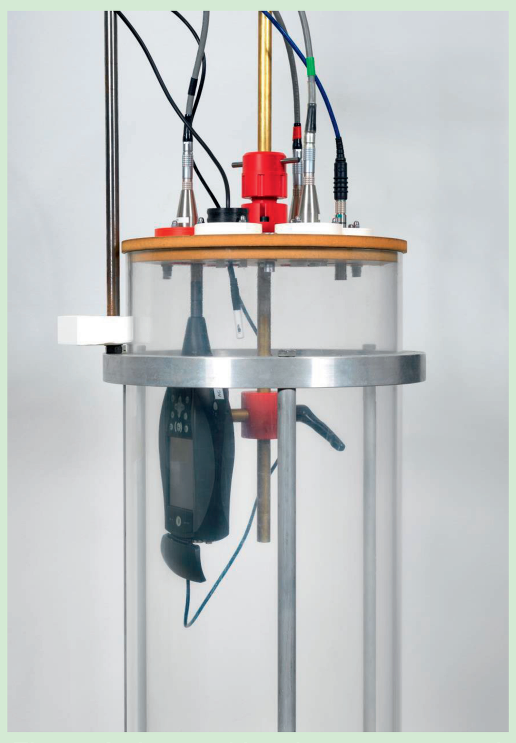

Figure 3: A sound level meter mounted in the tube for secondary calibration.

A primarily calibrated microphone serves as the reference in the secondary calibration setup which transfers the unit to field devices such as sound level meters. Both the reference microphone and a device under test (DUT) are placed in a closed chamber and subjected to a low-frequency alternating pressure. The sensitivity of the DUTis determined by comparison to the reference.
The setup allows to apply different vent positionings as required by the specific DUT. The dimensions of the tube (30 cm in diameter, 1.1 m in length) provide enough space for a variety of sensors such as microphones, sound level meters and even microbarometers.

The system works well in the frequency range between 0.5 Hz and 100 Hz. As an example, Figure 4 shows the result of the calibration of a microbarometer CEA/DASE MB2005. Microbarometers of this type are deployed in the infrasound stations belonging to the International Monitoring System (IMS) of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) which are located around the world.

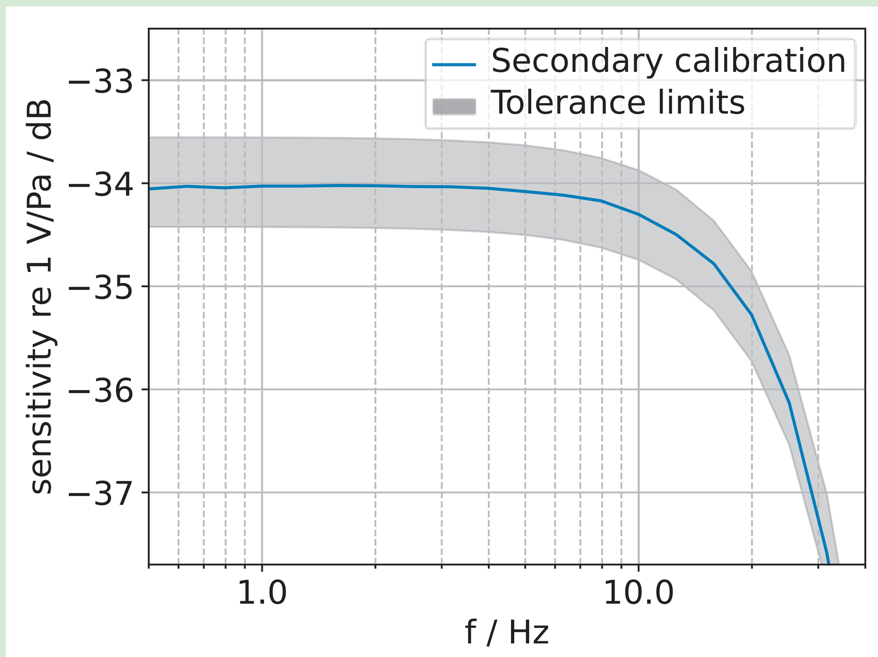


Figure 4: Calibration result of a MB2005 microbarometer plotted over the tolerance limits as stated by the manufacturer.

## Summary & Outlook

A novel primary and a secondary calibration method have been developed for application in low-frequency and infrasound frequency range between 0.1 Hz and 5 Hz and 0.5 Hz and 100 Hz, respectively. Uncertainties down to 0.2 dB can be reached which is comfortable for all applications in environmental noise measurement. When combined with common reciprocity calibration, which is available down to 2 Hz, traceability is provided without gaps between 0.1 Hz and the audible frequency range. Nevertheless, both setups presented may be improved. The influence of streaming and other impacting factors on the carousel method are under investigation to increase the upper limit of the exploitable frequency range of the novel method. Moreover, there is potential for extension to lower frequencies. The sound tube plays a major role in disseminating the calibration results. Its internal volume allows managing nearly all practically relevant sensors. Currently deployable down to 0.5 Hz, improvements regarding the sealing of the tube shall decrease this limit to about 0.1 Hz in the near future.
The newly developed calibration facilities enable establishing the complete traceability chain from infrasound to audible sound. They allow reliable and most notably traceable measurements in the complete frequency range which is particularly relevant for environmental investigations. They form the objective basis for noise exposure determinations for example at sites with renewable energy converters. The methods currently become a part of metrological services of PTB, thus, calibrations will be offered to customers worldwide.

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