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Status of national standards
Acoustics and Ultrasonics
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Feasibility study for a primary free-field microphone calibration technique in the low ultrasonic frequency range

Today ultrasound is extensively used in industrial and medical applications. Evidence on the harmful health effects of exposure to ultrasound suggests that caution should be taken in its use, but until now no internationally agreed limits exist. In order to establish appropriate limits and to test the output of ultrasound devices there is a need for the realisation of the unit of sound pressure in the frequency range from 20 kHz to about 150 kHz. A preliminary study of a primary free-field calibration technique for quarter-inch microphones with the reciprocity method had been carried out at the PTB. The first step was the measurement of the output signal of a Brüel & Kjaer microphone type 4135 used as a sound source. In the measurement set-up two microphones 4135 were located face-to-face in an anechoic chamber. A comparison of the experimental difference between signals corresponding to two different distances (10 cm and 20 cm) and the difference predicted theoretically resulted in a good agreement. The measurements showed a good reproducibility and a sufficient signal to noise ratio. These results are encouraging to start the development of a suitable reciprocity calibration method.

Phase calibration of hydrophones: time-delay spectrometry and broad-band pulse technique using an optical reference hydrophone

To date, primary and secondary hydrophone calibration techniques provide the amplitude of the hydrophone sensitivity of internal standards or for a calibration service. In many applications precise and reliable measurements are, however, impeded by the non-ideal transfer characteristic of the hydrophone. Deconvolution procedures can be applied for data correction requiring, however, that the complex sensitivity of the hydrophone be determined.

In PTB's Ultrasonics and Medicine Working Group two generally different methods were developed providing the complex hydrophone sensitivity. In the first technique time-delay spectrometry (TDS) is used to compare the phase response of the hydrophone to be calibrated with that of a standard hydrophone. This procedure is, however, lacking a suitable 'absolute' phase standard. The second method applies nonlinearly distorted, focused ultrasound pulses to the hydrophones also providing a comparison of phase responses. With the help of this technique, an optical multilayer hydrophone showing an extremely flat amplitude and phase response could be exploited as a phase reference. Transfer standard devices were calibrated for application by TDS since the pulse technique is limited to small diameter hydrophones.

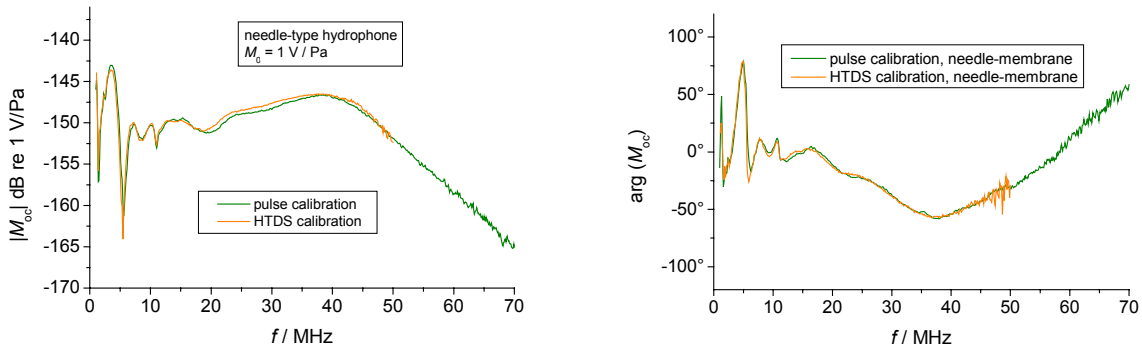

Fig. 1. Amplitude (left) and phase (right) of sensitivity of a needle-type hydrophone (∅ 0.2 mm) obtained with HTDS and pulse technique using the optical hydrophone.

To show the performance of the methods, a needle-type hydrophone with a sensor diameter of 200 µm was calibrated by TDS and the pulse technique in the frequency range from 1 to 50 MHz (70 MHz) (Fig. 1). An excellent agreement between the results was obtained even at higher frequencies. The data could be used for the correction of hydrophone measurement data obtained from investigating a commercial diagnostic device. A significant deviation of the corrected values from the original ones was observed proving the high relevance of deconvolution procedures, i. e. phase calibration data.

Development of transfer standard devices for ensuring the accurate calibration of ultrasonic physical therapy machines in clinical use

Physical therapeutic ultrasound equipment is widely applied to patients. However, many devices do not comply with the relevant standard stating that the actual output shall be within ± 20 % of the device indication. Extreme cases have been reported: from delivering effectively no ultrasound up to twice the amount indicated which can potentially lead to patient injury as well as mistreatment.

To improve this situation, an international collaborative project involving four participants and funded by the European Commission under the 5th Framework Programme has been started. The aim is to develop and establish a portable ultrasonic power standard traceable to NMIs and to be used at manufacturers, hospitals and other parties in order to check their ability to undertake correct ultrasound therapy device testing. Frequencies from 1 to 3 MHz and ultrasonic power values from 100 mW to 15 W are covered.

TNO/NL is the project coordinator and is responsible for the ultrasonic transducers, CSIRO/AU for the electronic drivers, NPL/UK for cavitation detectors and PTB/DE for the fundamental power measurement of the devices. The intended application is as follows: The key parameter values for each individual test are selected by the NMI and loaded into the device memory. The portable power standard is then sent to the laboratory under test and is to be used for "blind" ultrasonic power measurements the results of which have to be reported and can then be compared by the NMI with the prefixed values.

All devices have been fabricated and measured. Practical field tests have still to be undertaken and regulatory documents to be written. The fundamental power measurements for all devices have been performed by PTB along the lines, and using the measuring instruments, of the recent ultrasonic power key comparison. Some of the transducers failed during the measurements and were replaced but finally, the general objective of a temporal power stability of better than ± 3 % was met. The portable ultrasound power standard appears to be promising.