Physikalisch-Technische Bundesanstalt (PTB) 12 August 2002
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Development and improvement of national standards
Acoustics and Ultrasonics
(cf. draft agenda of 14/05/02, item 12.1)

Extension of the calibration technique for microphones to the ultrasonic frequency range
Ultrasonic devices find a wide-spread use in medical and industrial applications such as ultrasonic cleaning and welding, surgery instruments in hospitals, driving aids in automobile engineering, tightness tests for windows and distance meters in the building trade or pest control in gardening. The question is whether or not the radiated sound pressure of these devices might be harmful to the human ear. Until now, no internationally agreed limits exist. In order to establish appropriate limits and later on to test the output of the respective devices, it is necessary to develop a precise measuring technique including a calibration procedure for the measurement microphones (of IEC type WS3) used for the frequency range 25 kHz to about 200 kHz. At PTB the development of two calibration techniques are under consideration: Free-field reciprocity and interferometry.

Secondary calibration technique using ultrasonic loudspeakers
In the frequency range of human hearing free-field microphones and sound level meters are usually calibrated by means of the substitution method. In an anechoic room, a reference microphone and the device under test are successively placed in the same position in front of a loudspeaker and the output voltages are measured. By means of the known free-field sensitivity level of the reference microphone the sensitivity level of the device under test can be calculated.
At present it is evaluated at PTB, whether a similar or a modified test procedure with reasonable low measurement uncertainty can be applied for ultrasonic frequencies in air. A loudspeaker for frequencies up to about 120 kHz is tested using laser interferometry with a tomographic data evaluation. Difficulties are expected due to the facts that in this frequency range the loudspeaker as well as the microphones show sharp peaks in their directivity characteristics, the anechoic room may not be perfect at all test frequencies, the attenuation of sound propagation in air depends on frequency and the climatic parameters of the devices are still unknown.

Primary calibration of hydrophones using optical interferometry
In the years passed, the primary calibration technique for hydrophones at PTB was based on the reciprocity method in the frequency range 0.1MHz to 20MHz. Its extension to higher frequencies proved to be difficult because of the low signal to noise ratio. Therefore, a laser interferometric technique was built up, the efficiency of which could already been proven in connection with the recent CCAUV key comparison. In the meantime the frequency range could essentially be enlarged up to 50 (70)MHz. Its basic arrangement and procedure is as follows. The laser beam is incident from the air-backed side, and the interferometer determines the displacement of the pellicle which is mounted at the surface of the liquid and which is exposed to the sound field. To obtain sufficient signal strength, the acoustic field is generated by focussing transducers. The error caused by averaging over the spot

area and the frequency dependend transmission of the pellicle are corrected by numerical calculation. In the second step, the known acoustic field is measured with a membrane hydrophone to be calibrated. The frequency range in which suitable results can be obtained extends from 1MHz to 50 (70)MHz. Because another independent reference method in the frequeny range 20MHz to 50MHz is not available, a model describing the sensitivity and the electrical properties of the membrane hydrophones was prepared, and the comparison with the experimental results shows good agreement. The total uncertainty (95% confidence level) turned out to be 4MHz: 8.5%, 20MHz: 8.5%, 30MHz: 11.1% and 40MHz: 12.9%. Beyond 50MHz the uncertainty is >15%.

Optical multilayer hydrophone with constant frequency response in the range from 1MHz to 75MHz

Besides the improvement of the interferometric standard for hydrophone calibration an optical multilayer hydrophone was developed which is well suited for use as a reference for secondary hydrophone calibration. The optical measurement system comprises a thin high-finesse dielectric interference filter structure that is deposited onto a plane glass plate. The incident acoustic pressure wave deforms the layer system, and the induced variation of the optical reflectance is determined. The above mentioned primary interferometric calibration technique is applied to experimentally determine the pressure-voltage transfer function in the range from 1MHz to 75MHz. Within the measurement uncertainty a constant transfer factor is obtained for the whole frequency range. Measurements of broadband ultrasound pulses are influenced neither by acoustic resonances of the very thin sensing element nor by diffraction phenomena that are known to cause waveform distortions in small probe hydrophone measurements. In this device, high temporal and spatial resolution is combined with high durability of the probe.