Feasibility study for a primary free-field microphone calibration technique in the frequency range 20 kHz to 200 kHz

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Abstract: Today ultrasound is extensively used in industrial and medical applications. Evidence on the harmful health effects of exposure to ultrasound in air 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 developing reliable sound pressure measurements in air in the frequency range from 20 kHz to about 200 kHz. The aim is the development of a primary free-field calibration technique for microphones in this frequency range with ¼-inch microphones using the reciprocity method. Before starting the development of this method which is complex and time consuming, measurements of the output signal of a Brüel & Kjaer ¼-inch microphone acting as a sound source and electrostatic actuator calibration experiments were made as the first step of this project.

Introduction

The standard of sound pressure is defined by means of the sensitivities of one-inch and half-inch laboratory standard condenser microphones, calibrated with the reciprocity method [1]. But these two microphone types have a limited frequency range (maximum frequency 50 kHz for ½-inch microphones and 25 kHz for 1-inch microphones). In the PTB a project for the calibration of quarter-inch microphones by the reciprocity method has been started; thus extending the frequency range from 20 kHz to about 200 kHz. This method is based on the measurement of the electrical transfer impedance, of the effective distance between microphones and of the sound absorption in air. Before starting the development of a practical implementation the output signal of the B&K ¼-inch microphone used as a sound source, and its electrostatic actuator calibration were investigated.

Investigation on a ¼-inch microphone used as a sound source

In the measurement set-up two free-field microphones 4135 were located at a distance *d* from each other in an anechoic chamber of dimensions 7 x 4,5 x 6,5 m (volume of 203 m^3).

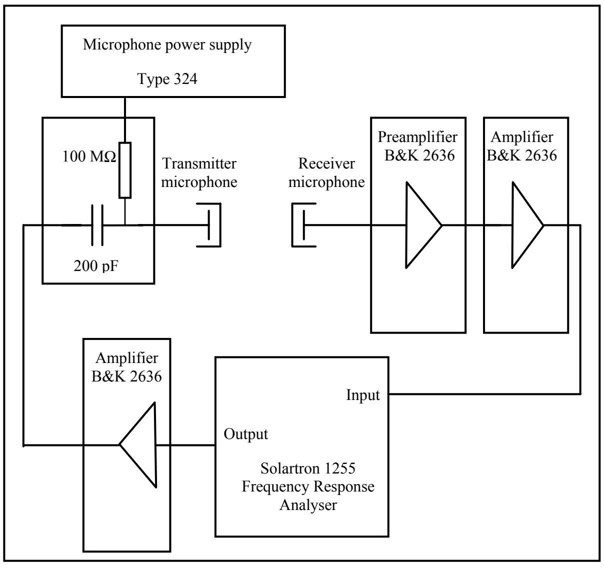

Figure1: Experimental arrangement

The free-field microphones B&K 4135 are used without protecting grid and with adapters ½-inch to ¼-inch B&K UA0035. A SOLARTRON 1255 Frequency Response Analyser was used as generator and as analyser. A polarising DC voltage of 200 V was applied to the transmitter microphone through a resistor of 100 MΩ. A constant AC voltage of 10 V was applied through a 200 pF capacitor to excite the transmitter microphone (Figure 1). Figure 2 represents the results of the output voltage of the receiver microphone B&K 4135 in the case of *d*=5cm, as a function of frequency from 20 kHz to 200 kHz.

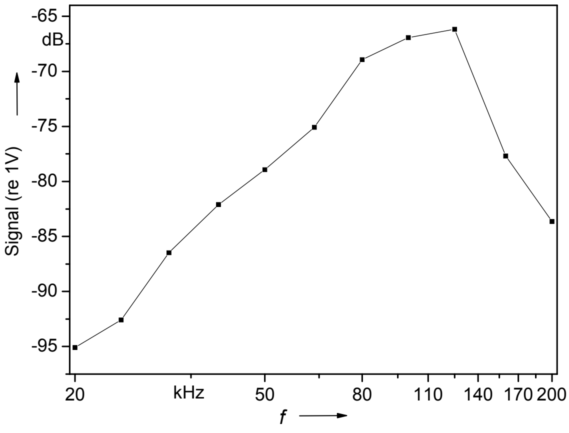

Figure 2: Output voltage of the receiver microphone B & K 4135 when the transmitter microphone is excited by an AC voltage of 10 V in the case of a distance d=5cm.

The measurements showed a good reproducibility and a sufficient signal to noise ratio (more than 60 dB for the whole frequency range used). The output signal as a function of the distance between the transmitter and receiver microphones is shown in figure 3. A comparison with the 1/r-law shows that at higher frequencies and for larger distances the attenuation of sound in air must be taken into account. The attenuation was calculated according to the formulas given in ISO 9613-1 [2] for the frequencies 40, 100 and 160 kHz (relative humidity *H=46%*, temperature *T=22,7 °C*). The good agreement between measurement and theory proves that the assumption of free-field conditions in the anechoic room used for the experiments is justified for these frequencies.

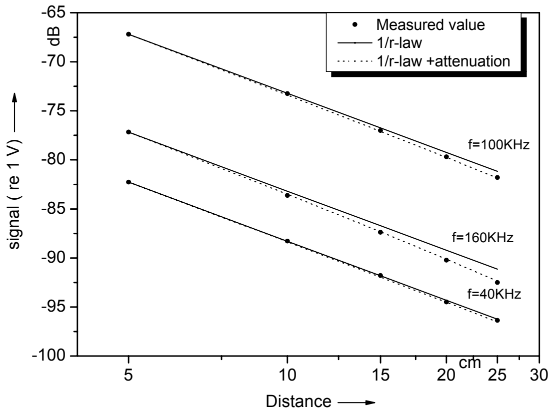

Figure 3: Measured output signal as a function of the distance between the transmitter and receiver microphones and comparison with theory.

Uncertainty of electrostatic actuator calibrations

Before starting the development of the reciprocity method, which is a complex and time consuming process, electrostatic actuator calibrations have been performed in order to be able to detect quickly whether the microphone‘s sensitivity has changed or not. The actuator method [3] is well suited for the measurement of the relative frequency response, and has been used as a simple, rapid and low cost method of determining the frequency response of microphones for frequencies up to 150 kHz. The sensitivity of microphones at a reference frequency is measured by using for example, a pistonphone, and the actuator is used for the determination of the frequency response relative to this frequency.

The electrostatic actuator B&K UA0033 is used for the calibration of a ¼-inch microphone B&K 4939 in the audio and ultrasonic frequency range. The experimental arrangement of the actuator measurement set-up is shown in Figure 4. An actuator voltage supply B&K WB 0736 WH 2942 generates 800 volts DC and 30 volts AC supplied to an actuator used with an adaptor for ¼-inch microphones. The free-field microphone B&K 4939 is used in this measurement with an adaptor ½-inch to ¼-inch B&K UA0035.

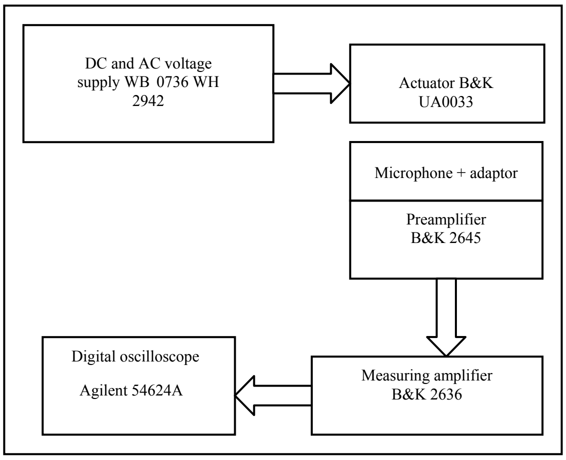

Figure 4: Schematic diagram of measurement set-up for electrostatic actuator measurements.

Figure 5 shows the actuator response for a ¼-inch microphone B&K 4939 in the frequency range100 Hz-200 kHz relative to the actuator response at 250 Hz. The maximum standard deviation under repeatability conditions on 10 different days is 0,05 dB up to 20 kHz and 0,15 from 20 kHz to 200 kHz. The standard uncertainty calculated as the square root of the sum of the square of the repeatability standard deviation and of the square the crosstalk error, results in 0,24 dB for 160 kHz. The uncertainty, based on the standard uncertainty multiplied with coverage k=2 (providing a confidence level of approximately 95%) [3], is estimated to be less than 0,5 dB up to 160 kHz (figure 5).

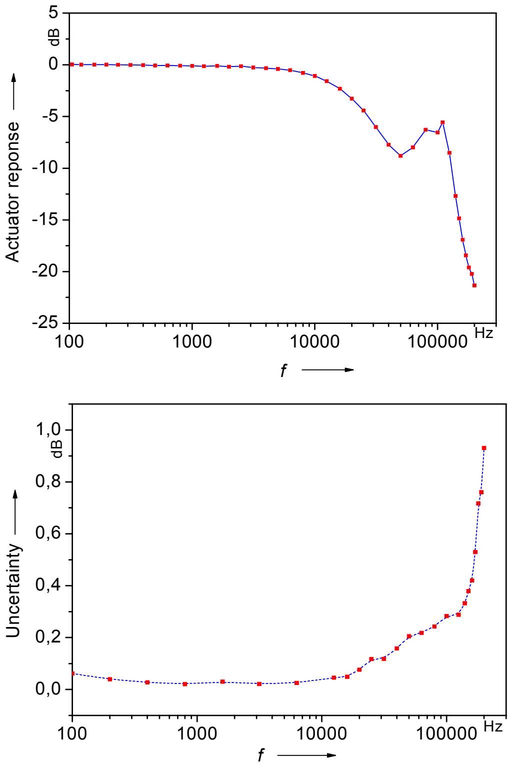

Figure 5: Actuator response of ¼-inch microphone B&K 4939 and its uncertainty.

Conclusion

Studies on the use of a ¼-inch microphone for generating sound in free-field reciprocity set-up and its electrostatic actuator calibration have been performed. The measurements showed a good reproducibility and a sufficient signal to noise ratio with good agreement between theory and experience. These results are encouraging to start the development of a suitable reciprocity calibration method.

References

[1] IEC 61094-3, Measurement microphones – Part 3: Primary method for free-field calibration of laboratory standard microphones by the reciprocity technique.

[2] Attenuation of sound during propagation outdoors – Part 1: calculation of the absorption of sound by the atmosphere, ISO 9613-1: 1993.

[3] IEC CDV 61094-6: 2003, Measurement microphones – Part 6: Electrostatic actuators for determination of frequency response.