Influence of the static pressure on the sensitivity of ¼-inch condenser microphones

T. Fedtke, N. Bouaoua, M. Brandt
Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany, thomas.fedtke@ptb.de

1. Introduction

The sensitivity of condenser microphones depends on the environmental conditions (static pressure, temperature, humidity). Variations in the environmental conditions will change the acoustic properties of the air between the diaphragm and the back-plate of the condenser microphone. To achieve a precise and repeatable free-field reciprocity calibration of ¼-inch condenser microphones, the measurements should be carried out in a controlled environment (23 °C and 101.325 kPa). Because of the variation of the static pressure inside the anechoic room, a microphone sensitivity correction for the changes in static pressure is required. The corrections for the influence of the static pressure on the sensitivity of 1-inch and ½-inch condenser microphones have been studied by different authors, see e.g. [1], [2]. It was reported that, over the static pressure range from 94 kPa to 106 kPa, the sensitivity levels of the ½-inch microphone of type B&K 4180 and GRAS 40AG changed by 0.05 dB at 1 kHz and 0.12 dB at 20 kHz [2]. Therefore, the determination of a sensitivity correction for ¼-inch microphones seems to be necessary.

2. Electrostatic actuator calibration

The actuator method is well-suited for the measurement of the relative frequency response of condenser microphones. Combined with the measurement of the absolute sensitivity at one frequency point, usually by means of a sound calibrator, it provides a rather simple, quick and low-cost procedure for determining the frequency response of microphones.

An electrostatic actuator is a metallic grid placed very close to the microphone diaphragm. An alternating voltage biased by a high direct voltage is supplied between the diaphragm and the actuator, and thus, an electrostatic force is produced and acts on the microphone diaphragm as a sound pressure.

An electrostatic actuator B&K UA0033 was used in the experimental arrangement as shown in Fig. 1. By means of an actuator voltage supply B&K WB 0736 WH 2942 a superposition of 800 V (DC) and 30 V (AC) was supplied to the actuator which was used with an adapter for ¼-inch condenser microphones. The free-field microphones B&K 4939 were used in this measurement with an adapter ½-inch to ¼-inch type B&K UA0035. Fig. 2 shows the actuator response for a ¼-inch microphone B&K 4939 in the frequency range from 100 Hz to 200 kHz relative to the actuator response at 250 Hz.

Because of the relatively small dimensions the microphone with the actuator can be placed in a pressure vessel for the determination of the static pressure coefficients.

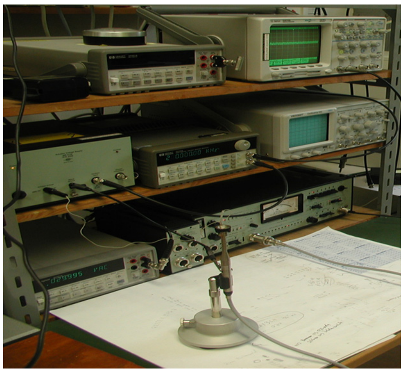

Fig. 1: Photo of a measurement set-up for electrostatic actuator calibration

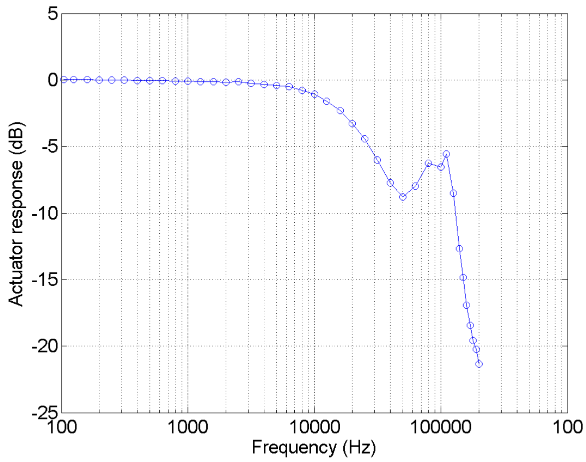

Fig. 2: Electrostatic actuator response of a microphone B&K 4939

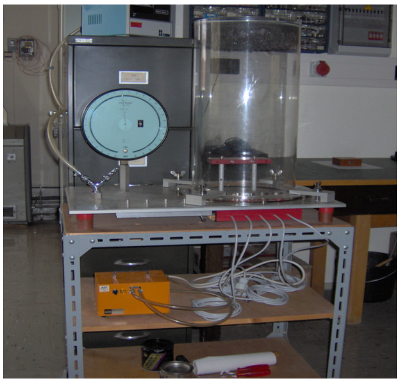

Fig. 3: Photo of the static pressure vessel

3. Static pressure coefficients

The change in the output voltage of three ¼-inch microphones of type B&K 4939 (Serial numbers 2389646, 2389698 and 2389701) was measured by means of an electrostatic actuator calibration at five static pressures in the range from 90 kPa to 105 kPa in a closed pressure vessel (Fig. 3).

The microphone sensitivity corrections for each frequency were calculated for these pressures in the frequency range from 0.25 kHz to 150 kHz, by subtraction of the sensitivity at the reference static pressure of 101.325 kPa from the sensitivities at these pressures (Fig. 4). From 90 kPa to 105 kPa, the variation of the sensitivity was about 0.1 dB at 5 kHz and approximately 0.45 dB at 150 kHz. The maximum variation was observed at 95 kHz, being 2.95 dB.

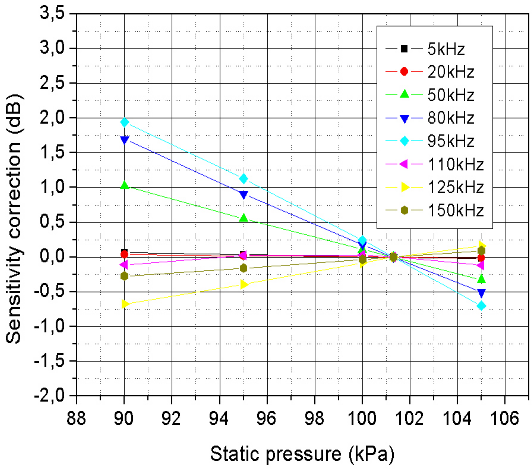

Fig. 4: Sensitivity correction as a function of the static pressure.

The pressure coefficients shown in Fig. 5 were determined at each frequency by a straight-line interpolation of the calculated sensitivities, defined as gradients of these lines and expressed in dB/kPa. The straight line was fitted by an ordinary least square method programmed with Matlab. The maximum pressure coefficient for the three microphones was found at 95 kHz; the corresponding maximum is about 0.2 dB/kPa.

4. Empirical equation for the static pressure coefficients

In order to know the static pressure coefficients at any frequency, and to derive an expression valid for this type of microphones, the results of the pressure coefficients variation over frequency were approximated by a polynomial interpolation of fourteenth order for each microphone. The static pressure coefficients can be calculated from the empirical equation

$$\delta_{Static\,Pressure} = a_0 + a_1 \cdot f + a_2 \cdot f^2 + \ldots + a_{14} \cdot f^{14}$$

Table 1 gives the average value for the resulting polynomial coefficients a_0-a_{14} . The graph of this equation of the static pressure coefficients is shown in Fig. 5.

Table 1: Polynomial coefficients for the empirical equation for of the static pressure correction

Coefficient a_i	
a_0	$-2.40\ 10^{-25}$
a_1	$2.64\ 10^{-22}$
a_2	$-1{,}29\ 10^{-19}$
a_3	$3{,}71\ 10^{-17}$
a_4	$-6{,}94\ 10^{-15}$
a_5	$8{,}87\ 10^{-13}$
a_6	$-7{,}92\ 10^{-11}$
a_7	$4{,}96\ 10^{-9}$
a_8	$-2.16\ 10^{-7}$
a_9	$6.36\ 10^{-6}$
a_{10}	$-1.20\ 10^{-4}$
a_{11}	$1.36\ 10^{-3}$
a_{12}	$-8.00\ 10^{-3}$
a_{13}	$1.91\ 10^{-2}$
a_{14}	$-1.24\ 10^{-2}$

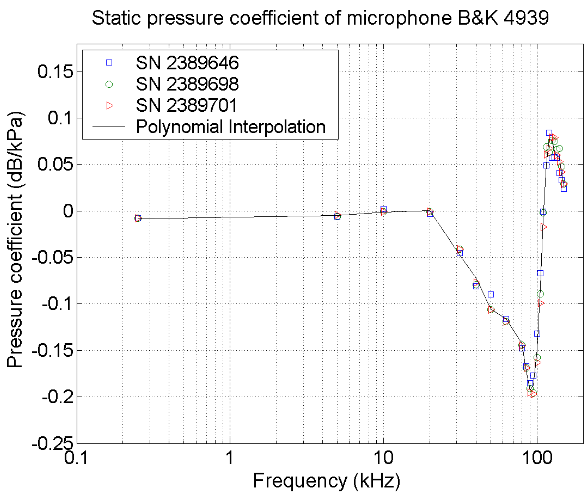

Fig. 5: Static pressure coefficients – polynomial interpolation

5. Conclusions

The pressure sensitivity coefficients for three ¼-inch condenser microphones type Brüel and Kjær 4939 were determined inside a closed pressure vessel over the barometric pressure range from 90 kPa to 105 kPa by using the electrostatic actuator method. The maximum static pressure coefficient was 0.2 dB/kPa at 95 kHz. An empirical equation for the average static pressure coefficient for this type of microphone has been developed. Further investigation will be needed for an uncertainty analysis of the static pressure correction.

References

[1] Rasmussen, K., ''The influence of environmental conditions on the pressure sensitivity of measurement microphones'', B&K Technical review No 1, 2001, 1-13.

[2] Wu, L., Wong, G.S.K., Hanes, P., Ohm, W., ''Measurement of sensitivity level pressure correction for LS2P laboratory standard microphones'', Metrologia **42** (2005), 45-48.