Measurement of static pressure coefficient of laboratory standard microphones at low frequencies by primary method for pressure calibration of microphones

Merita Sinojmeri
Bundesamt für Eich und Vermessungswesen, Arltgasse 35, 1160 Wien, Austria
Email: m. sinojmeri@metrologie.at

The calibration system for measuring the pressure sensitivity of laboratory standard microphones is described. The influence of environmental parameters as static pressure, temperature and humidity on the measurement uncertainty is shown. The static pressure coefficients of LS1 laboratory standard microphones at a frequency range 2 - 250 Hz, were measured by the pressure reciprocity technique in a pressure controlled environment. There are several models proposed which practically simplify the frequency dependence of static pressure coefficient to a single frequency function. The analysis of the experimental results from the point of view of best approach is presented.

Introduction

The realisation of airborne sound pressure unit Pascal is done through the primary calibration of condenser microphones. The accuracy of this method is dependent on the voltage, condenser, frequency, pressure, temperature and humidity units. The last units determine the acoustic properties of the medium in which the microphone is situated. That is the reason why the unit of sound pressure determined indirectly from the transducer microphone transfer factor [V/Pa] is recommended [5] to be given under the reference conditions.

This means the Primary Laboratories should maintain this conditions in order to have the highest accuracy. Due to the fact that these conditions are not always possible to maintain and also from the point of view of dissemination of this unit, the dependence coefficients of the microphone transfer factor from the environmental parameters is necessary to be determined. The study of these coefficients helps our understanding on the behaviour of the acoustical standards, the condenser microphones as well as considering the uncertainty components.

In [6] the static pressure coefficient is determined using the static actuator method for microphones B&K type 4144 in order to be used for the microphones B&K type 4160 as laboratory standard microphones. This paper describes the experience using the reciprocity method for determining static pressure coefficients.

Theoretical considerations

The electromechanical model of a microphone is a well known model for explaining the behaviour of the microphone.

For laboratory standard microphones the equivalent circuit is presented in [1]. The parameters describing the microphone are given by the manufacturer for a certain type of microphone.

The microphone is represented as an electrical equivalent circuit of the diaphragm, the air film between the diaphragm and the back electrode, the holes and slits of the back electrode and the air volume behind it, the so called back cavity.

The pressure equalisation system is situated between the diaphragm and the back electrode which plays a significant role for frequencies below 5 Hz.

A theoretical approach of the behaviour of microphone at low frequencies is described in [1,6]. The influence of pressure equalisation vent was considered [6] as an active resistance which can be derived from the cut-off frequency f_L.

The mathematical simulation of the model shows a linear correlation between sensitivity and static pressure in the range of 80-115 kPa for a given frequency and for static pressure coefficient a function of frequency as well as function of mechanical parameters of the microphone like for e.g. surface tension or density of membrane.

Calibration system

The pressure reciprocity calibration method is based on the international standard [2]. In short this method is based on the reciprocity feature of the condenser microphones. The microphones are measured pair wise against each other using couplers in between which realise a uniform sound pressure over the microphone membrane. The sensitivity product which is measured is given as a function of electrical and acoustical properties, means as function of the parameters mentioned in the paragraph 1. The calibration equipment which realises this method is the B&K Type 5998 which includes the low frequency option. The system is equipped with a closed chamber in which the microphones with preamplifiers and coupler are situated. This chamber was placed in a vibration isolated table. The chamber volume is extended with another container volume and this system is pressure controlled. The multimeter Datron Type 1281 was used for voltage measurements. Band pass filter B&K Type 1617 as well as B&K Type 1051 signal generator were part of the system.

Experimental results

Three triplets of B&K 4160 microphones were measured. The uncertainty of static pressure measurements was 0,03 kPa, the temperature was measured inside the coupler corpus with a PT100 with an uncertainty 0,1 °C.

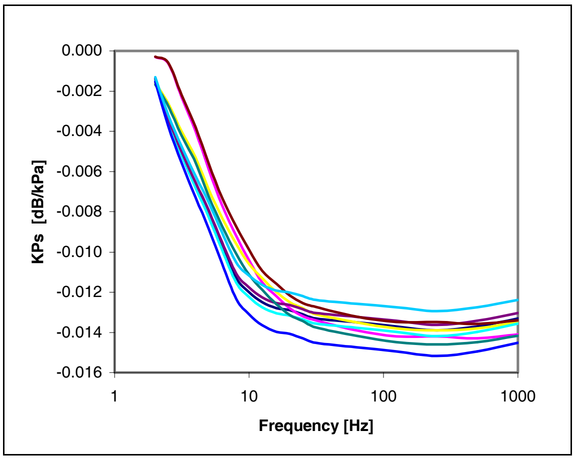

Figure 1. Modulus of the static pressure coefficients of nine microphones type B&K 4160

The environmental parameters were monitored during electrical measurements. The complete pressure reciprocity calibration was performed at 5 different static pressures in the range 90 kPa to 110 kPa, with a gradient during the measurements of +/- 0,02 kPa, keeping the constant temperature 23 °C ± 0.5 °C. At this static pressure range the results seem to be linearly correlated so the conventional linear regression was performed to determine the static pressure coefficient. The correlation coefficient was greater than 0.98 except the 2 Hz frequency where the static pressure coefficient is very small.

The modulus of the static pressure coefficient $K_{Ps} = (\frac{\partial S}{\partial P})_T$ of these microphones as function of frequency, are given in the figure 1.

Analysis of experimental results

The results in the figure 1 are presented for frequencies up to 1 kHz in order to be compared with the published ones [4]. The results show a very good agreement for the microphones B&K 4160. The theoretical approach simulated in PC appear to be very similar with the experimental one, which means that this model is not far from the reality and can be used as a model function for fitting the experimental values. In this way a relative simple function was found which correlates the values of static pressure coefficient in the region of 2-250 Hz. The fitting function for the static pressure coefficient in the region mentioned above is given in the equation (1) below

$$K_{Ps} = \frac{a + b * \ln(f)}{\log(f / f_L)} \qquad (1)$$

where the constants a and b are respectively
–0.0071 ± 0.0004 and 0.0055 ± 0.0015 in the case of the batch of microphones which were measured. In order to determine the respective function for a certain microphone it is necessary at least one static pressure value for e.g.
250 Hz as well as cut-off frequency.

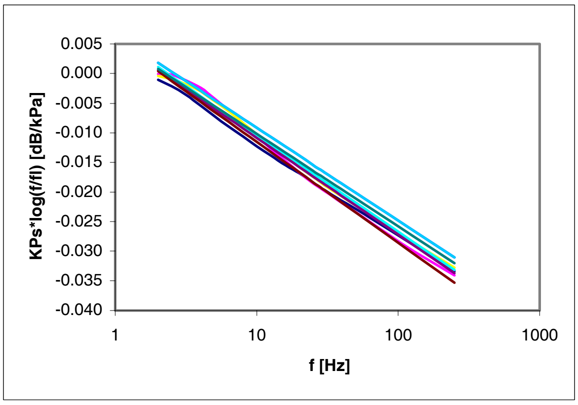

Figure 2. Modified modulus static pressure coefficient for measured microphones Type B&K 4160

Conclusions

The presented results are valid only for the static pressure interval 80 - 115 kPa. The microphones even from the same type have practically different mechanical parameters like for e.g. diaphragm surface tension or density and it is impossible to find a unique function for all microphones to represent all the results of the static pressure coefficient. Depending on the measurement uncertainty the spread might not be relevant but the user should be aware of it. The function which was taken here as fitting function for the results of the microphones measured shows a certain spread for the constants a and b. These constants can be more precisely determined for a certain microphone when at least one value of static pressure in this interval of frequency is known as well as cut-off frequency. For this reason the calibration laboratory performing the low frequency sensitivity measurements of the microphones should measure and give the results of static pressure coefficient at one or more frequencies as well as the cut-off frequency, in analogy with the normal frequency measurements when the resonance frequency is also given.

References

1. H. Gerber, “Acoustic properties of fluid filled chambers at infrasonic frequencies in the absence of convection”. J. Acoust. Soc. Am. 36, 1427-1434

2. IEC 61094 Measurement microphones - Part 2: Primary method for pressure calibration of laboratory standard microphones by the reciprocity technique, 1992

3. Handbook of condenser microphones: Theory, calibration and measurements. AIP Press, NewYork, 1995

4. K. Rasmussen. “The static pressure and temperature coefficients of laboratory standard microphones”, Metrologia, 1999, 36, 265-273

5. G. Wong , L. Wu “Controlled environment for reciprocity calibration of laboratory standard microphones and measurement of sensitivity pressure correction, Metrologia 1999,36,275-280

6. R. Kosobrodov, S. Kuznetsov. “Static pressure coefficients of laboratory standard microphones in the frequency range 2-250 Hz., Eleventh Int. Congress on Sound and Vibration, 5-8 July, 2004, St. Petersburg, Russia