On the primary calibration of measurement microphones in diffuse-field

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Abstract: Primary calibration of measurement microphones is already performed in pressure and in free-field, but it is under research in diffuse-field. In this paper, a proposed procedure to perform primary calibration in diffuse-field is presented. In the proposal, microphones are coupled using a reverberation chamber, the electrical transfer impedance is obtained from measurements performed at different positions and the acoustic transfer impedance is obtained from reverberation time. A comparison with an alternative method shows differences lower than 0.6 dB and supports the viability of the proposal, but only a comparison between primary calibrations can tell if it works to the satisfaction.

Keywords: Measurement microphone; primary calibration; diffuse-field.

1. INTRODUCTION

Calibration of a measurement microphone usually consists in determines its sensitivity as function of frequency, i.e., the ratio between the output voltage and the incoming sound pressure. At low and medium frequencies (20–1000 Hz), it is nearly independent of the surrounding sound field, but at high frequencies (> 1000 Hz) it changes according to the sound field [1,2,3]. So, when is necessary to calibrate a microphone, it should be made in a sound field similar to one that it is expected that the microphone will be used. For microphone calibrations, there are three different standardized sound fields: pressure, free- and diffuse-field. In pressure field, the sound wave has the same magnitude and phase in any position on any section of the sound field, for example, on a diaphragm of a microphone coupled to a sound source creating a small closed cavity. In free-field, the sound wave comes from one direction, free of any disturbance. Lastly, in diffuse-field, sound waves come from all directions simultaneously, with equal probability and magnitude. Figure 1 illustrates these three conditions [1].

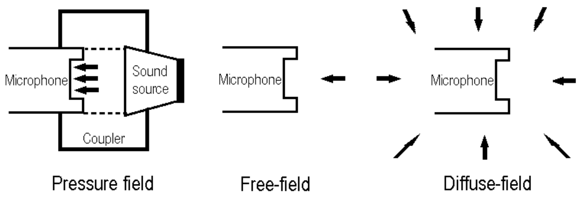

Figure 1. Sound fields for microphone calibration.

In pressure and free-field, primary calibration of microphone is already performed [4] and so, the secondary calibrations' traceability is well structured [5]. On the other hand, in diffuse-field, primary calibration is under research [4] and the secondary calibrations' traceability is based in corrections to pressure or free-field sensitivity; or in measurements performed in free-field with the sound wave coming sequentially from different directions [3,5]. In this paper, a proposal to perform primary calibration in diffuse-field is presented.

2. MICROPHONE CALIBRATION BY THE RECIPROCITY METHOD USING THREE MICROPHONES

Primary calibration of measurement microphones is usually performed by the reciprocity method [6,7,8]. It could be carried out by means of three microphones or by means of an auxiliary sound source and two microphones, the former being the most common. In the reciprocity method using three microphones, they are combined in pairs, one microphone being used as a sound source and the other as a sound receiver. When the microphones are acoustically coupled, the electrical and acoustic transfer impedances between them are measured. Figure 2 illustrates that procedure. From these measurements, the product of the sensitivities of the coupled microphones can be determined. From the wise combinations of the microphones, three mutually independent products are available, from which an expression for the sensitivity of each of the three microphones can be derived.

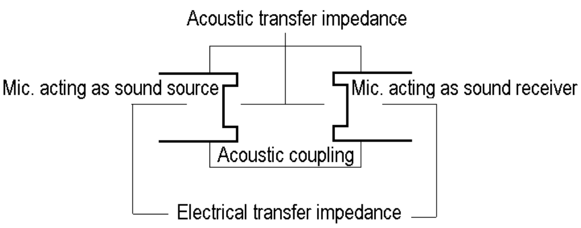

Figure 2. Procedure for primary calibration by reciprocity.

For pressure field calibration, microphones are usually coupled using plane wave couplers; for free-field calibration, using an anechoic chamber; and for diffuse-field calibration, using a reverberation chamber.

3. PROPOSED PROCEDURE

The electrical transfer impedance is obtained from the average of measurements performed at twenty-four different positions in the reverberation chamber. For each position, the transfer-function is measured and the corresponding impulse response is obtained. At that time, reverberation part is selected using a window function and the corresponding frequency response is obtained. Then, the electrical transfer impedance is calculated and smoothed in frequency bands using a sliding window. After this procedure, the spatial average between them is calculated. The gain of the preamplifiers and amplifier are eliminated using the insert voltage technique [7,8].

The acoustic transfer impedance is obtained from chamber's reverberation time. It is measured by the integrated impulse response method [9] using the impulse responses employed in the measurement of the electrical transfer impedance.

4. SETUP, MEASUREMETS AND RESULTS

Three half-inch measurements microphones were calibrated.

A small (1.98 m^3) rectangular reverberation chamber with boundary diffusers [10] was used. Signal generation and measurements were made using the CMF22 platform and signal processing was executed using the software Monkey Forest. Figure 3 shows a photo of the chamber.

Figure 3. Reverberation chamber with boundary diffusers and microphones inside it.

Figure 4 shows the average electrical transfer impedance and figure 5 shows the chamber's reverberation time.

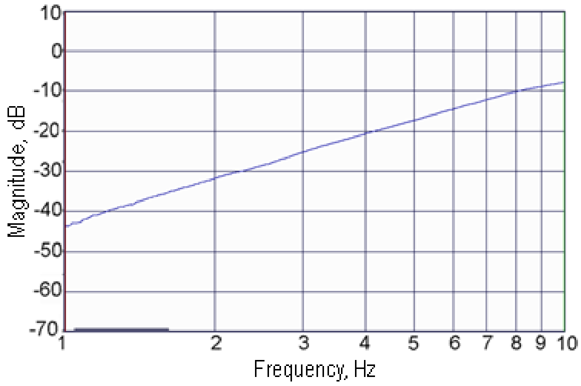

Figure 4. Electrical transfer impedance between a pair of microphones. Average between measurements performed at twenty-four different positions.

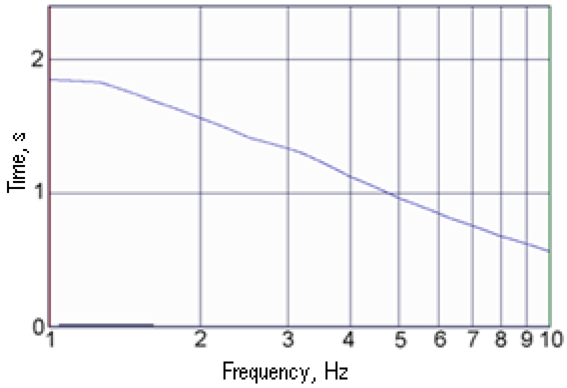

Figure 5. Chamber's reverberation time.

In order to compare the obtained diffuse-field sensitivity with results obtained by an alternative method, the same microphones were calibrated by comparison with a reference microphone whose pressure field sensitivity was corrected to diffuse-field [3]. The diffuse-field sensitivities are presented in figure 6.

It was verified that the differences between the results go from 0.6 dB at the lowest frequency to 0.2 dB at the highest frequency (10 kHz). For frequencies above 10 kHz, no comparison calibration data were available. This results support the viability of the proposal, but only a comparison between diffuse-field primary calibrations can tell if it works to the satisfaction.

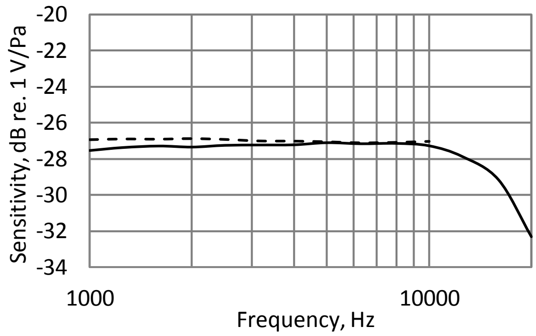

Figure 6. Diffuse-field sensitivities for one of the three half-inch microphones measured. —— sensitivity obtained by the proposed procedure and – – sensitivity obtained by the comparison method.

The expanded uncertainties were estimated as 1.8 dB at lowest frequencies, 0.8 dB at midrange and 1.2 dB at highest frequencies. These uncertainties are high for a primary calibration comparing to the others (pressure and free-field) primary calibrations, although it is expected that they should be higher because the lower signal-to-noise ratio of the electrical transfer impedance's measurements in diffuse-field.

Figure 7 shows the contribution to combined standard measurement uncertainty at 3.15 kHz. It is noted that, the major contribution is the voltage ratio (i.e. the electrical transfer impedance) because of the high standard deviation of the spatial average. The same behavior is seem at other measured frequencies.

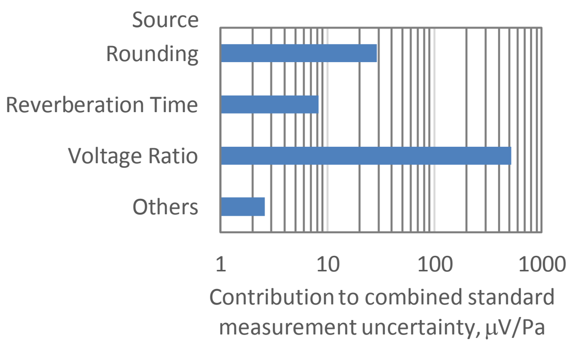

Figure 7. Contribution to combined standard measurement uncertainty at 3.15 kHz.

5. CONCLUSION

A procedure was developed for primary calibration of measurement microphones in diffuse-field by the reciprocity method.

It is important that a comparison between diffuse-field primary calibrations be performed to see if the proposed procedure works to the satisfaction.

It is necessary to make an effort to reduce the estimated expanded uncertainties. One idea is increase the number of positions of the electrical transfer impedance's measurements to decrease the contribution of their standard deviation.

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