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Low frequency calibration of measurement microphones

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Abstract: Due to the more interest in calibration of measurement microphones at infrasound frequencies, this paper presents an overview of important aspects involving microphones' low frequency cut-off and shows the equipment used by Inmetro, the national metrology institute of Brazil, to perform low frequency calibration. Initially, microphones' low frequency cut-off, caused mainly by its static pressure's equalization time constant and by external region to which the equalization vent takes place (facing or not facing the sound field), is discussed. Following, the influence of the preamplifier, caused by its own low frequency cut-off, is showed. At last, calibration at Inmetro is presented.

Keywords: Measurement microphone; calibration; low frequency; cut-off.

1. INTRODUCTION

The interest in microphone calibration at frequencies down to 1 Hz has grown in the last years in many countries. In Brazil, the mining industry has demanded for geophone calibration from 1–250 Hz [1]. Due to these practical needs, the frequency range for primary and secondary calibrations methods is being extended now to the infrasound. This paper presents an overview of important aspects involving microphones' low frequency cut-off and shows the equipment used by Inmetro, the national metrology institute of Brazil, to perform the secondary calibration.

2. MEASUREMENT MICROPHONES' LOW FREQUENCY CUT-OFF

One of the most used measurement microphones is the condenser microphone, which is made to have flat frequency response in a specified type of sound field (pressure, free- or diffuse-field) and in a determined frequency range. Normal low frequency cut-off for many high quality measurement microphones is 3–5 Hz while for infrasound microphones it should be 0.1–0.5 Hz. The lower limiting frequency of a condenser microphone is mainly acoustically controlled by its static pressure's equalization time constant and the external region to which the equalization vent takes place (facing or not facing the sound field) [2,3].

A good measurement microphone should equalize the static pressure as fast as possible in order to cut off unwanted pressure variations, but by closing the vent channel (and thus allowing the leakage to occur only through stray leakage) a very low cut-off frequency is obtained. So, the pressure equalization time constant should be chosen as a compromise between linearity of frequency response and ability to equalize [2,3].

The way the microphone is used is also important. If the opening of the equalization vent is facing the sound field in the measurement situation, the frequency response will be completely different if it is not facing the sound field. In condenser microphones, this opening of the equalization vent is, usually, on the side of the cartridge (called "side vented") or on the back

(called “back vented”). It should be noted that the vent opening can be in the sound field also for back vented microphones, as the preamplifiers used have sufficient leakage to transfer the sound pressure to the backside of the cartridge at the low cut-off frequencies normally used [2,3]. These two situations are illustrated in figure 1.

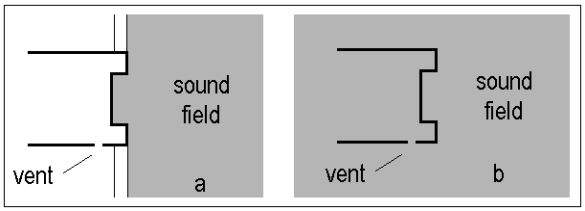

Figure 1. Measurement microphone with the equalization vent: (a) not facing the sound field and (b) facing it.

In figure 2, are illustrated the microphone’s frequencies responses when the opening of the equalization vent is not facing the sound field and when it is facing it.

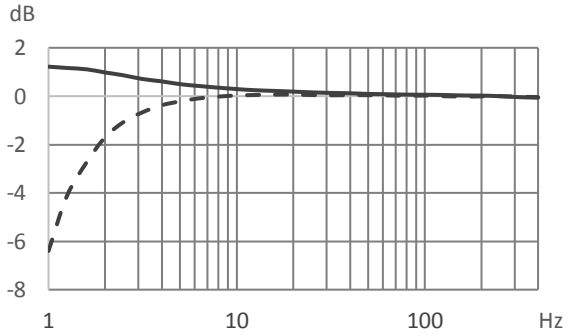

Figure 2. Frequency response of one-inch microphone (Brüel and Kjaer type 4145). —— for microphone with vent not facing the sound field and – – for microphone with vent facing it.

No less important is the preamplifier used, as it has its own low frequency cut-off. In the case of modern FET-preamplifiers (field effect transistor preamplifiers) having input impedances of 10 GΩ or more, very low frequency cut-off are obtainable. If the transducer is shunted with a capacitor, even lower frequencies may be covered by the system. The cut-off variation is significant between different measurement microphone and preamplifier combinations [2,3]. This is illustrated in figure 3.

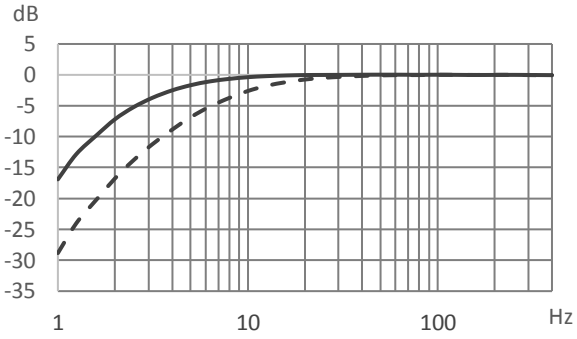

Figure 3. Microphone and preamplifier combined cut-off for different combinations. —— for microphone 1 (Brüel and Kjaer type 4145) and preamplifier 1 (Brüel and Kjaer type 2673) and – – for microphone 2 (Brüel and Kjaer type 4191) and the same preamplifier 1.

The low frequency response is given by the electrical cut-off of the preamplifier and by the acoustic cut-off of the microphone capsule [2]. It is possible to separate each of these contributions. The results are shown in figure 4. Preamplifier’s frequency response is measured by the inserted voltage technique.

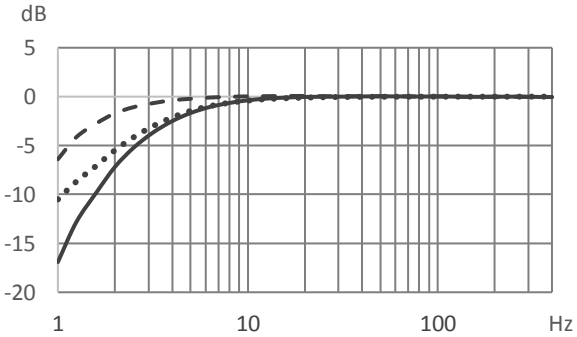

Figure 4. Individual frequency responses for microphone and preamplifier. —— for microphone (Brüel and Kjaer type 4145) and preamplifier (Brüel and Kjaer type 2673) together, – – for the microphone and · · · for the preamplifier.

The impedance of the cavity behind the microphone’s diaphragm also influences the lower limiting frequency. The impedance varies proportionally to the static pressure but this fact

is of less importance for measurements performed at ground level [3].

A minor effect is due to the air compression process occurring in the internal cartridge cavity, which changes from adiabatic conditions at higher frequencies to isothermal conditions at lower frequencies [3].

3. CALIBRATION OF MEASUREMENT MICROPHONES

At Inmetro, the secondary low frequency calibration of a measurement microphone is carried out from 400 Hz down to 1 Hz, in third-octave bands, by comparison to a reference microphone using a sound pressure chamber. The reference microphone is a one-inch laboratory standard microphone [4] also calibrated at Inmetro, in the frequency range from 1 Hz to 10 kHz, by the reciprocity technique (a usual primary method) in pressure field according to the international standard IEC 61094-2 [5]. The sound pressure chamber is composed by 8 L cylinder and a loudspeaker, which is totally enclosured. As excitation signal, a swept sine is used. The transfer-function is measured and the correspondent impulse response is obtained, which is gated to suppress noises (acoustical and electrical) and distortion [1]. A typical frequency response of a one-inch measurement microphone is shown in figure 5.

The sound pressure chamber, which allows the calibration down to 1 Hz, is shown in figure 6. It delivers around 128 dB re. 20 µPa at 40 Hz. The expanded uncertainties are estimated to be around 0.4 dB at 1–1.25 Hz, 0.3 dB at 1.6–6.3 Hz and 0.2 dB at 8–400 Hz.

4. CONCLUSION

Calibration of measuring systems for measurements below 20 Hz is often necessary as many parameters may influence their frequency response. When it is necessary, it is important to calibrate the microphone together with its preamplifier. Simply calibrate the microphone may inflicts a systematic error on the measurements because it does not take into account the preamplifier's low frequency cut-off.

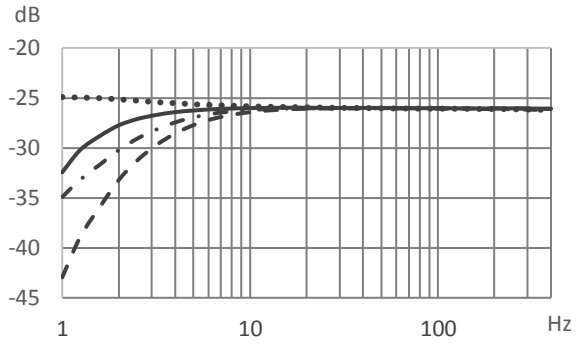

Figure 5. Measurements of microphone's and of microphone combined with preamplifier's cut-off. ── for microphone (Brüel and Kjaer type 4145) with vent facing the sound field, ─ ─ for microphone combined with preamplifier (Brüel and Kjaer type 2673) also with vent facing it. · · · for the microphone with vent not facing the sound field and a ·─· for the microphone combined with the preamplifier also with vent not facing it.

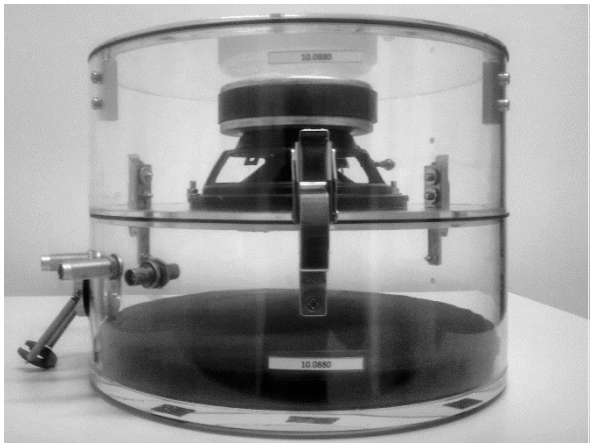

Figure 6. The sound pressure chamber used to calibrate microphones at low frequencies.

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