A full bandwidth calibrator for a sound pressure and particle velocity sensor

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Abstract

In literature it is shown that it is possible to calibrate a sound pressure and a particle velocity sensor in the free field at higher frequencies. This is done by calculating the acoustic impedance at a certain distance of a spherical loudspeaker. If the sound pressure is measured with a reference microphone the particle velocity can be calculated. At lower frequencies this setup does not work.

The pressure microphone is calibrated by comparing its response with the reference microphone.

In this paper the method is extended for lower frequencies by placing the reference microphone in the loudspeaker. At low frequencies the sound pressure in the sphere is proportional to the loudspeaker movement. If the movement is known, the particle velocity in front the loudspeaker can be derived.

Introduction

In this paper a full bandwidth calibration technique of a PU probe outside an anechoic room with a spherical loudspeaker is presented.

The concept that is presented here is an extension of the method that is presented in the JASA paper of Finn Jacobsen [1]. In that paper the near field calibration concept that has proposed in [2] was improved by using a relatively large (20cm diameter) spherical loudspeaker.

The most accurate method is when a known radiation impedance of a spherical loudspeaker is used to calibrate a Microflown in an anechoic room at 70cm distance [1]. This method works well at higher frequencies (i.e. f>50-100Hz). With the knowledge of the radiation impedance, the response of a Microflown can be compared with a reference microphone to find its frequency dependent sensitivity. The pressure microphone of the PU probe can be calibrated in the full bandwidth in this setup.

The novel extension concept to calibrate velocity probe at lower frequencies is based on the very near field: 'very' close to a vibrating object the particle velocity is similar to the vibration of the object [3].

At low frequencies, the sound pressure inside the sphere is proportional to the loudspeaker vibration and is measured with a reference pressure microphone. With the vibration of the loudspeaker known, the particle velocity in front of the loudspeaker is determined and the Microflown can be calibrated.

Because at lower frequencies the particle velocity field behaves incompressible and the measurement takes place close to the loudspeaker, no background noise problems and no problems with reflections are found with the low frequency sphere method [3], [4].

In this paper two sphere calibration techniques (HF (high frequency) sphere and LF (low frequency) sphere) in two realizations (large sphere and small sphere) are investigated with respect to the behavior in the presence of background noise and room reflections.

It is also shown that both the high as the low frequency method can be applied in a normal room (so outside an anechoic room).

High frequency calibration with a sphere

The high frequency calibration with a sphere is presented in [1]. In this paper the same technique is used but outside an anechoic room and it is repeated with a smaller sphere. A smaller sphere has some mathematical advantages compared to a larger sphere.

The specific acoustic impedance in front of the spherical loudspeaker can be calculated. Therefore one can relate the particle velocity to the sound pressure. So the particle velocity at the position of the probe is known when the sound pressure at the position of the probe is measured with a reference pressure microphone and divided by the (known, calculated) specific acoustic impedance.

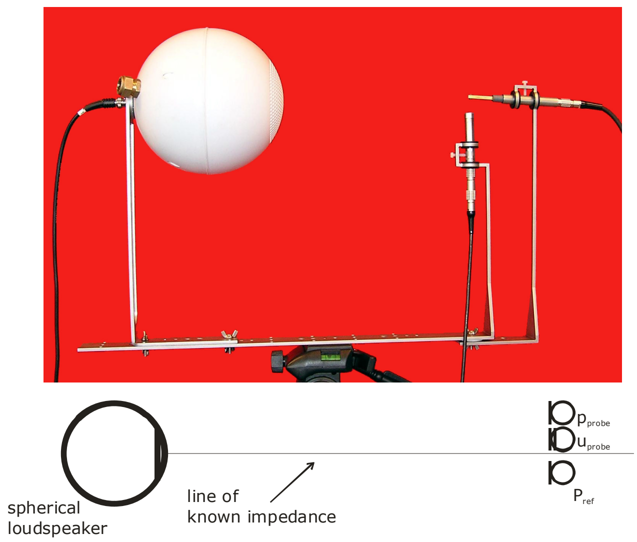

Fig. 1: Measurement set up for the 'piston in a sphere' high frequency calibration (f>50~100Hz).

At lower frequencies the acoustic impedance of the loudspeaker can hardly be measured because the particle velocity at the probe under test is caused by the loudspeaker and the sound pressure by the background noise. In practice this means that the calibration with this technique becomes impossible below 100Hz (outside an anechoic room).

The pressure microphone of the pu-probe can be calibrated with this set up down to 20Hz. It is because at lower frequencies the sound pressure microphones (the microphone to be calibrated and the reference microphone) are omni-directional and therefore it does not matter if the sound pressure at the calibration position is caused by the loudspeaker or by the background noise.

Low frequency calibration of the velocity probe

If the reference sound pressure microphone is put inside the sphere it is measuring the pressure variations that are caused by the movements of the loudspeaker, see Fig. 2. If the wavelength is much longer than the sphere diameter the sound pressure is distributed uniformly in the sphere and the relation is a simple expression.

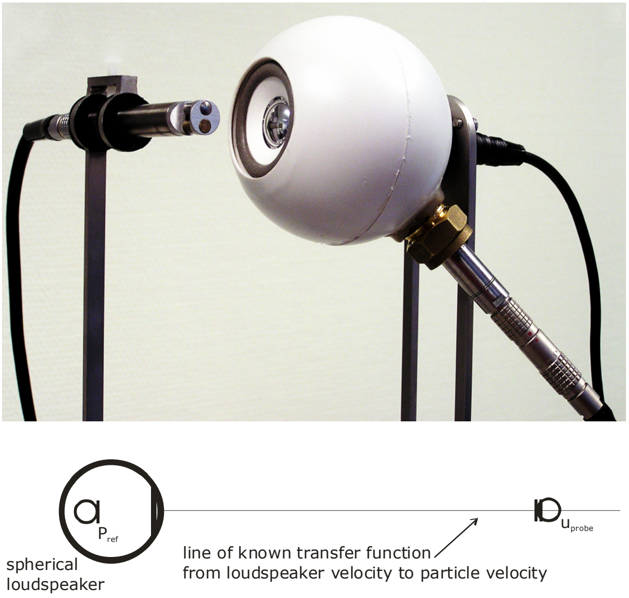

Fig. 2: Measurement set up for the small sphere low frequency calibration (f<500~1kHz).

The sound pressure in the sphere depends on the movements of the loudspeaker and not on the velocity of the loudspeaker. Therefore the pressure signal has to be differentiated with respect to time (multiplied with angular frequency and the complex value i) to get a signal that is linear depending on the loudspeaker velocity.

Correction for the pressure response inside the sphere

The pressure field in the sphere is uniform at low frequencies but at higher frequencies standing waves occur in the sphere. The deviation of the pressure response of the LF sphere calibration is determined as a simple cosine function.

Comparison with SWT method

The two sphere calibration methods (LF&HF) with a large sphere and a small sphere are compared with the standard standing wave tube method [1]. The deviation of the methods is shown in Fig. 3.

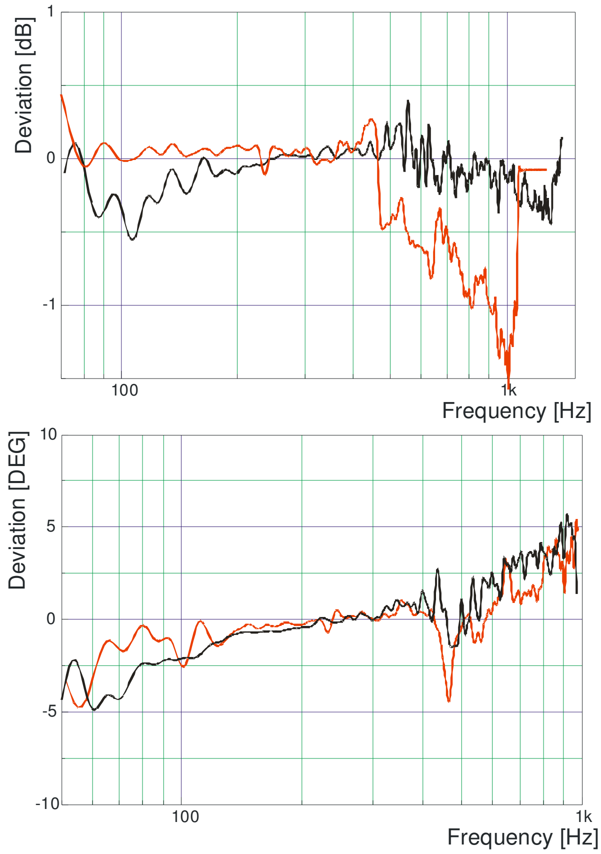

Fig. 3: Deviation between short standing wave tube and LF sphere calibration. Pressure probe is put so that the membrane is close to the internal surface of the sphere. Red: large sphere, black: small sphere. Upper: difference is dB, lower: difference in degrees.

Conclusion

A two step, free field calibration technique is demonstrated that is able to calibrate a pu-probe outside an anechoic room. The method shows to be practical and is used nowadays as the standard calibration method.

References

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