PRIMARY METROLOGY IN FRANCE
IN ACOUSTIC AND VIBRATION FIELD

1. Organisation

In 2005 the French government passed a decree entrusting LNE with overall responsibility for all French metrology. Renamed the Laboratoire National de Métrologie et d'Essais, LNE took over from the Bureau National de Métrologie, which had performed this function since 1969.

LNE possesses extensive scientific and technical resources to meet requirements in a wide range of SI reference standards. The covered fields are electricity and magnetism, dimension, mass and related quantities (pressure, force, torque, acoustics, vibration), amount of substance, radiometry-photometry, temperature and thermal quantities. The laboratories of acoustics and vibration have a permanent staff of 5 persons.

2. Activities in acoustics and vibrations

In its mission to disseminate metrological standards to the society and the industry, LNE is active in a variety of fields in acoustic and vibration.

- Pressure reciprocity calibration of microphones from 31,5 Hz to 25 kHz
- Free-field reciprocity calibration of microphones from 1000 Hz to 31,5 kHz
- Type approval and calibration of sound level meters
- Type approval and calibration of sound calibrators
- Primary calibration of accelerometers with sinusoidal excitation in the frequency range of 10Hz to 10kHz, for an acceleration magnitude between 1 $m.s^{-2}$ and 800 $m.s^{-2}$
- Consulting on acoustics and vibration metrology fields

3. Research areas in the acoustic field

Since 2002 LNE has started a study in the field of acoustical metrology, in order to improve accuracy in microphones calibration and also in order to develop a method to measure the acoustical impedance of little elements such as the capillarity ducts build in the artificial ear. The research program, from October 2006 – October 2008 is presented in this report.

3.1. Ear simulator

Many applications (artificial ears, loudspeakers, microphones, among electro acoustic devices, especially those that will be miniaturised in the future using MEMS techniques) would require characterising the behaviour of small acoustic components such as small tubes, slits and cavities. These small devices are usually described analytically using modelling wherein viscosity, heat conduction, inertia and compressibility of the fluid are considered, beyond realistic boundary conditions.

Characterising experimentally the input of these kinds of components, that is to say measuring their input impedance, was quite impossible until now because their input impedance is usually much greater than those involved in the measuring set-up. A measurement procedure has been developed which is assumed optimised. Indeed, it uses the very well optimised reciprocity calibration method and the corresponding set-up available on the market.

To validate the measurement method suggested, by direct comparison with the theoretical input impedance, and evaluate its accuracy, two basic acoustic elements derived from the design of the artificial ear have been selected. These were chosen on the basis that they could be modelled accurately as well as studied experimentally. The first one is a thin, short annular slit open at its end on a free space. The second one is a set of four thin, short cylindrical tubes.

In order to show that there is a close agreement between the analytical and experimental results (up to several kHz), a coupler with a set of four tubes has been designed with a very high accuracy: all of them have a radius of 225 µm with an uncertainty lower than 1 µm and a length of 3.8 mm with an uncertainty lower than 10 µm (Figure 1Figure 1). The results obtained are shown in Figure 2Figure 2: the experimental and theoretical results are in very good agreement up to 5 kHz (the uncertainties are around 1% for the modulus and 1 degree for the phases), showing that the method permits the experimental characterization of the input behaviour of such components with a good accuracy. The manufacturing of an other high accuracy coupler with an annular slit is currently in progress.

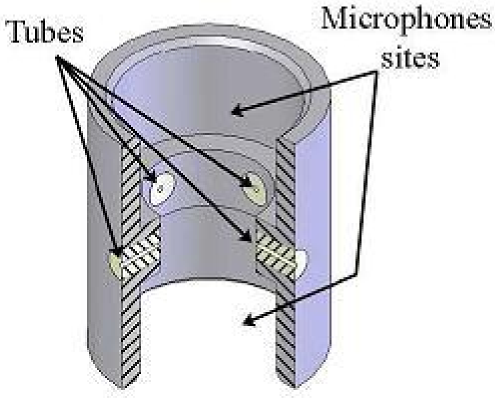


Figure 1. New coupler designed for the measurement of the input acoustic impedance of four tubes open at its ends.

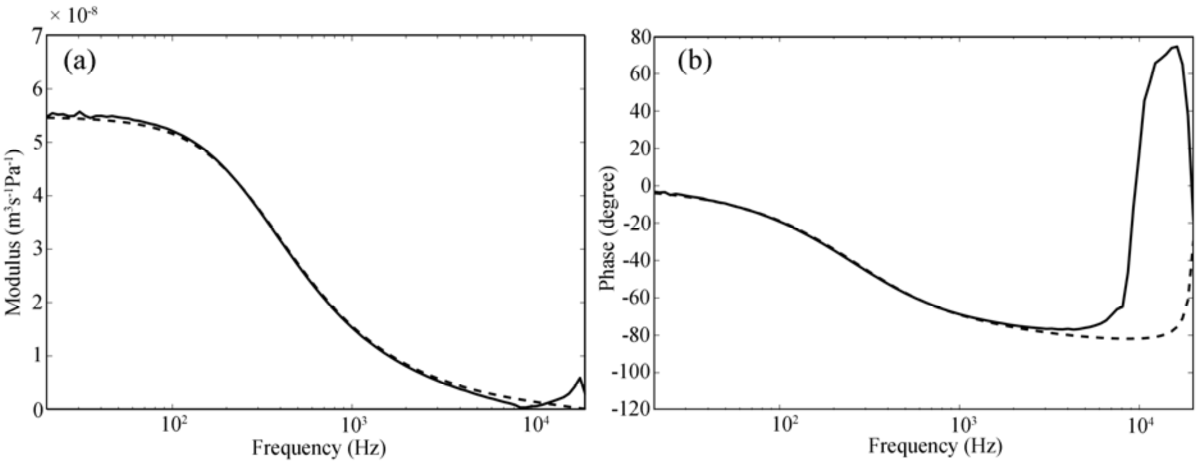


Figure 2. Acoustic input admittance of four open tubes (high-accuracy device), (a) modulus and (b) phase, experimental and theoretical results: (—–) experimental admittance, (- - -) theoretical admittance.

3.2. New method for the determination of the acoustic centre of acoustic transducers

The concept of the acoustic centre is important in practical realization of free-field reciprocity calibration of microphones. The accuracy in the position of the acoustic centre has a significant influence on the accuracy of the estimated free-field sensitivity of the microphones.

The last experimental methods used for half inch microphones allow to obtain results only from 2 kHz (the current lower frequency limit). In order to broaden this frequency range (in the lowest frequency domain, from nearly 400 Hz to 2 kHz), an improved experimental method which increases the signal to noise ratio has been studied.

The setup considered is a circular sound source flush-mounted on an infinite baffle and coupled with the acoustic receiving transducer to be tested through a semi-infinite field. This receiving transducer is mounted on a semi-infinite rod in the axis of the source (Figure 3Figure 3).

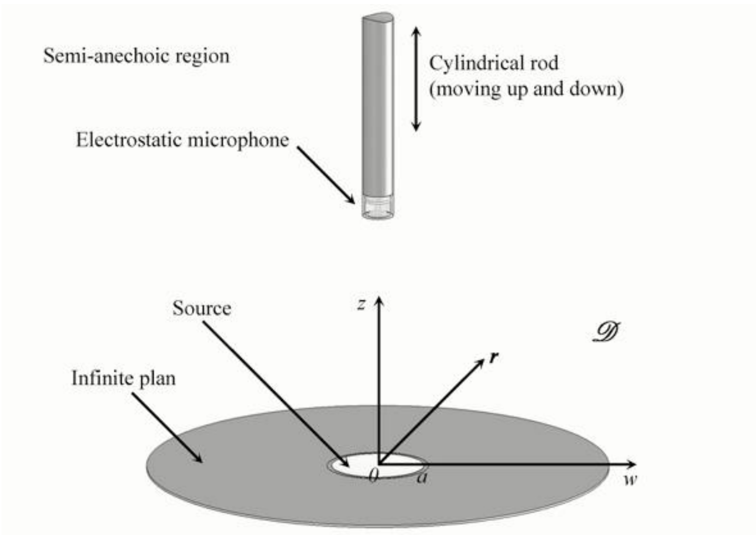


Figure 3. Setup used in the experimental determination of the acoustic centre of acoustic transducers.

The ability to proceed to the measurement of the acoustic centre of the receiving microphone implies knowing firstly the coordinates of the acoustic centre of the emitter. This coordinates are obtained from an analytical formulation. So far as the attenuation factor and the acoustic centre of the source are known, measuring the modulus of the acoustic pressure as a function of the distance z yields the value of the acoustic centre abscissa of the tested acoustic transducer.

The results obtained experimentally are in good agreement in the lower frequency range with several others obtained from the literature (Figure 4Figure 4), namely the normalized ones (full line), and those obtained experimentally using the reciprocity method (stars and crosses). Oscillations in the higher frequency range of the experimental results around the normalized ones come from the disturbances due to the acoustic energy diffracted in the vicinity of the emitting microphone. Here, these disturbances are attenuated using an optimised filtering process.

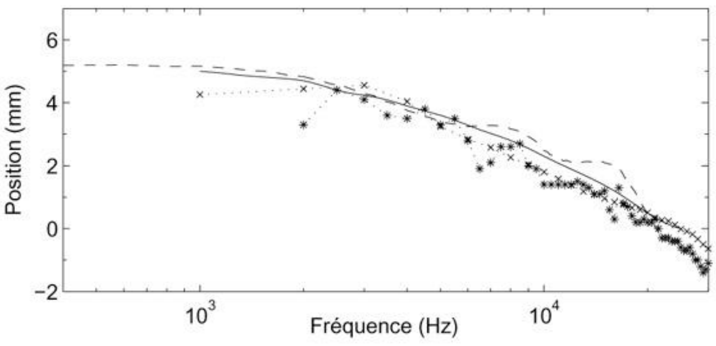
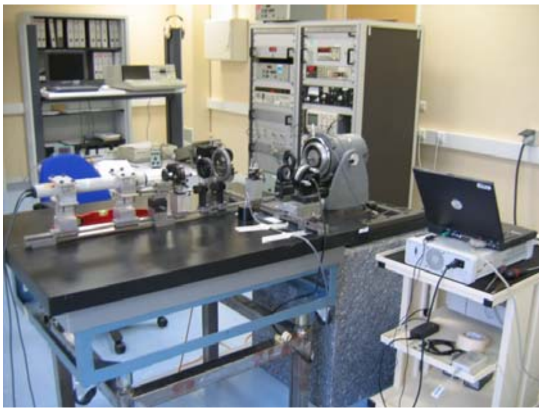


Figure 4. Acoustic centre position of a condenser microphone B&K 4180; measured values (dashed line), IEC standard values (solid line), and experimental values obtained from the literature (stars) and (crosses).

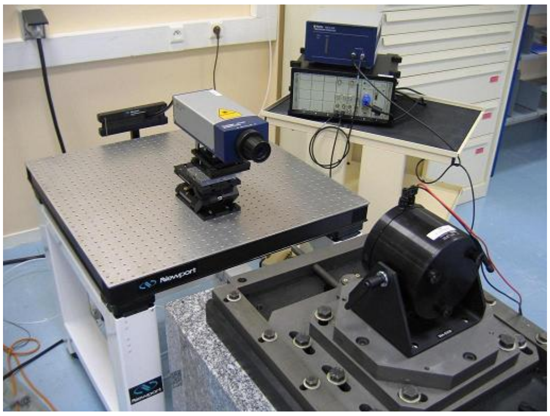
4. Situation of the vibration laboratory

4.1. Change of the laser interferometer

LNE is the reference laboratory for vibration measurement in France. The old equipment for medium and high frequency vibration has been modified. A new laser interferometer is now used. Uncertainties measurements are the same. With this change, reliability and usability are improved.



Before change of the laser interferometer



With the new laser interferometer

Figure 5. Equipment for medium and high frequency vibrations.

Qualification of a new analysing system using sinus approximation method is in progress.

The change of the vibrator is also planed.

A study on the influence of the accelerometer assembly on the measurement results is in progress and will be published next year.

1.1. Installation of a knew low frequency vibrator

A new vibrator for low frequency vibration has been selected. A granite block weighing over a ton (1200 kg) was also provided. It was placed on a concrete mat (base) of the type used under the LNE mass comparator blocks. Qualification of this equipment is planed for the end of this year.

Figure 6. Equipment for low frequency vibrations.

5. Publications and communications

[1] D. Rodrigues, J.-N. Durocher, M. Bruneau, A.-M. Bruneau. A new method for the determination of the acoustic centre of acoustic transducers. Submitted to Acta Acustica.

[2] D. Rodrigues, C. Guianvarc'h, J.-N. Durocher, M. Bruneau, A.-M. Bruneau. A method to measure and interpret input impedance of small acoustic components. J. Sound Vib., 315(4-5):890-910, 2008.

[3] D. Rodrigues, J.-N. Durocher, J. Perdereau, J.-M. Lambert, P. Cellard. La mesure des dispositifs d'écoute individuelle. Acoustiques et Techniques, n°52, 2008.

[4] D. Rodrigues, J.-N. Durocher, M. Bruneau, A.-M. Bruneau. Free-field calibration of microphones: theoretical and experimental determination of the acoustic centre. J Acoust Soc. Am. 123 (5):3847, Acoustics'08, Paris, 2008.

[5] D. Rodrigues, C. Guianvarc'h, J.-N. Durocher, M. Bruneau, A.-M. Bruneau. Input behaviour of small acoustic components: measurement procedure and its accuracy. 19th International Congress on Acoustics, Madrid, 2007.

[6] D. Rodrigues, C. Guianvarc'h, J.-N. Durocher, M. Bruneau, A.-M. Bruneau. Méthode de mesure d'impédance de petits éléments acoustiques. 18ème Congrès Français de Mécanique, Grenoble, 2007.

[7] P. Averlant. « Transfert du banc de référence en accélérométrie du Cea-Cesta au LNE » Revue française de métrologie Volume 2007-2 n°10