Automatic sound field sampling mechanisms to disseminate the unit watt in airborne sound

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ABSTRACT

For the dissemination of the unit watt, the sound pressures emitted by primary and secondary sound power standards are to be measured. Disseminating the unit in reverberant fields requires the measurement of a volume average whereas in hemi-anechoic fields, measurements on an enveloping surface are appropriate. For the latter situation, automatic sound field scanning mechanisms were developed by LNE, SP and PTB. At PTP, an arc with 24 microphones is used which can be tilted to cover a hemispherical measurement surface. Different radii can be realised by manual adjustment of the microphones. At SP, a single microphone is moved on a semi-circular arc. Different latitudes can be realised by manual arrangements. LNE developed a scanning mechanism consisting of a hemi-circular arc. A microphone can be positioned on arbitrary altitude positions on the arc and the arc can move on a circular path. This way, arbitrary positions on a hemispherical measurement surface can be realised. The contribution introduces the different mechanisms and lists advantages and disadvantages of the different technical solutions.

Keywords: Sound power, traceability; Calibration; Free-field over a reflecting plane (hemi-anechoic rooms)
I-INCE Classification of Subjects Number(s): 72.4, 71.9 and 73.2

1. INTRODUCTION

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2. GOAL

Standardisation provides many different proposals for the discretisation of the enveloping surface. ISO 3745 [1] proposes four microphone arrangements on a hemispherical surface, see two examples illustrated in figure 1:

- An array of 20 fixed microphone positions. It is possible to move sequentially one or more microphones from position to position or to use the full necessary array.
- To move a single microphone along circular horizontal paths or to rotate the noise source around the vertical axis with fixed microphone positions.
- To move a single microphone along meridional arcs, arcs provided by rotating the noise source around the vertical axis
- To move a single microphone along a spiral path around the vertical axis.

Of course, if the choice is made for an acquisition during a microphone movement (path), the mechanism must be quiet enough.

Other easier arrangements can be used if the source is assumed vertically axisymmetric, for example. The expected source directivity and time stability must be taken into account to obtain the

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best compromise between efforts (time or microphone number) and the sound power evaluation accuracy.

As the surface sampling must be fine according to the calibration objectives, the automation must be pushed to use spatial discretisation beyond the requirements of the ISO 3745 standard.

Influences of the room and microphone support structure are largely compensated for by applying a substitution method for sound power determination. However, it is best to avoid structures which are causes of excessive correction factors.

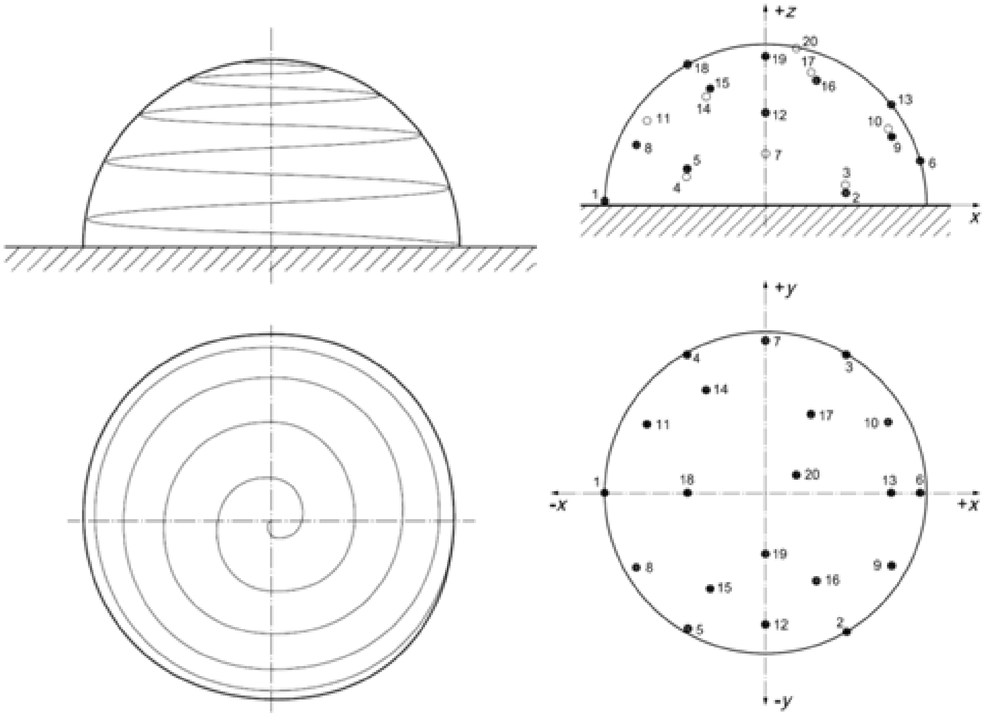

Figure 1 – ISO 3745 drawings of microphone arrangements on a hemispherical surface

3. APPARATUS DESCRIPTIONS

3.1 PTB

The PTB scanning apparatus enables the sound pressure measurement of a stationary sound source over a physical hemisphere in PTB's hemi-anechoic room (Figure 2). It consists of a hemi-circular stainless steel arc, where up to 24 microphones can be mounted and a motor, which tilts the arc onwards and backwards over the source under measurement. The sound source is placed at the center of the measurement surface which is slightly off the centre of the hemi-anechoic room. The motor that moves the arc is placed outside the measurement room to reduce the background noise during the measurements. The connection of the motor to the arc is realised by a metallic wire. The scanning movement settings, including the duration, are controlled by software. The scanning movement can be continuous or stepped.

There are two arcs of different radii available enabling measurements at different distances to the source. Both arcs can be easily removed from the hemi-anechoic room. Figure 2 shows both arcs of the scanning apparatus.

Microphone positions are chosen that each microphone covers equal partial surface areas. . As it can be seen in figure 2, the microphones are attached to 70 cm long acrylic glass rods, which can be manually fixed at different measurement radii.

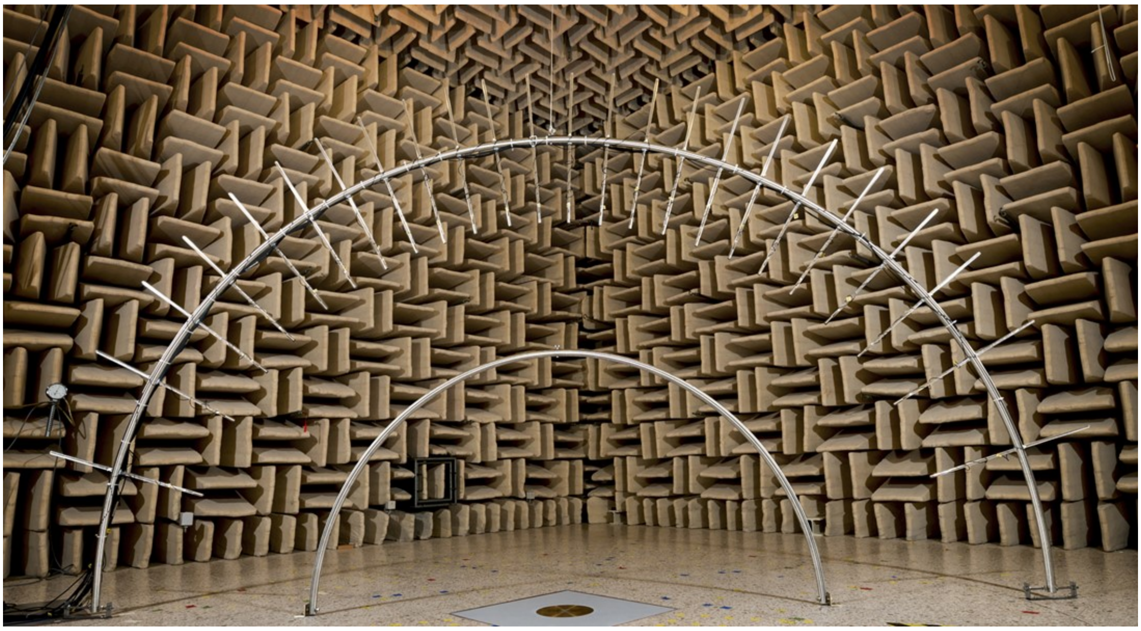

Figure 2 – PTB's scanning apparatus

3.2 LNE

At LNE, the scanning apparatus specifications were defined with a list of requirements. Some of them are common to the JRP-Protocol, but others are specific to an LNE design. One main choice is the use of only one microphone, which will be moved on each position by an automatic device, controlled by software that will manage both the scanning apparatus and the acoustic signal analyser acquisition. One movement is along a rail describing a vertical arc of 90°. The second movement is to move this arc around a vertical axis to cover the entire hemispherical surface. A third movement displaces the microphone on the radius from 1 cm to evaluate the intensity by two steps.

Structurally, two designs were studied, see figure 3, one with a self-supporting circular rail on the floor, the other with a fixed part, an H-shaped beam hanging from the ceiling of the room, and a bow turning around a vertical axis, see figures 3 and 4. The second design was chosen. To obtain a structure both mechanically rigid and acoustically discreet enough, all beams have a triangular section made of three linked tubes.

Given the large cantilever between mountings in the ceiling and microphone positions, settings are necessary before using the device. To take the correct position to 1 cm radially, qualification uses a laser to check the measuring radius, see figure 5.

The software pilots the microphone movements according to predefined arrays, the analyser (with the ability to measure transfer functions between the microphone and the source) and the generator (if any). It can also simulate the radiation of a piston, to calculate the differences with the measurements or as a test of the software.

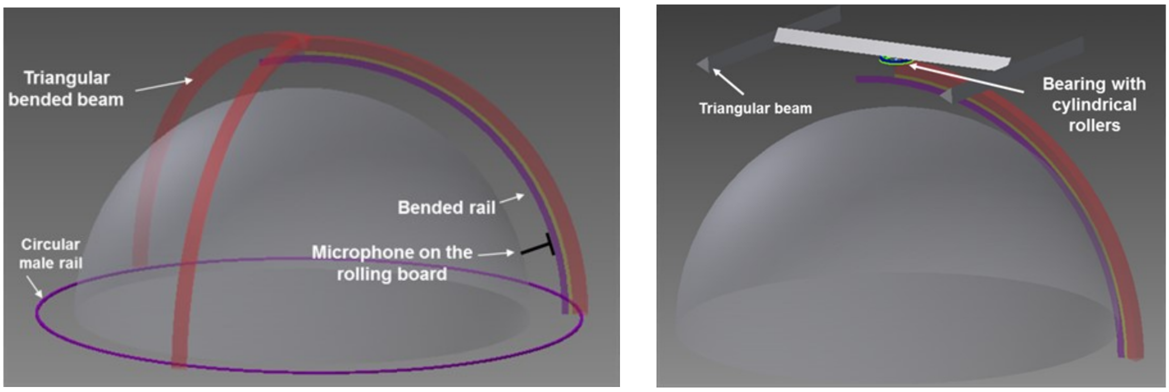

Figure 3 – Two LNE's designs

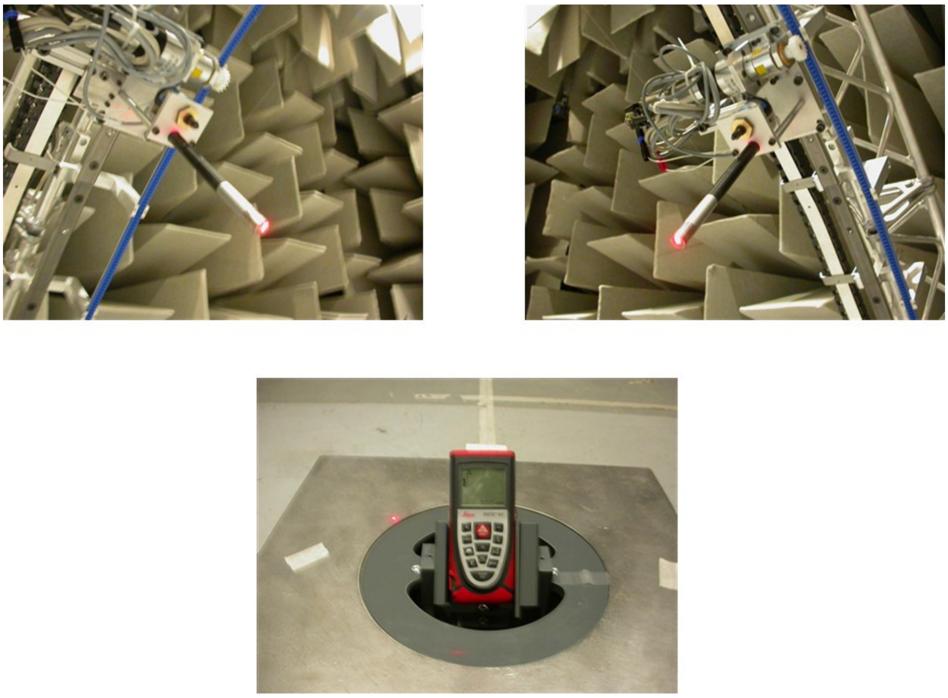

Figure 4 – Checking of the microphone positioning with a laser rangefinder

3.3 SP

The principle is automatic scanning along a single meridional arc about a horizontal axis, as proposed by the third proposal of microphone arrangements given in the ISO 3745 standard. The scanning apparatus has to be manually turned around the vertical axis. The scan can be running a continuous path or stop at predefined heights. The scanning speed and spatial resolution of the measurement points can be set freely.

The frame of the apparatus is made of Ø10 mm carbon fibber tubes with all joints in small dimensions in order to not cause any sound reflections. See figure 5. The microphone is mounted with the axis perpendicular to the normal of the measurement hemisphere. This is to be consistent with ISO 6926 at frequencies above 10 kHz.

The scan is accomplished by a string pulling the frame of the apparatus. The string is winded by a stepper motor mounted on the roof of the hemi-anechoic chamber. A software is synchronising the scan with a B&K PULSE measurement system.

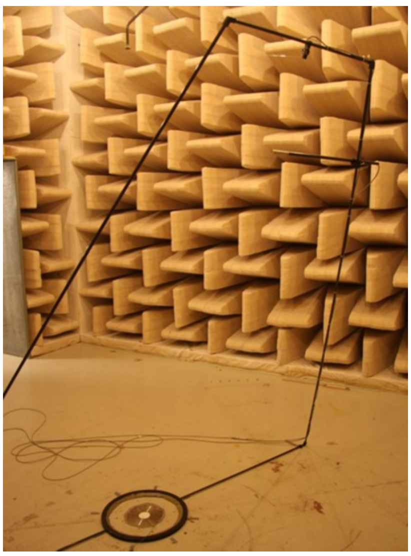

Figure 5 – SP's scanning apparatus

4. ADVANTAGES AND DISADVANTAGES

Each developed solution has advantages and disadvantages. There is no question of opposing these solutions but to indicate to a laboratory that would develop such a system the specification elements and where the compromises to do are.

Table 1 –Advantages and disadvantages

Design	PTB	LNE	SP
Advantages	Short acquisition time Reproducible positioning Different radii are possible Scanning movement continuous or stepped Quiet	The microphone position choice is totally free. Using the third axis movement (radial) and a source signal, the intensity can be measured.	Discreet, small disturbance of the sound field Different radii are possible Scanning movement continuous or stepped Quiet
Dis-advantages	Not fulfilment of a standardised spatial discretisation	Time consuming measurement. Risk of poor positioning Difficult to move in another room	Need to be manually turned on different meridional arcs. Too weak to carry a sound intensity probe.
Effort	High because of 24 channels and a complex mechanical structure	High because of the mechanical structure and its motorisation	Medium because of one measurement channel and relatively easy mechanical structure

5. CONCLUSIONS

For the JRP Soundpower, an acoustic metrology research program, various techniques have been tested for finely discretising a hemispherical surface with an automatic device. The partners have chosen different designs, according to their facilities and experience.

The experience allows evaluating the advantages and disadvantages of the three presented approaches. Some aspects of the specification cannot be transposed to the more classical industrial measurements with a lower spectral discretisation and the need of absolute measurement, instead of the purpose of making measurements by substitution authorising the cancellation of some defects in the structure. However, the presented work shows the ability to automate sound power measurements by scanning apparatus.

ACKNOWLEDGEMENTS

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