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Reflections in anechoic rooms

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Abstract

Anechoic rooms have to fulfil anechoic conditions to ensure that measurements are taken in a (almost) perfect free field. The practical use of the room however requires the presence of potentially reflecting elements that disturb the sound field. ISO 3745 prescribes a qualification method to assess the quality of anechoic rooms using a continuously moving microphone. Measurements have been made in several rooms using this method, showing significant deviations from the inverse law. It was found that the described method in ISO 3745 is very sensitive to low level reflections. Although most anechoic rooms will be sufficiently fit for their purpose, it is expected that many of these rooms do not comply with ISO 3745, especially if they have been assessed less accurately using discrete measuring points. An anechoic room of 200 m³ and a working space of 5.2 x. 5.2 x 7.8 m had to fulfil the requirements of ISO 3745 after renovation. Measurements show that this room, being redesigned and renovated with new wedges and other new elements, does fulfil the requirements of ISO3745 from 100 Hz to 10 kHz fully.

1. Introduction

Anechoic rooms are especially suitable for making accurate acoustical measurements, such as source radiation patterns, microphone calibration, sound power emission of machines, head-related transfer functions etc. The degree to which an anechoic room approaches the ideal free field in which the sound pressure is being inversely proportional to the distance, determines the accuracy of the measurements. To realize a free field, the walls, floor and ceiling are usually lined with sound absorbing wedges. Practically there will always be some reflections left in an anechoic room. This is due to the inevitable use of elements such as a door, lighting, fixings, floor etc. All of these elements have to be designed carefully, based on knowledge and experience, to keep the level of reflections sufficiently low.

Peutz & Associés has advised about the recent redesign and renovation of an existing anechoic room of TNO in Soesterberg (NL) and has performed measurements. After completion the room had to fulfil ISO 3745 for frequencies from 100 Hz up to 10 kHz. To qualify the room according ISO 3745 a new measuring system has been developed.

2. ISO 3745

The international standard ISO 3745-1977 (E) deals with the “Determination of sound power levels of noise sources – Precision methods for anechoic and semi-anechoic rooms” [1]. In annex G of this standard some guidelines for the design of anechoic rooms are given.

The qualification procedure to assess the quality of the room and of its free field is given in annex A, being the sound-pressure decrease test:

By placing an omnidirectional source (±1dB) in the middle of the room the sound pressure has to be measured as a function of distance along a radial line from the acoustic center of the source. The sources shall be operated at discrete frequencies covering the entire range of interest, with octave steps between 125 Hz and 4000 Hz and one-third octave steps outside this range. Usually different sources are needed for different frequency ranges.

Microphone traverses have to be made along at least 8 straight paths away from the center of the room in different directions, 4 of which towards the edges. The microphone (≤ ½”) shall be moved continuously along the paths for each test frequency and the sound pressure levels recorded. These levels are to be compared with the decay predicted by the inverse square law and the differences between the measured and theoretical levels are to be calculated for each path and each test frequency. These differences should not exceed ±1,0 dB between 630 Hz and 6300 Hz or ±1,5 dB outside this region.

2. Development of measuring system

The qualification method of ISO 3745 with continuously moving microphone is practically rather elaborate, partially because the measuring set-up may not influence the free field in the room. That may be the reason that many times only several fixed points are being measured, called the discrete-point-method [3][4]. At high frequencies both methods require the intervals to be sufficiently small in order to describe the possible interference patterns and its minimums and maximums sufficiently and to determine realistic deviations. For instance at 10 kHz an interval of 4 mm is necessary to obtain a sufficient number of measurements (at least 8) to describe one wavelength [5].

With the discrete-point method such small intervals are usually practically not feasible, leading to loss of accuracy. However, in a revised draft ISO/DIS 3745 the discrete-point method has been added as a qualification method, requiring at least 10 measuring positions for each path, and intervals not larger than $\lambda/4$. For frequencies above 1 kHz intervals of “0,1 m or so” are allowed. At high frequencies these intervals of 10 cm are too large (@10 kHz about 4 mm required) to describe interference patterns correctly.

As a first attempt to realize a setup with continuously moving microphone, the microphone was attached to a small carriage travelling on a rail that was suspended in the room, more or less comparable with other systems elsewhere [2]. In this case the carriage was driven by wires and a motor attached to the end of the rail. This first setup appeared to be rather inaccurate, due to too many reflections from the rail itself and an insufficient driving system.

In a completely new set-up the complete driving system was placed outside the room, mainly consisting of a rotating cylinder (Ø30 cm) that winches the microphone cable and is being driven by a stepping motor.

The small microphone (Sennheiser ME-102) and its cable are being attached to a thin carriage of copper wire, which travels smoothly along two guiding lines of thin fishing line (Ø0.16 mm), see figure 1. To realize a constant microphone velocity and a flat measuring path, both guiding lines as well as the microphone cable are being tensioned using pulleys and additional weights at the ends. To cover the frequency range of interest two omnidirectional sound sources have

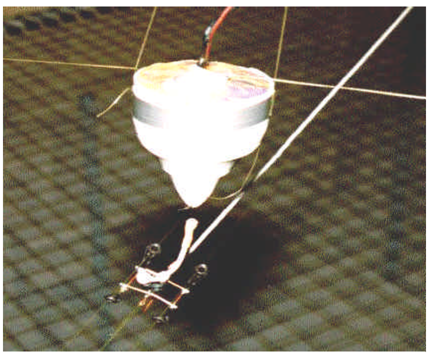

Figure 1: Microphone on carriage passes the source

been used, a Bose 102 and a modified piezo-driver. Starting from shortly behind the source, the microphone passes near the source and away with constant velocity. The maximum velocity is determined by the integration time of the level recorder (125 ms) and the highest measuring frequency of 10 kHz, at which at least 8 measurement intervals of 4 mm are required to describe one wavelength. Simultaneously, the sound level of the source is being recorded on digital tape as well as on paper.
The analogue microphone signal is being written on paper of a level recorder without any data-manipulation, giving a direct measurement output of the decrease with distance. By overlaying the measurement with the theoretical decrease with distance and the allowable deviations according ISO 3745, direct visual information becomes available about the deviations measured and whether the measurement satisfies ISO 3745. Figure 2 gives an example of this visual output, for a case that does not fulfil ISO 3745 due to reflections from the floor.

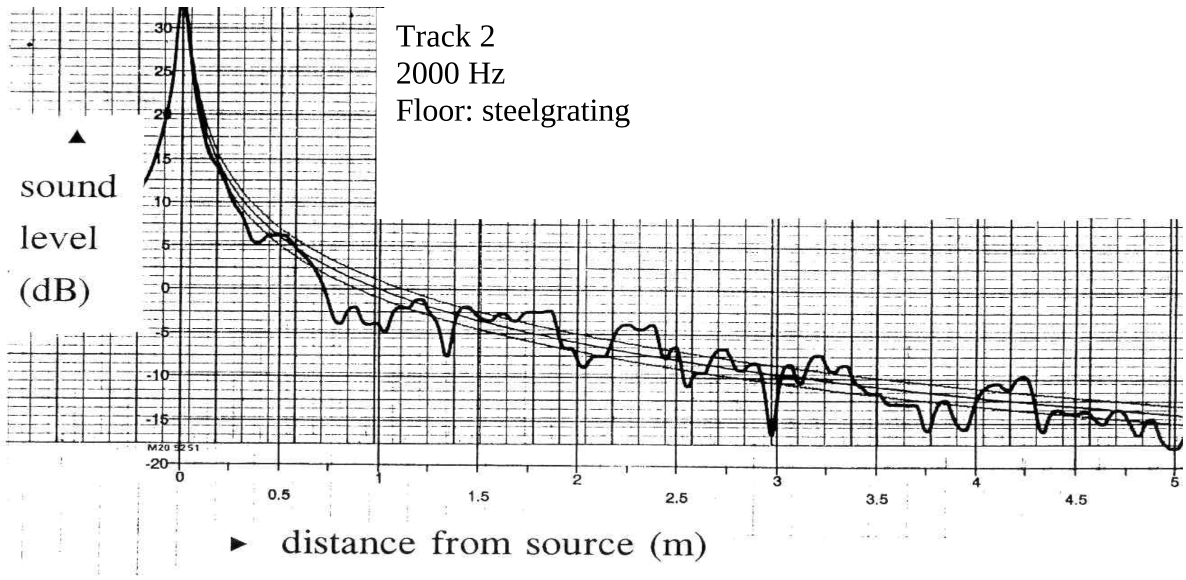

Figure 2: Measured decrease with distance overlaid with theoretical lines and tolerances of ISO 3745. Measured with continuously moving microphone in an anechoic room with steel grating floor.

3. Investigations with new set-up

During the development of the final measuring set-up, as described in chapter 2, extensive measurements with a continuously moving microphone have been performed in several anechoic rooms, leading to several experiences:

- The measurement set-up used is very sensitive to reflections of low level. For two “anechoic” rooms it was shown that they did not qualify for ISO 3745, despite earlier claims of qualification.
- Floors of stiff, thick steel elements cannot satisfy ISO 3745 (see figure 2). Only a grid of narrow stretched steel wires does, provided that supports are sufficiently small or made absorbent;
- Lighting elements with standard sizes can already cause too many sound reflections, especially at the highest frequencies (10 kHz);
- Entrance-doors can be likely to result in too many reflections despite lining with wedges, unless all remaining visible structures (> 1cm) are being treated with sound absorbing material;

- Using impulse response measurements can be a very useful tool to investigate the cause of certain deviations in a measurement of the decrease with distance at a certain microphone position, because it gives a complete oversight of all reflections, their levels and arrival times.

4. Results of new anechoic room

Within the existing volume 200 m³ the anechoic room in question was completely renewed, resulting in an anechoic chamber with a volume 200 m³ and interior dimensions between the wedge-tips of 5.2 x. 5.2 x 7.8 m. Some of the most relevant provisions taken are:

- A new absorption lining of wedges with a cut-off frequency of 100 Hz (more than 99% absorption above this frequency), consisting of glass-wool wedges of 85 cm long;
- A new grid floor of tensioned steel wires, for which the existing building structure had to be strengthened with additional steel beams. Under this floor special bearings have been applied as a support for removable floor elements to cope with occasional heavier loads;
- The door construction was specially designed with sound absorbing material added to the structure;
- Small pl-lights are hung from the ceiling in between the wedges.

For all 11 frequencies required between 100 Hz en 10 kHz, 8 different paths have been measured using the set-up with continuously moving microphone according ISO 3745, resulting in 88 figures. In all these figures the deviations of the theoretical inverse square law remain within the tolerances of ISO 3745, proving that this anechoic room does fulfil the requirements of ISO 3745 outside the near field of the source for the full measuring surface.

5. Conclusions

The new anechoic room has proven to fulfil the requirements of ISO 3745 for frequencies from 100 Hz up to 10 kHz.

The measuring set-up as developed proves to be sufficiently accurate to qualify an anechoic room according ISO 3745. Furthermore, it is sensitive enough to detect almost any unwanted or possibly disturbing reflection, even if it is a reflection of a very low level.

In order to prove that the deviations from the ideal free field are within the +/- 1 dB for the entire measuring-surface, a set-up with continuously moving microphone is necessary.

The addition of the discrete-point method in de draft ISO/DIS 3745 is doubtful and will lead to an inaccurate qualification method, especially since for frequencies from 1 kHz and higher the size of a measuring interval as allowed is much larger than physically required to describe the interference pattern.

In order to build an anechoic room that shall fulfill ISO 3745 utmost care has to be taken in the design of all possibly disturbing elements, such as door(s), floors, supports, pipes, grillwork, lighting etc.

References

1. ISO3745-1977 (E), “Acoustics – Determination of sound power levels of noise sources – Precision methods for anechoic and semi-anechoic rooms”.
2 Ingerslev e.a, ”New rooms for acoustical measurements at Danish Technical University”, Acustica vol. 19(1967/1968), p.185-199.
3 Duda, J., “Inverse Square Law Measurements in Anechoic Rooms”, Sound and Vibration, dec. 1998, p.20-25.
4 Eckoldt, D. e.a., “Alternative Schallabsorber für reflexionsarme Messräume”, Zeitschrift für Lärmbekämpfung 41 (1994), 162-170.
5 Ballagh, K.O., “Calibration of an anechoic room”, J.S.V.B. (1986)**105**(2),233-241.