Audio Engineering Society
Convention e-Brief 627
Presented at the 149th Convention
Online, 2020 October 27-30



# Design and validation of a low-cost acoustic anechoic chamber

Bram Cuyx[1,2,3], Wim Buyens[3], Wim Desmet[2,4], and Toon van Waterschoot[1]

[1] *KU Leuven, Dept. of Electrical Engineering (ESAT-STADIUS), Leuven, Belgium*
[2] *KU Leuven, Dept. of Mechanical Engineering (LMSD), Leuven, Belgium*
[3] *SoundTalks NV, Leuven, Belgium*
[4] *Flanders Make, Core Lab DMMS, Leuven, Belgium*

Correspondence should be addressed to Bram Cuyx (`bram.cuyx@kuleuven.be`)

**ABSTRACT**

This engineering brief describes the design, construction and validation of a low-cost acoustic anechoic chamber. This anechoic chamber will be used in a production setting as well as for research and development of a microphone array system. Three chambers have been built using the same method. The performance of the rooms is evaluated in terms of sound isolation, deviation from inverse square law, frequency response function and reverberation time. Results show that in the frequency range of interest (250 - 11025 Hz), the reverberation time for the three chambers is 19 $\pm$ 3 ms. The difference between the frequency response of the chambers is $\pm$ 4 dB in the frequency range of interest for the two latest built chambers, whereas the first chamber shows a larger deviation.

## 1 Introduction

In order to satisfy the need for made-to-measure anechoic chambers for production testing, the choice was made to design and build one instead of buying a commercially available one.

Traditionally anechoic chambers are large and expensive to construct. The main reason for this is to achieve a satisfactory performance at lower frequencies. If the frequency range can be limited, the cost and size can be reduced.

Koidan and Hruska [1] discuss the testing procedure for a chamber qualified for measurements in the range of 40 to 63000 Hz.

Ressl and Wundes [2] discuss how the size and cost of an anechoic chamber can be reduced by building for a specific application, in this case for hearing aid research. The frequency range of interest for this chamber is 250 - 4000 Hz

Whisperroom inc. [1] offers a low-cost (from 3905 USD at the time of writing) commercially available solution but little specification is available on the performance of this chamber.

In this engineering brief, we propose a design procedure for a custom low-cost anechoic chamber and compare the performance of three acoustic chambers based on the same design.

## 2 Design

There are two main use cases for these acoustic anechoic chambers.

[1] https://whisperroom.com

1. As a controlled environment for the final test of a SoundTalks SOMO gen 2[2] after production.

2. For further research and development on the SOMO gen 2 device.

Before designing these chambers, requirements were set. The chambers have to be moveable on a pallet jack and fit through a standard garage door. The chamber will be used for measurements in the frequency range of 250 - 11025 Hz. The background noise in the location of the chamber is measured to be 50 dB(A). According to ISO 3745:2012 [3], the background noise level should be 10 dB less than the sound pressure level of the source under test.

To fulfill the requirement of being moveable the choice was made to make the room a rectangular cuboid. The internal dimensions are 2.09 m x 1.11 m x 0.94 m, this also allows a person to enter the room. This introduces standing waves at frequencies that can be found using equation (1). It is important that these standing waves occur outside of the frequency range of interest. The frequencies for the standing waves due to the height, width and depth are calculated in equations (2), (3) and (4) respectively.

$$f = \frac{c}{2d} \tag{1}$$

$$f_{height} = \frac{c}{2d} = \frac{340m/s}{2 \cdot 2.09m} = 81\,\text{Hz} \tag{2}$$

$$f_{width} = \frac{c}{2d} = \frac{340m/s}{2 \cdot 1.11m} = 153\,\text{Hz} \tag{3}$$

$$f_{depth} = \frac{c}{2d} = \frac{340m/s}{2 \cdot 0.94m} = 180\,\text{Hz} \tag{4}$$

After a first chamber was built, observations and measurements on this chamber led to changes in the design of the subsequent two acoustic chambers (e.g. the two newer chambers have an additional door encasing).

The chambers are built as a wooden beam structure with oriented strand board (OSB) and medium-density fibreboard (MDF) double walls of 1.8 cm thickness covering it. The space between the double wall is filled with polyethylene (PE) foam. The door is a single wall of OSB/MDF of 1.8 cm thick. The inside of the room is covered with pyramid shaped polyurethane (PU) foam of 10 cm thickness.

[2]The SoundTalks SOMO gen 2 is a 6 microphone array system designed to continuously monitor sound in livestock facilities aiming to provide early warnings of animal distress.

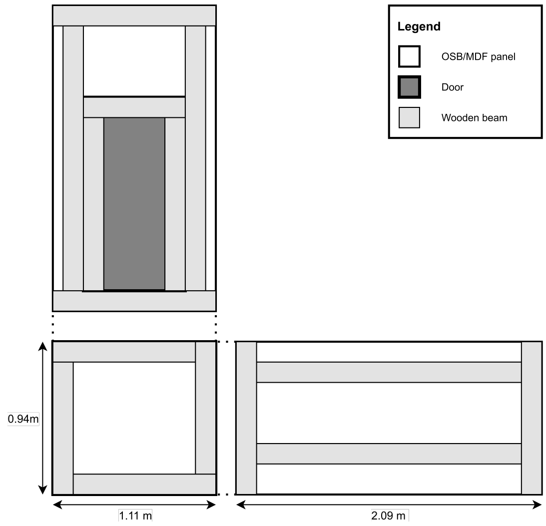


**Fig. 1:** Diagram of the support structure of the room.

Holes for cable passthrough are made in the sides of the anechoic chambers. Foam plugs are used to close the holes.

Figure 1 shows how the structure of the room is built up.

## 3 Methods

The performance of the acoustic chambers is tested on four different criteria. For each of these criteria the comparison will be made between the three chambers that were built according to the design specified in section 2.

### 3.1 Sound isolation

The sound isolation is measured for the three acoustic chambers. This is done by playing back a white noise sound signal in the space where the chambers are located and measuring the power spectral density (PSD) outside of the chamber and inside the chamber. To calculate the sound isolation values per frequency bin, the PSD inside the room is subtracted from the PSD outside the room.

### 3.2 Deviation from inverse square law

This is a test specified in the ISO 3745:2012 [3] norm for sound pressure level measurements in (hemi-)anechoic rooms. A reference sound pressure level measurement is done at 1 m distance from a sound source placed inside the room. For 10 different measurement positions, each 0.1 m away from the previous one, a sound pressure level (SPL) measurement is done. This results in 11 SPL measurements for distances 0.5 m to 1.5 m away from the source. The excitation signal used is 30 seconds of white noise. For each of the measurements the SPL per third octave band is calculated. The deviation from SPLs found using the reference measurement and the inverse square law is a measure on how well the anechoic chamber approaches free-field conditions. ISO 3745:2012 [3] specifies how much the SPL can deviate from the inverse square law to be qualified as either a hemi-anechoic chamber or an anechoic chamber.

### 3.3 Frequency response function

The impulse response is measured using the swept sine method described by Farina [4]. This method measures the response to a exponential sine sweep and convolves the measured signal with the time-reversed equalized excitation signal, resulting in an estimate of the impulse response. The signal used is a 2 minute long exponential sine sweep between 250 and 25600 Hz. The frequency response function is found as the Fourier transform of the impulse response.

### 3.4 Reverberation time

Using Schroeder‘s method described in [5] the reverberation time (RT60) can be estimated from the impulse response. To estimate the reverberation time per octave band, the impulse response is filtered by an octave band filter bank. On the resulting subband impulse responses the Schroeder method is applied to calculate the reverberation times.

## 4 Results

### 4.1 Sound isolation

Figure 2 shows sound isolation as a function of frequency. Here it is apparent that the changes made to the door encasing of Chambers 2 and 3 led to better overall sound isolation in the frequency range of interest.

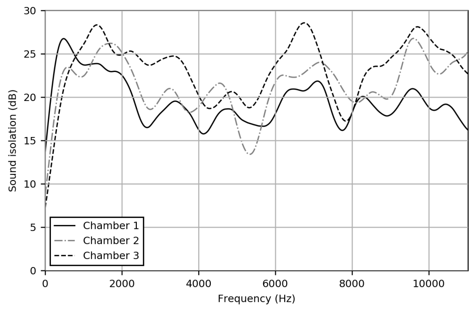


**Fig. 2:** A comparison of the sound isolation per frequency bin between the three chambers.

### 4.2 Deviation from inverse square law

Table 1 shows the maximum allowed values to be qualified to be in conformance with ISO 3745:2012 [3] for (hemi-)anechoic chambers and the values measured on the chambers described in this engineering brief. The values in this table are absolute values of the maximum deviation per third octave band.

The results show larger deviations from the inverse square law in the lower frequencies. A plausible explanation for this are reflections inside the room that are not absorbed by the pyramid foam.

### 4.3 Frequency response function

Figure 3 shows the frequency response functions for the three chambers. The two latest built chambers (Chamber 2 and Chamber 3) show the same frequency response $\pm$ 4 dB in the frequency range of interest. In the lower frequencies these two rooms show a flatter frequency response than the chamber that was built first. This can be explained by the improved door encasing.

### 4.4 Reverberation time

Table 2 shows the RT60 values for the three chambers. Figure 4 shows the reverberation time per octave band for the three chambers. This result shows no significant difference between the reverberation times of the three chambers.

**Table 1:** Maximum deviation from the inverse square law according to ISO3745

| Third octave bands | ISO3745 Anechoic | ISO3745 Hemi-anechoic | Chamber 1 | Chamber 2 | Chamber 3 |
|---|---|---|---|---|---|
| 250 - 500 Hz | 1.5 dB | 2.5 dB | 6.8 dB | 10.5 dB | 8.2 dB |
| 630 - 5000 Hz | 1.0 dB | 2.0 dB | 8.9 dB | 5.7 dB | 5.1 dB |
| $\geq$ 6300 Hz | 1.5 dB | 3.0 dB | 2.4 dB | 2.2 dB | 2.4 dB |

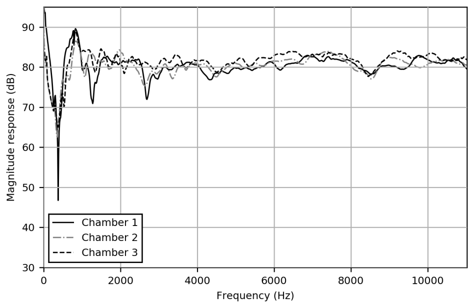


**Fig. 3:** The frequency response function of the three chambers using the swept sine method.

**Table 2:** RT60 in the frequency range of interest

| | RT60 (ms) |
|---|---|
| Chamber 1 | 17 |
| Chamber 2 | 22 |
| Chamber 3 | 20 |

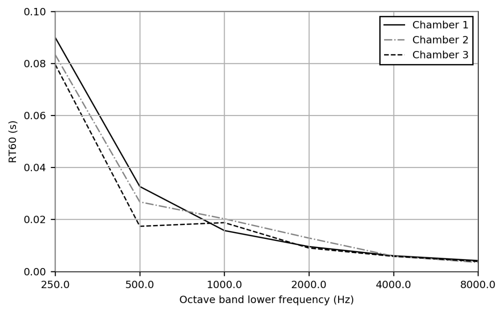


**Fig. 4:** The reverberation times per octave band for the three chambers

## 5 Conclusions

In this engineering brief the design, construction and validation of a low-cost acoustic anechoic chamber is presented.

Results show that the chambers perform well at higher frequencies. A remaining concern is usability at lower frequencies where performance is not as good as illustrated by the deviation from the inverse square law and the frequency response function. This can be due to the limited depth of pyramid foam that is used to absorb sound and forego reflections.

The improved door encasing in Chamber 2 and 3 leads to a flatter frequency response in the lower frequencies and better overall sound isolation.

For the purpose of providing a controlled environment for the final testing of the Somo Gen 2 array system, the performance of the chambers is satisfactory.

Further work on this subject includes a comparison with a commercially available acoustic testing chamber.

## 6 Acknowledgements

This work was supported by a Baekeland PhD grant of the Flanders Innovation Entrepreneurship agency

(VLAIO, Belgium) (HBC.2019.2200). The research leading to these results has received funding from the European Research Council under the European Union's Horizon 2020 research and innovation program / ERC Consolidator Grant: SONORA (no. 773268). This paper reflects only the authors' views and the Union is not liable for any use that may be made of the contained information.

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