Single Bass Array Documentation

Nils Öllerer

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Table of contents

1 Requirements

The goal of the development was a subwoofer system for a home cinema. The following requirements were placed on the system.

- Reference level (115 dB)
- Frequency range up to below 20 Hz
- Room influences should be eliminated
- Low variance over several seats
- Invisibly integrable

Various subwoofer systems were evaluated. These include a multi-sub-arrangement, the Single Bass Array (SBA) and the Double Bass Array (DBA). Detailed documentation of this investigation can be found here. In the end, the decision felt on the rear damped SBA, as it is cheaper than the DBA and can be easily integrated behind an acoustically transparent screen.

The decision was made to implement the subwoofers as closed boxes. This has the advantage that the lower cut-off frequency depends only on the equalization and the existing displacement volume. In addition, the group delay distortion due to the drop is very low at 12 dB/oct.

The room has the dimensions 6 x 4.8 x 2.2 m (L x W x H).

2 Development

The decision was made in favor of the Peerless XXLS12 (P830845). This 12" long-throw woofer features a linear drive and very low noise at high excursions. A total of 18 drivers in 65 l each were installed.

Illustration 1: Peerless XXLS12

First, the entire front was designed in a CAD program. It consists of four individual subwoofer housings that contain three or six woofers. In between, the HKL-01 home cinema speakers are flush-mounted into the wall.

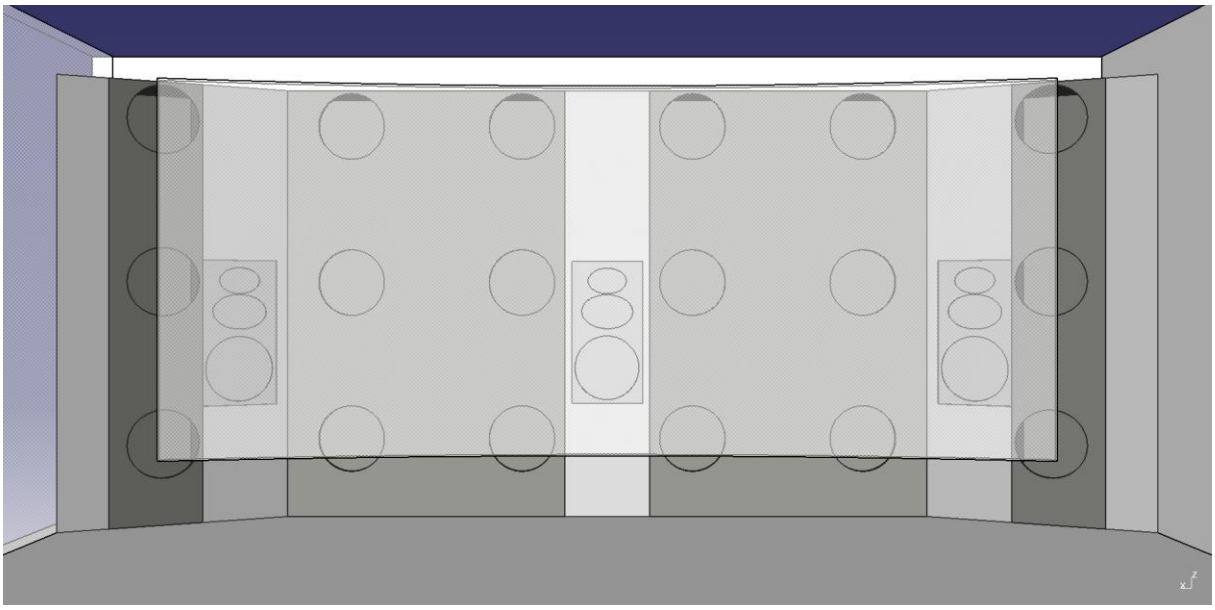

Illustration 2: CAD design of the subwoofer front

The side speakers are angled to the listening position. The outer subwoofers are accordingly a little further in the room.

MDF was used as the material. The enclosures of the subwoofers were milled with a router. Thus, they could be installed flush.

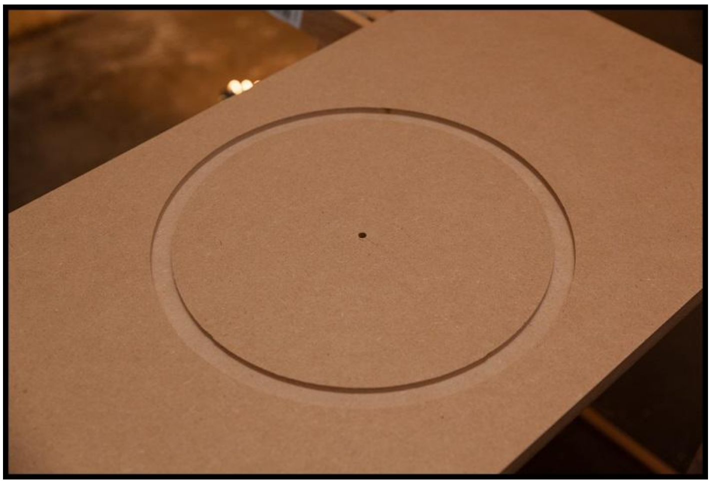

Illustration 3: Milling for flush mounting

A total of 144 drive nuts were installed so that the drivers are connected to the housing as tightly as possible.

The 4 mm² cables have been attached to the housing wall so that they do not rattle on the housing during large excursions. The housings were stiffened on the inside with struts.

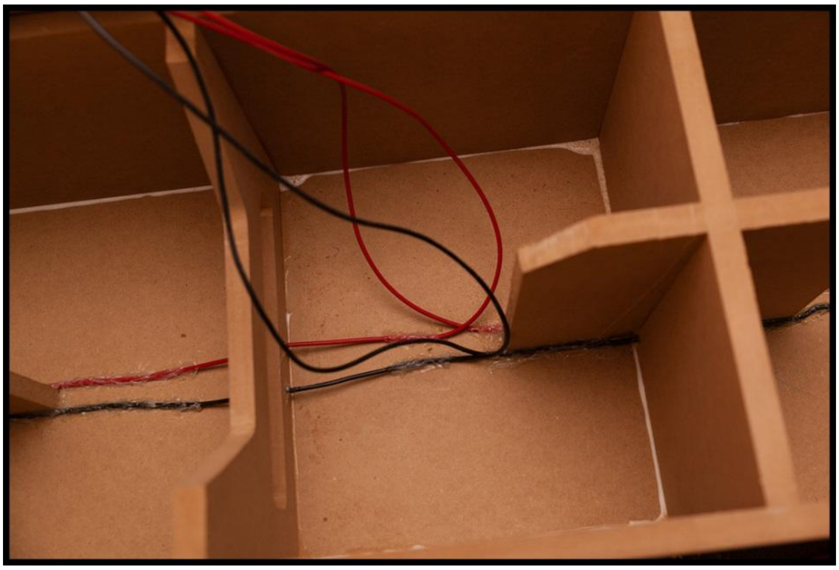

Illustration 4: Fastening the cables

The edges of the cabinets were treated with a flush and round milling cutter so that the MDF does not flake off as much as possible when positioned in the room.

Illustration 5: Two columns before painting

After painting with black, matt paint, the damping material could be introduced. The decision felt on Caruso Iso Bond. This dampens modes that may be excited by harmonic distortion. It also increases the virtual volume.

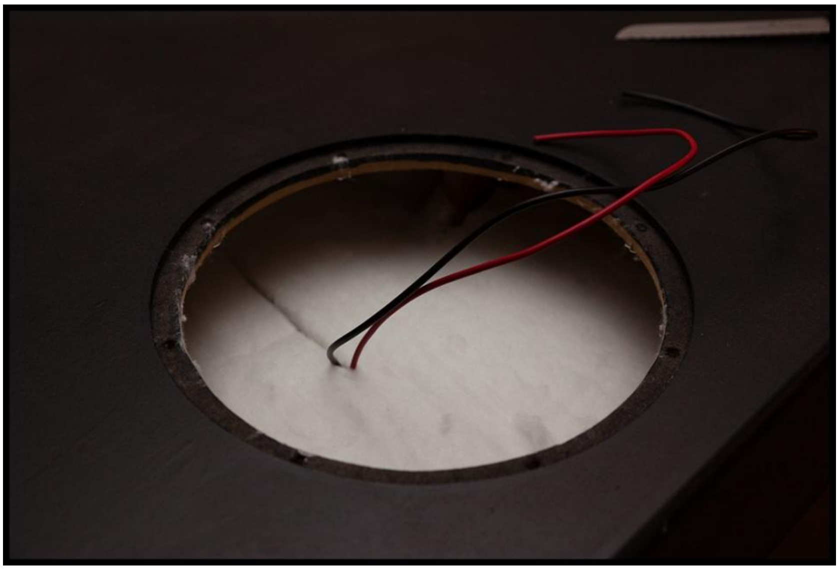

Illustration 6: Caruso Iso Bond

The last step was soldering the drivers to the cables.

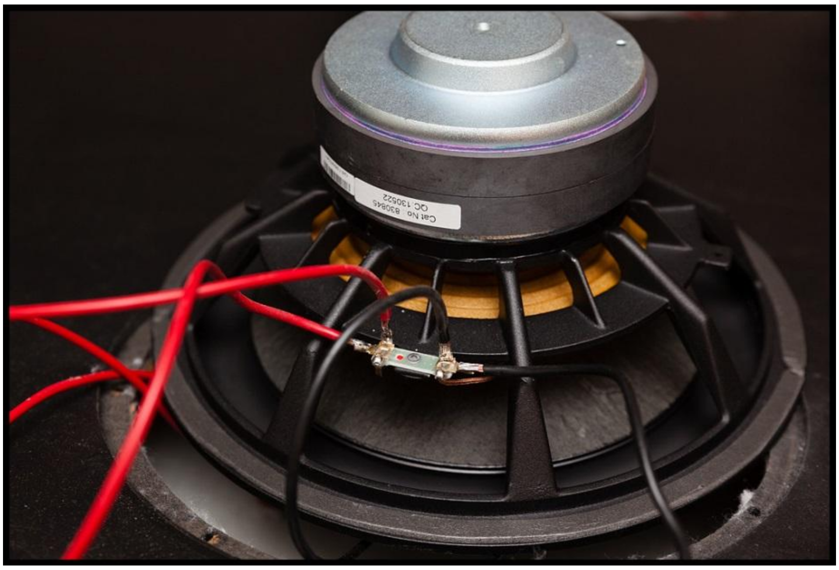

Illustration 7: Solder Contacts

Three drivers per column are connected in parallel. Three of these columns in a row. This results in a minimum of 5.4 ohms, which is no problem for commercially available power amplifiers.

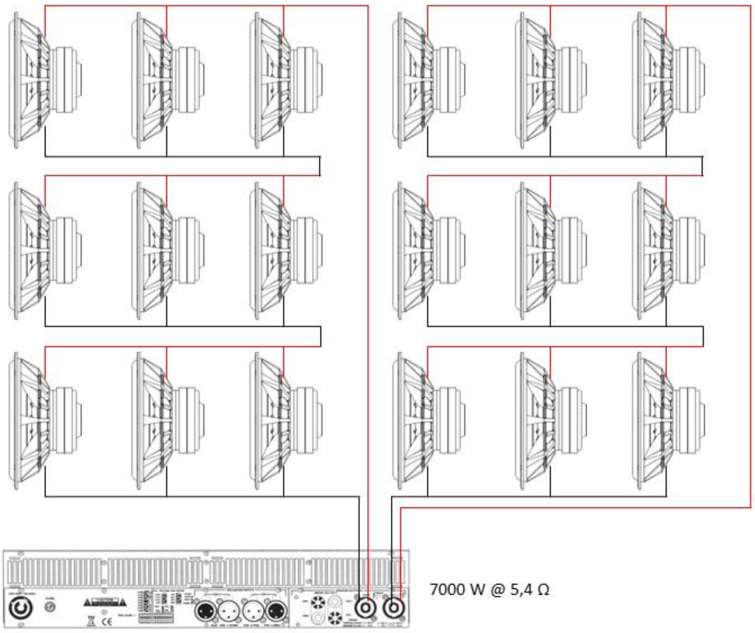

Illustration 8: Wiring of the 18 drivers

After being set up and screwed to the wall and the concrete floor, the front speakers were installed between the subwoofers. They are decoupled so that no vibrations are transmitted between the subwoofer and HKL-01.

Illustration 9: Finished front

As a final step, the rear absorber was built. It serves to dampen the longitudinal modes and thus ensure a linear amplitude response and fast decay. It is made of 55 cm thick rock wool (Sonorock) and has been back-ventilated for 10 cm to prevent mould problems.

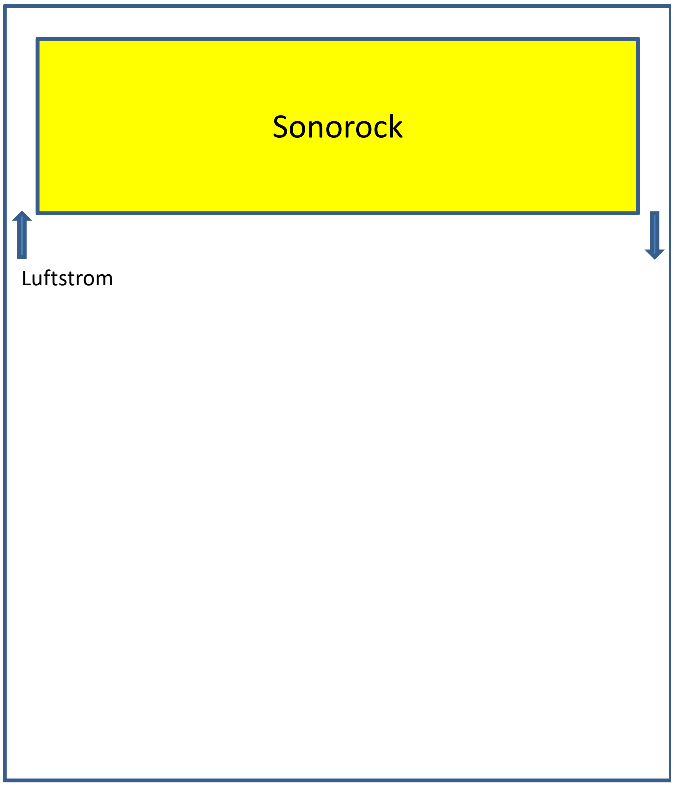

Illustration 10: Rear absorber (top view)

3 Measurements

3.1 Amplitude response

The amplitude response in room shows a very low lower cut-off frequency of about 4 Hz. This is due to the room gain. The area of the 1st longitudinal mode has an exaggeration, which, however, does not resonate for long, as can be seen in the decay spectrum. In general, the ripples are low. For a linear amplitude response between 3.3 – 200 Hz, few filters are required in the equalizer.

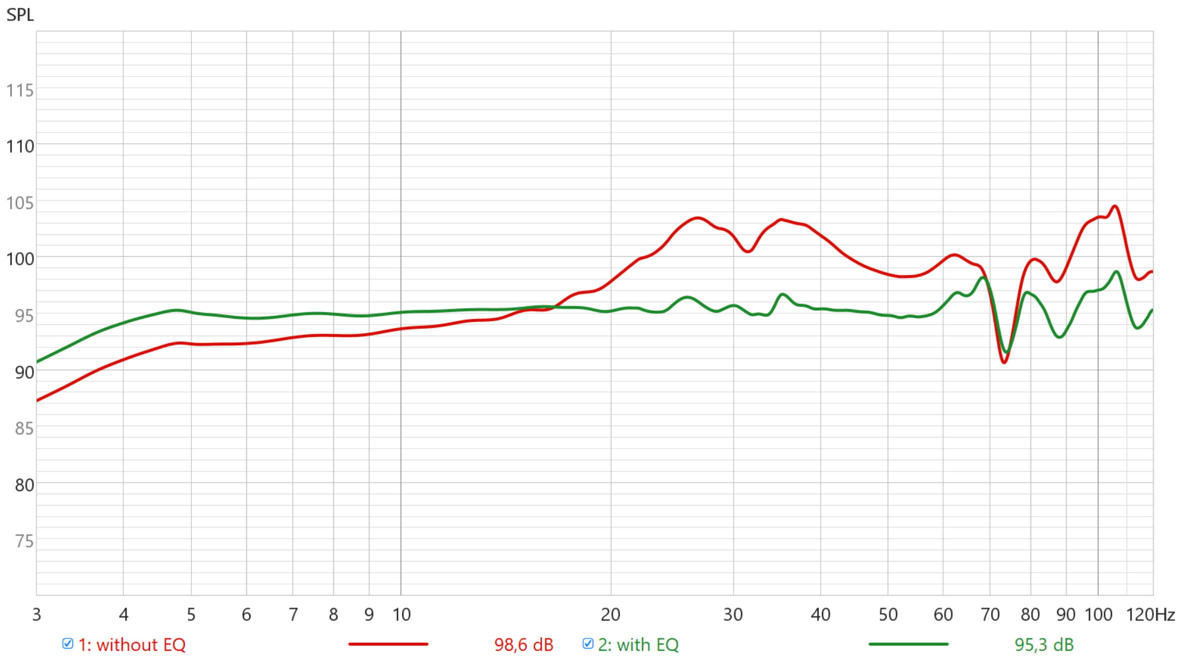

Illustration 11: Amplitude response

3.2 Time response

First, the initial state is considered. Without the rear absorber, the longitudinal modes are maximally pronounced. The slump between the 1st and 2nd longitudinal mode is also present as expected.

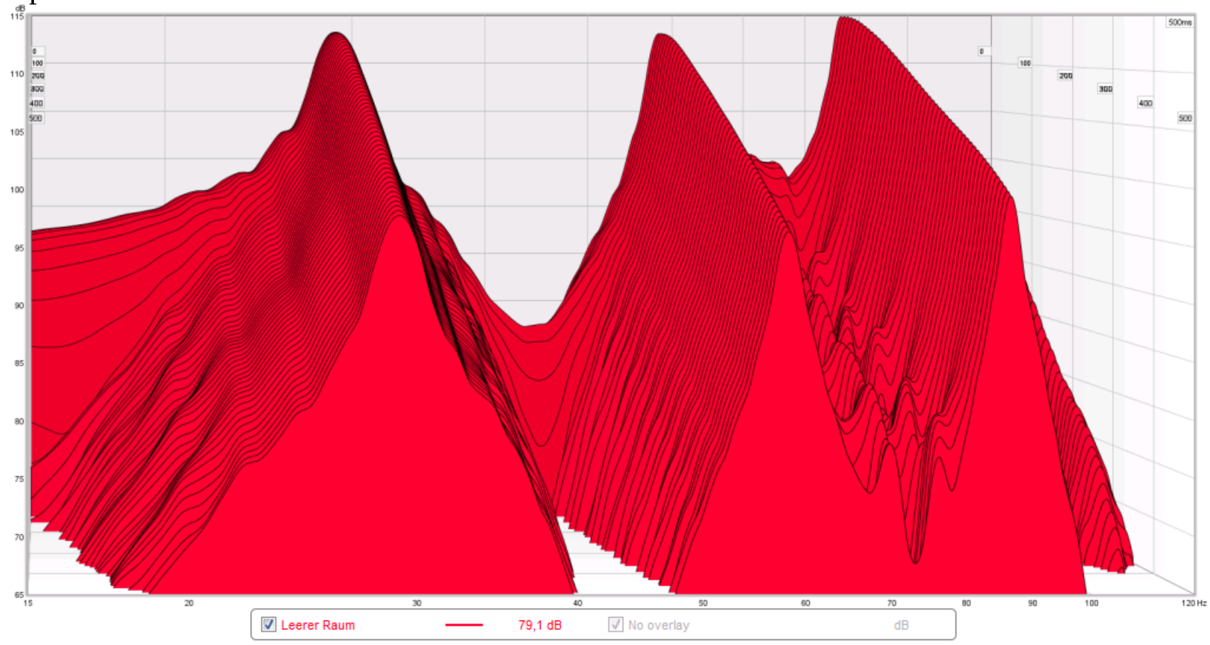

Illustration 12: Decay spectrum in empty room

With Absorber, a completely different picture emerges. The rock wool absorbs the longitudinal mode almost completely and the sink has also disappeared completely.

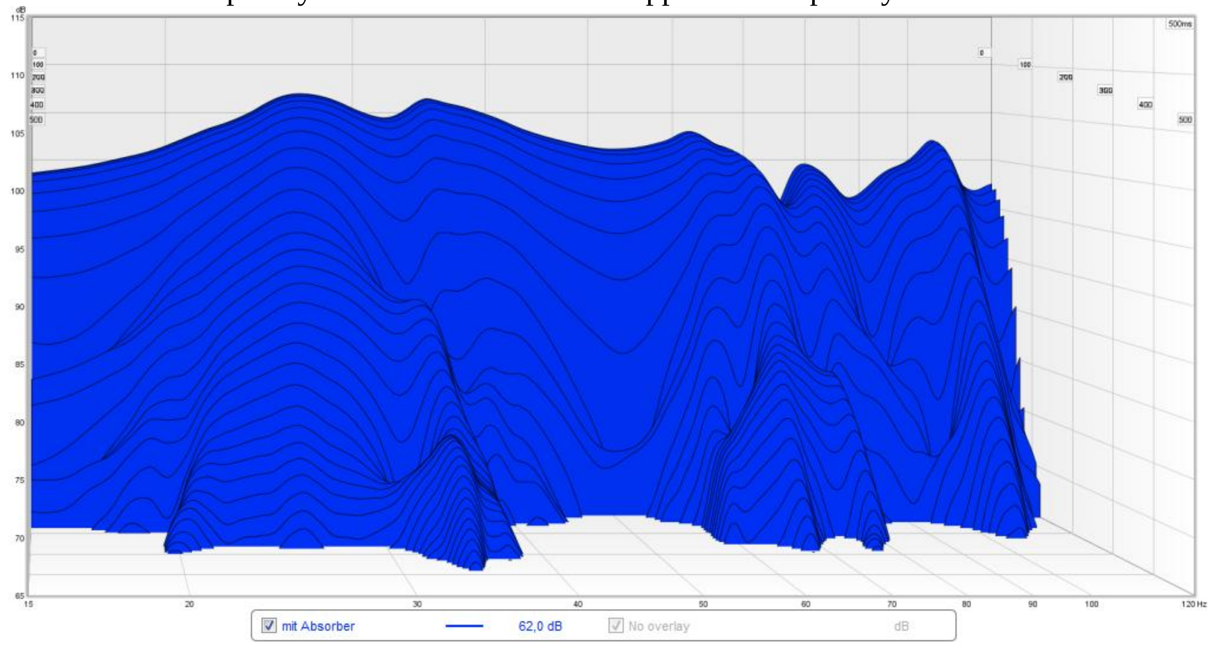

Illustration 13: Decay spectrum with absorber

The remaining decay of the 1st longitudinal mode can be further reduced by using an equalizer. Since the fashion has a minimum-phase character, an IIR equalizer is sufficient. All that is needed is a peaking filter that fit to the Q factor of the mode as accurately as possible.

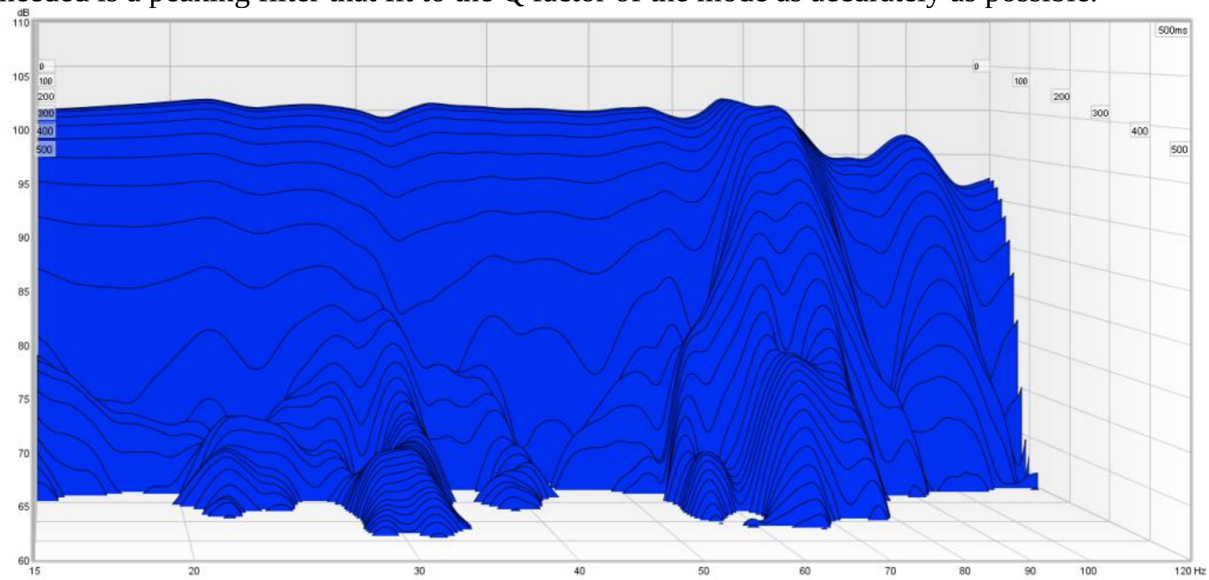

Illustration 14: Decay spectrum with absorber and equalizer

In the group delay distortions, it can be seen that not only the frequency domain but also the time domain is corrected.
In general, the group delay is very low (<10 ms) due to the low lower cut-off frequency. The closed boxes enable this good timing behavior.

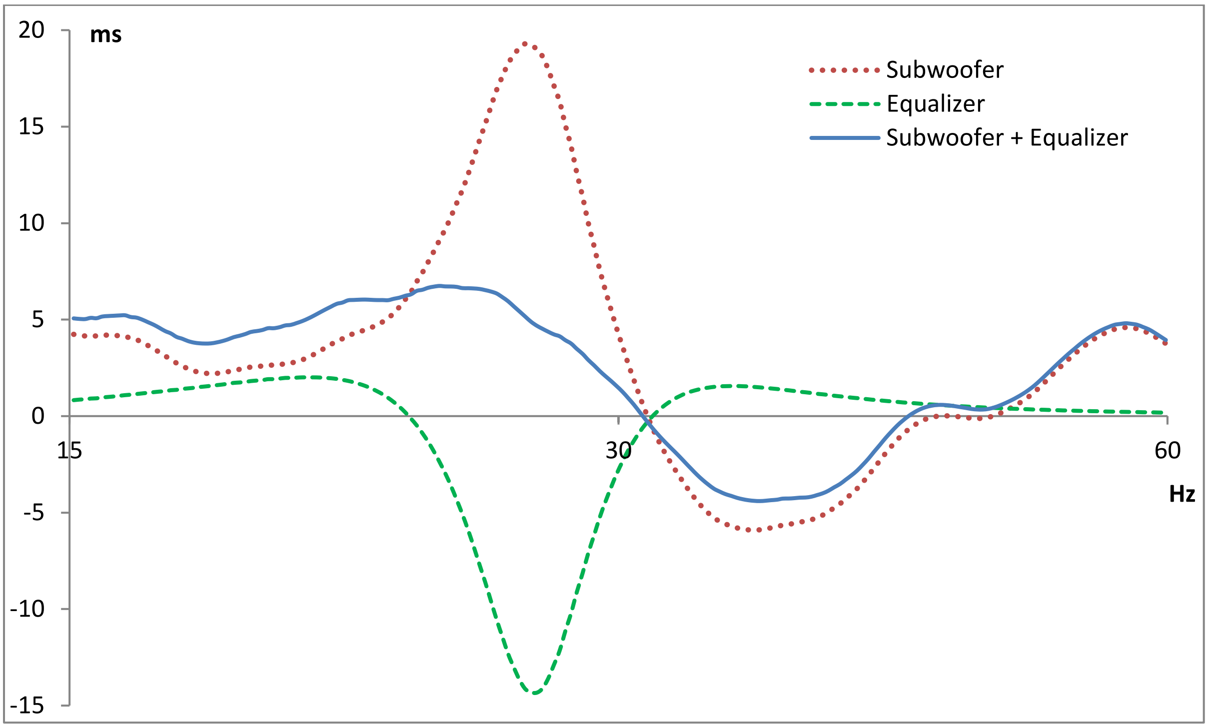

Illustration 15: Group Delay

3.3 Variance over several seats

The aim was to investigate how large the variances are at different seating positions. Since there are two rows of seats, the measuring positions were chosen accordingly. The colors of the measurement positions in the schematic representation correspond to those of the measurements.

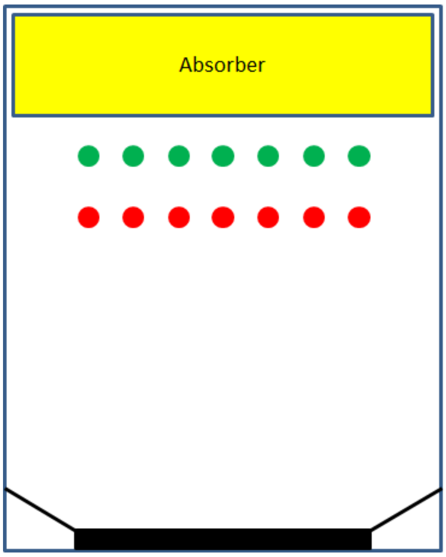

Illustration 16: Measuring positions

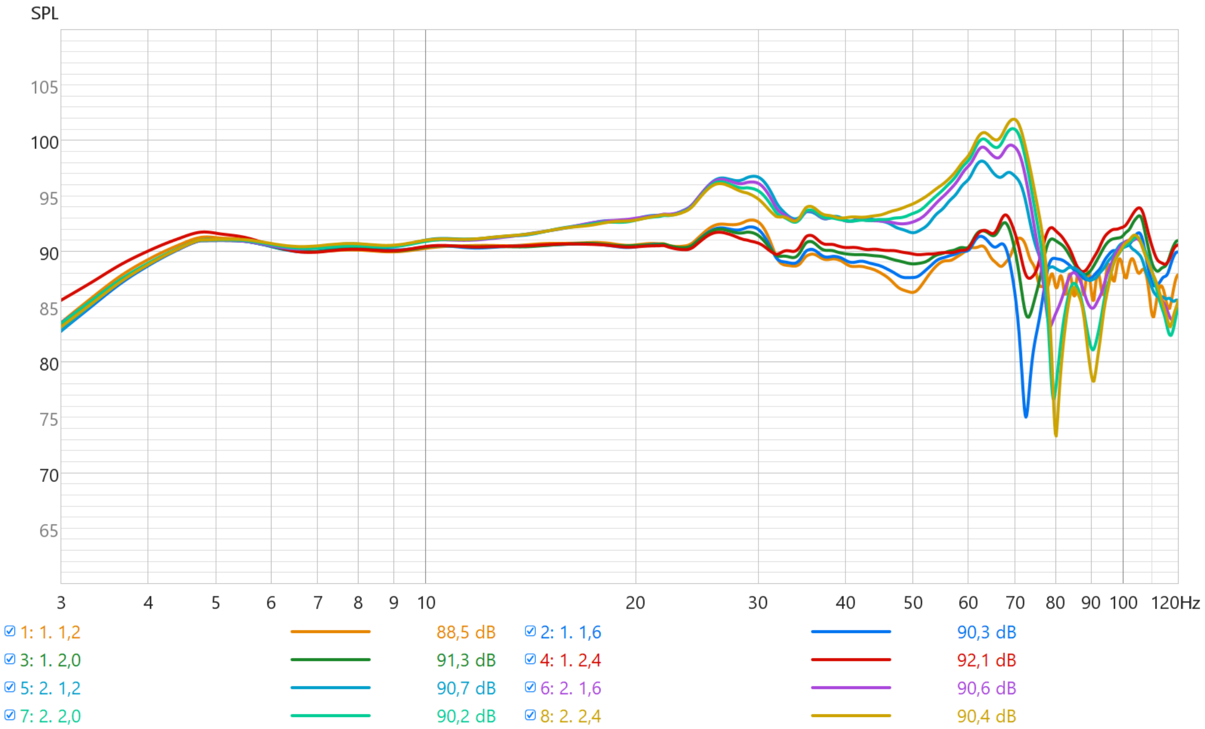

Illustration 17: Frequency responses in the seating area

As expected, the variance in the first row of seats is very low. The frequency response in the second row is raised around the 1st and 2nd longitudinal modes, which is due to the shorter distance to the rear wall. This was also to be expected, as the absorber does not work ideally, of course.

3.4 Non-linear Distorsion

The measurements of the non-linear distortions should be considered in context. The SBA can only take measurements directly in the room, so vibrating parts (e.g. the door) can have a strong influence on the measurement. Furthermore, the room gain ensures that the fundamental wave is amplified compared to the harmonics, which brings about an improvement in non-linear distortion, especially in the lower frequency range.

At 90 dB, K2 reaches values of a maximum of 0.2% in large parts. Only at 10 Hz does it rise to 0.7%. K3 is around 0.1%.

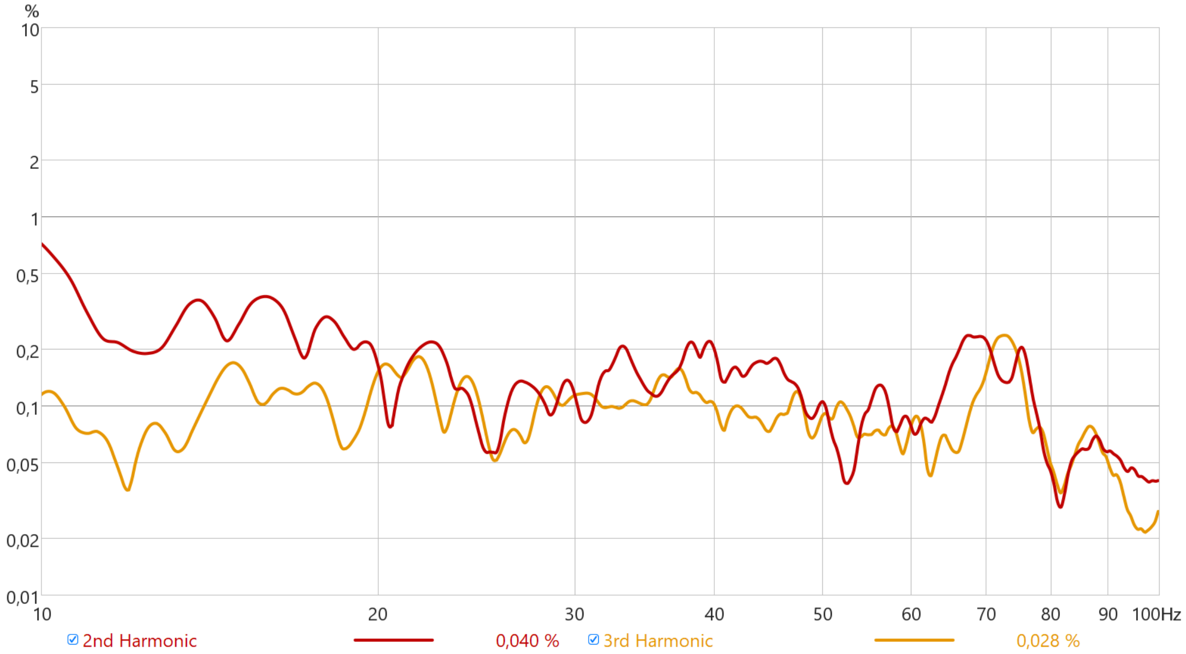

Illustration 18: Non-linear distortion at 90 dB

At 100 dB, K2 rises to almost 1% below 20 Hz. Above that, it is < 0.3%. In K3, no increase can be recorded.

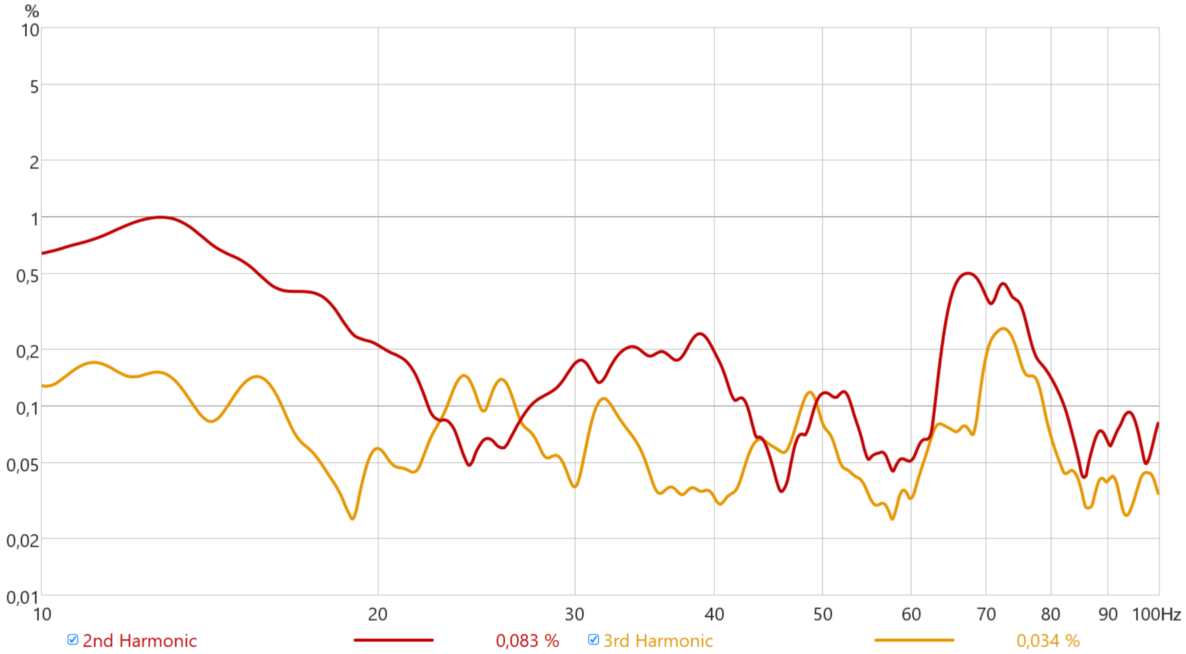

Illustration 19: Non-linear distortion at 100 dB

At 110 dB, K3 rises to just under 0.7% above 20 Hz. Below 20 Hz, K2 reaches a maximum of 2.5%. Overall, this is a very good result.

Illustration 20: Non-linear distortion at 110 dB

3.5 Maximum SPL

In the following, the maximum SPL was determined based on CEA bursts. The sound pressure level was increased until background noise was clearly audible, or the measured sound pressure no longer increased linearly. Reasons for this are the achievement of X_{max} of the drivers or the maximum electrical power of the power amplifier.

The measurement is compared to the simulation. Furthermore, the room gain was measured and added to the sound pressure level of the simulation. The deviation between measurement and simulation is about 2 dB in the lower frequency range.

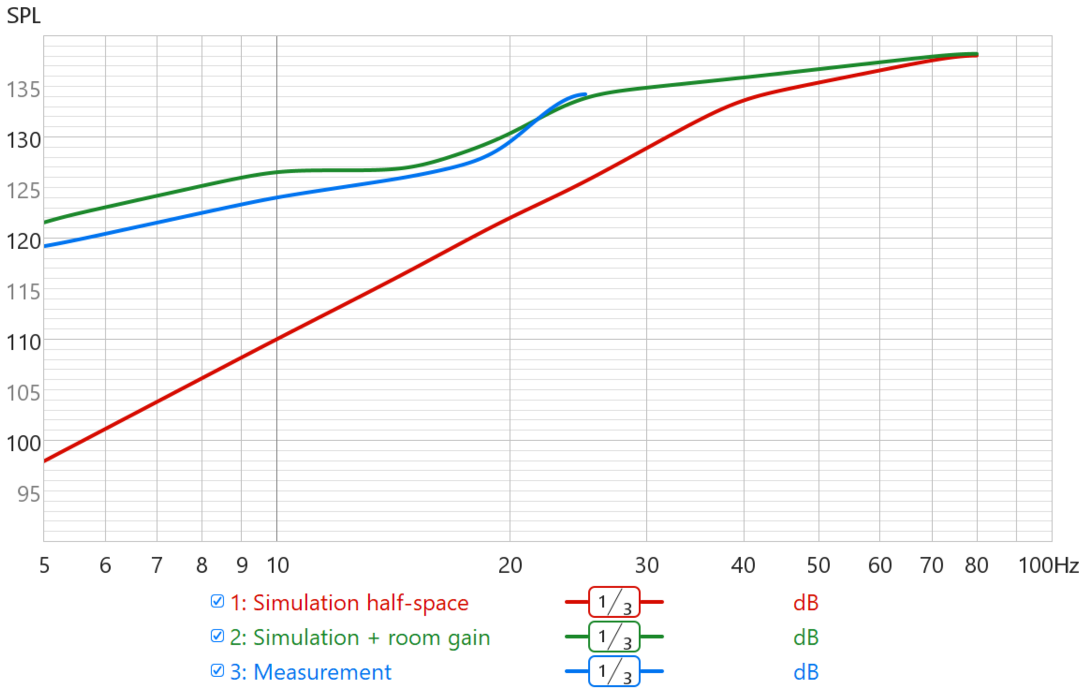

Illustration 21: Maximum SPL

4 Specifications

Woofer:	18 × Peerless XXLS12
Diaphragm area:	8836 cm²
X_{max}:	± 12.5 mm
Frequency range:	3.8 Hz – 120 Hz (± 1.5 dB)
THD (25 Hz):	0.1% @ 100 dB
	0.5% @ 110 dB
Maximum SPL:	>130 dB @ >20 Hz
	130 dB @ 20 Hz
	124 dB @ 10 Hz
	119 dB @ 5 Hz
Power amplifier:	2 x 3500 W RMS @ 5.4 Ω
Subsonic filter:	no
Dimensions:	420 x 200 x 20 cm (B x H x T)
Rear absorber:	55 cm rock wool + 10 cm air gap