Variants of the Double Bass Array

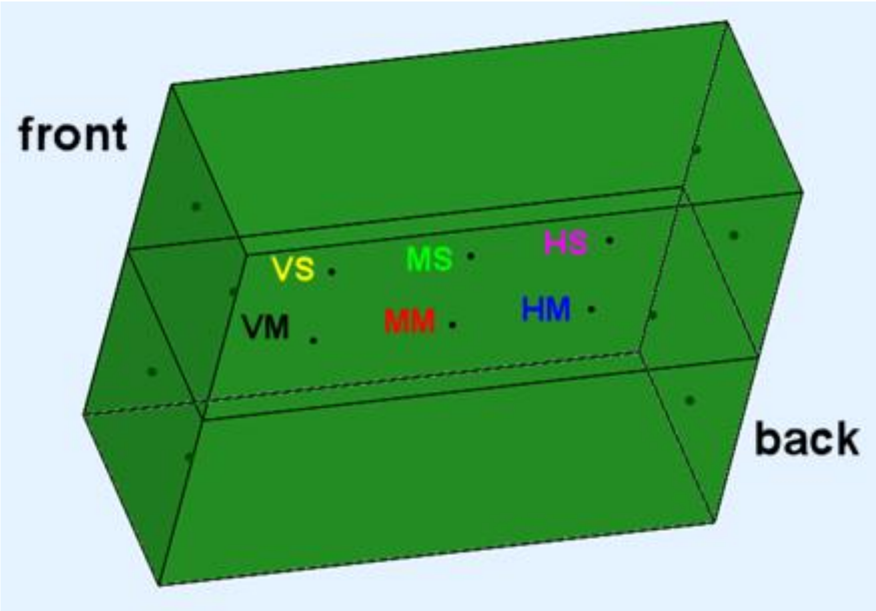
1. Content

2. Motivation

The aim is to investigate whether a double bass array can be reduced in such a way that its function is minimally impaired. The goal is to find alternative arrangements that save costs and can be integrated into non-optimal rooms. For example, if a door blocks the ideal position of a driver.

3. Simulation

The simulations were performed with ABEC. The virtual room measures 6 x 4.8 x 2.4 m. The measuring positions of the virtual microphones were 1.5, 3 and 4.5 m away from the front wall and doubled again to a distance of 1 m from the center towards the side wall. A total of six measuring points exist in the room.



Colors of the measuring positions in the amplitude response:

- **Black: Center Front**
- **Yellow: Front side**
- **Red: Center Center**
- **Green: Middle Side**
- **Blue: Centre back**
- **Purple: Back Side**

Room modes (up to 120 Hz):

- **Length: 29 Hz, 57 Hz, 86 Hz**
- **Width: 36 Hz, 71 Hz, 107 Hz**
- **Height: 71 Hz**

A front woofer grid and a rear one is modeled from ideal point sound sources. The rear one is inverted and delayed. The delay corresponds to the travel time it takes for sound to pass through the length of the room. Furthermore, the signal from the rear grid is slightly attenuated to compensate for the low wall attenuation.

The two grids will not always be symmetrical in the following. In these cases, the sound pressure level of the rear grid has been adjusted to match that of a symmetrical arrangement. If, for example, there are only half as many drivers at the rear as at the front, they are fed with twice the signal level.

In addition, a flat high-pass was placed in front of all woofers, which simulates the drop of a closed subwoofer. This compensates for the strong increase to low frequencies of the interfacial amplification ("pressure chamber effect") and generates amplitude responses that come relatively close to reality.

For each simulation, it was checked whether the 1st longitudinal mode no longer has any effects in the entire room. For this purpose, the sound pressure level was displayed as a sonogram (top view). In the following, this diagram will not be published for every simulation, as differences were practically non-existent. The variance is very low in the whole room.

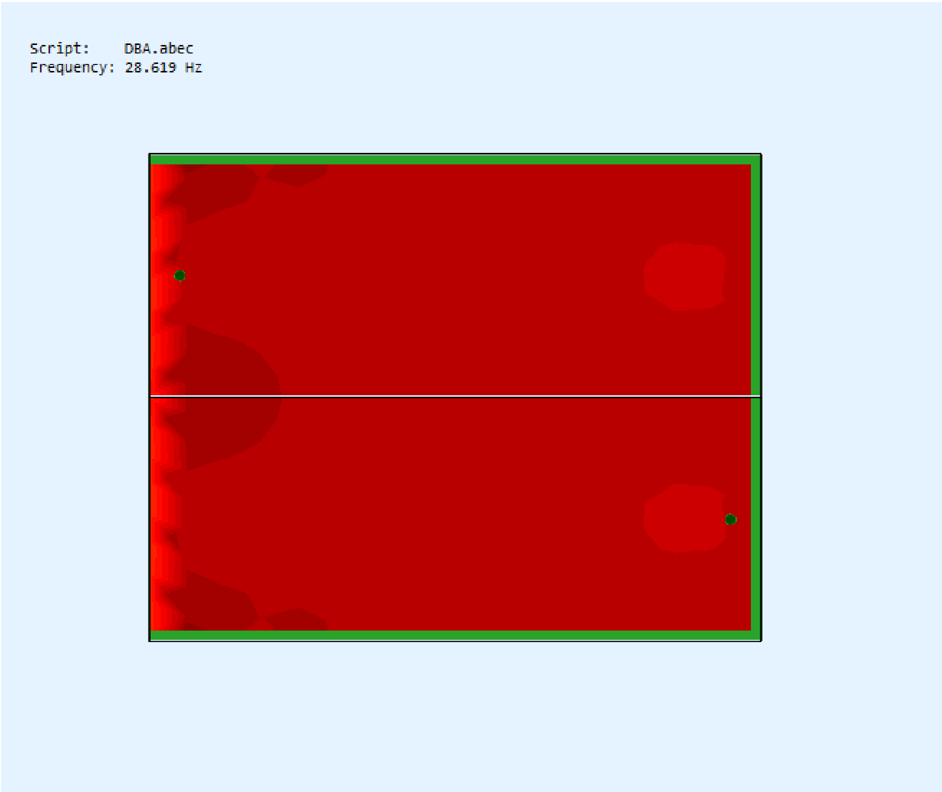


Figure 1 - 28 Hz on a Double Bass Array

For comparison, a sonogram in which only the front grid is active. The strong expression of the 1st longitudinal fashion is clearly visible. This is also noticeable in the amplitude response as an increase.

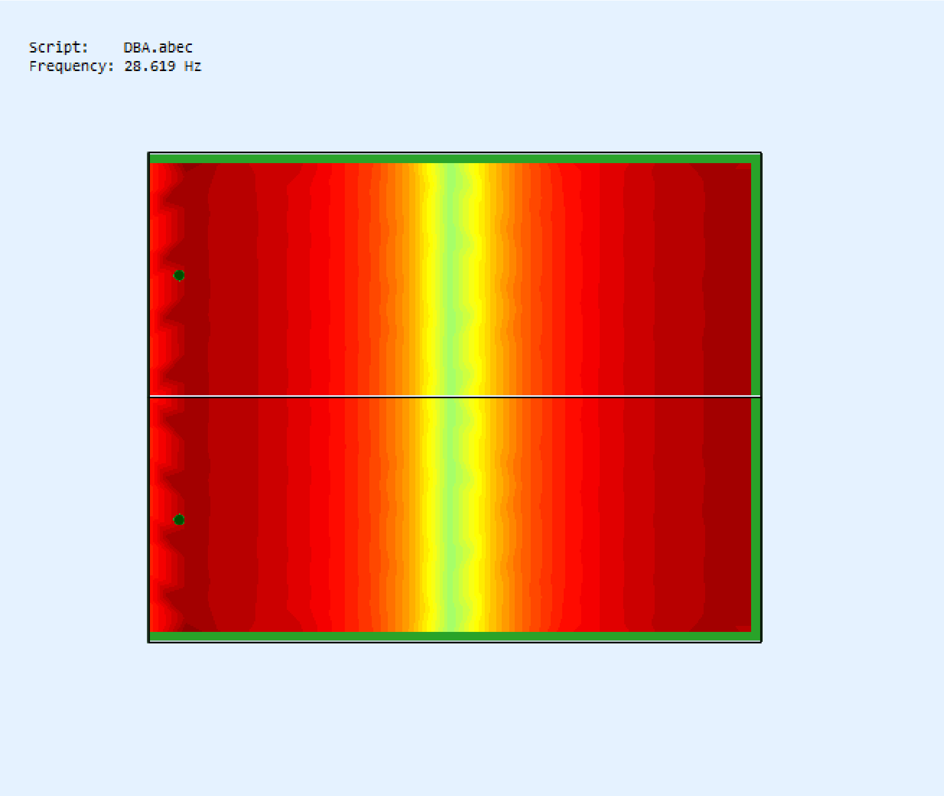
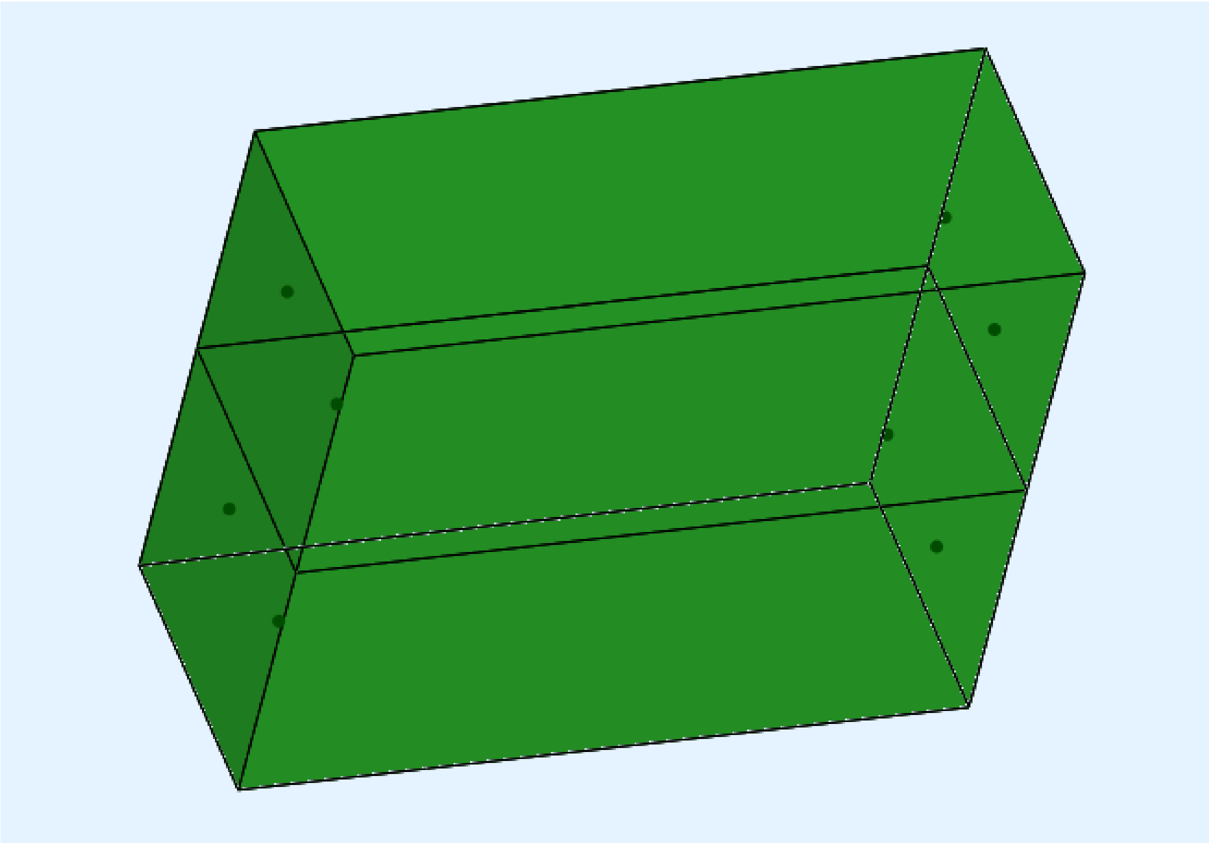


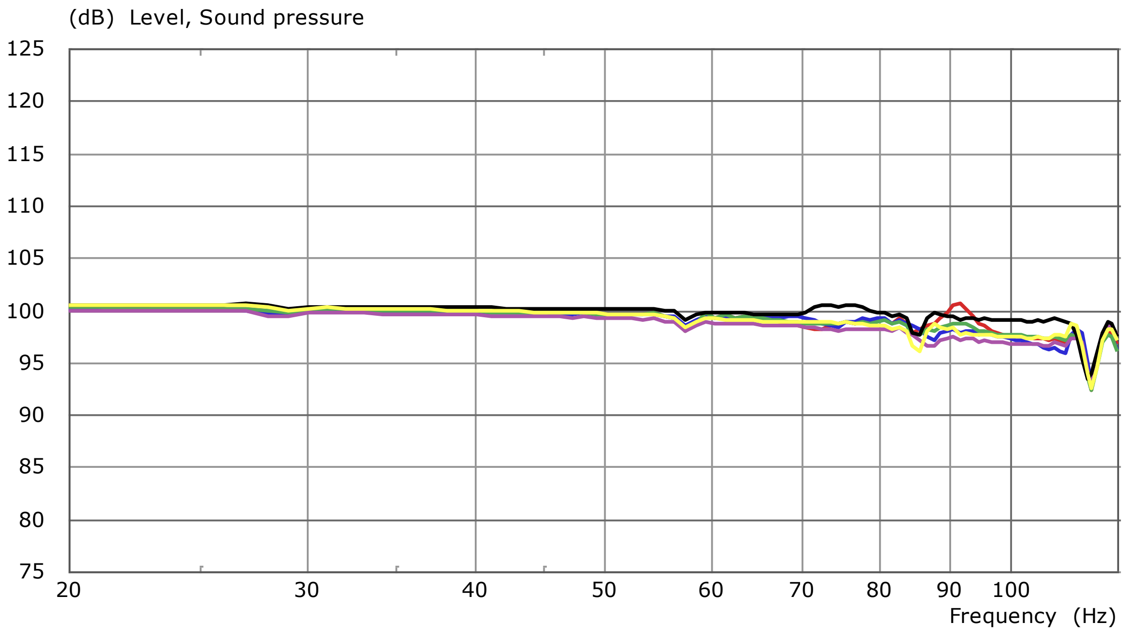
Figure 2: 28 Hz with active front grid (undamped SBA)

4. Mono DBA

4.1. 4 drivers per grid

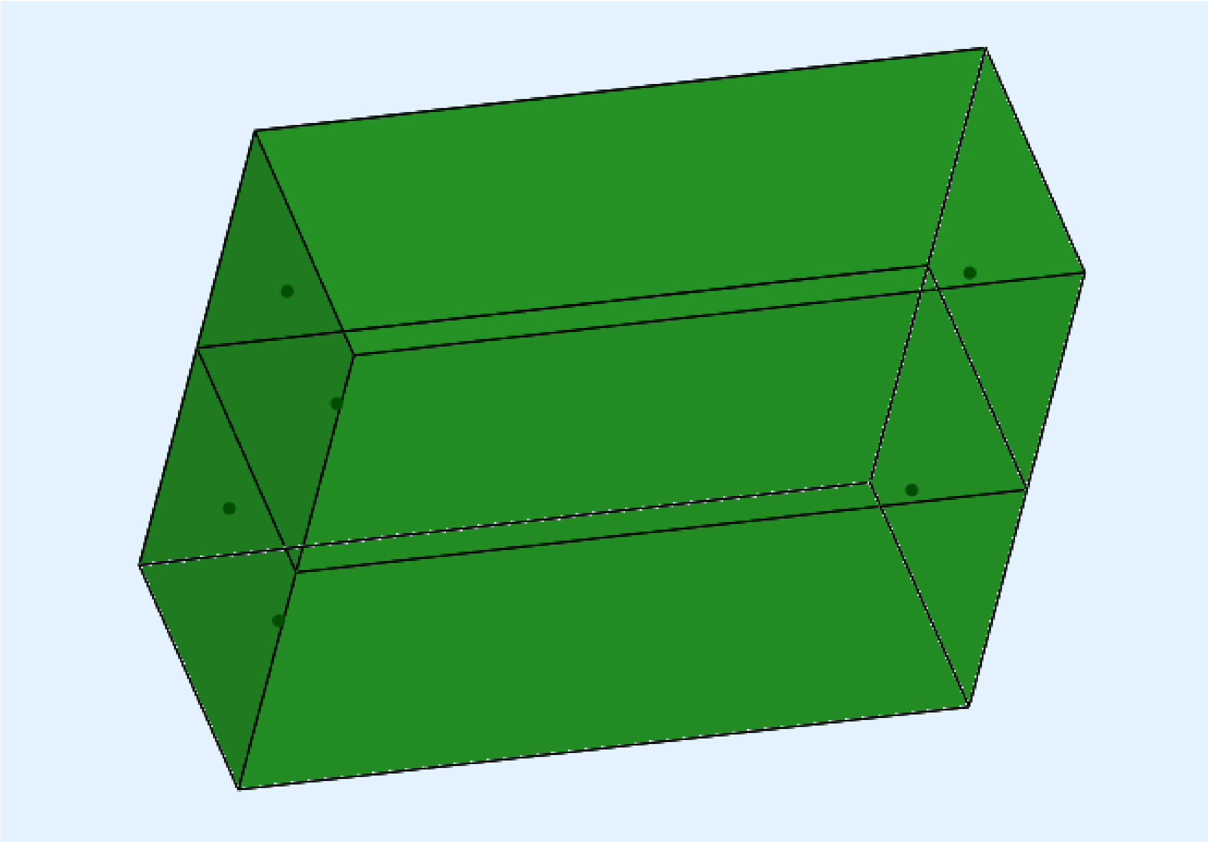
This simulates the typical DBA arrangement with four drivers per grid at ¼ and ¾ of the width and height.

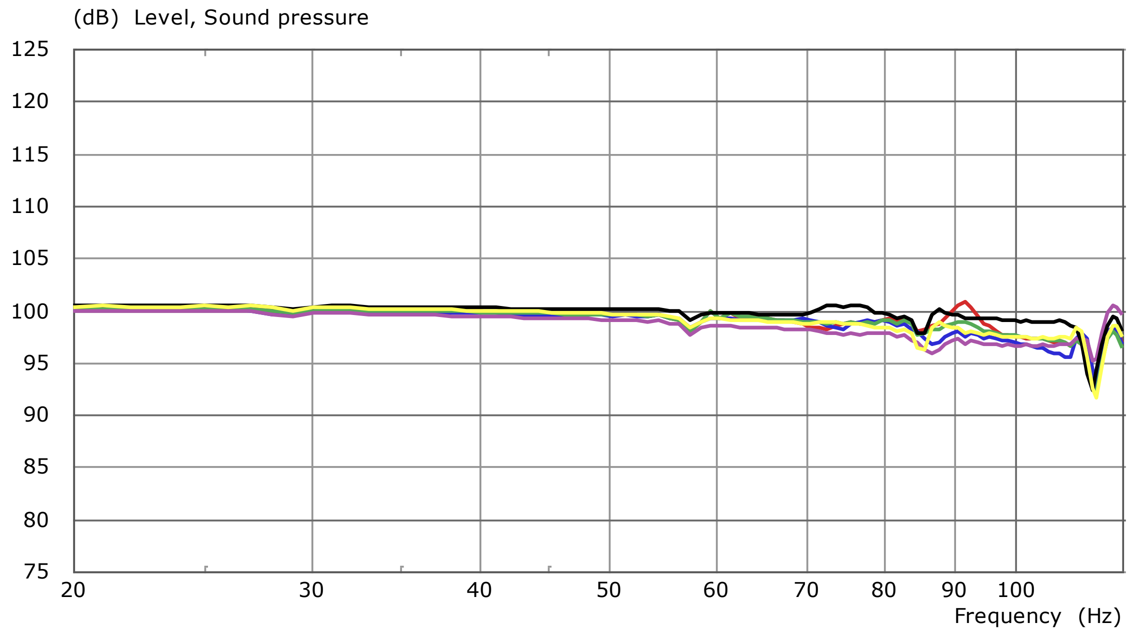




4.2. 4 drivers at the front, 2 drivers at the rear

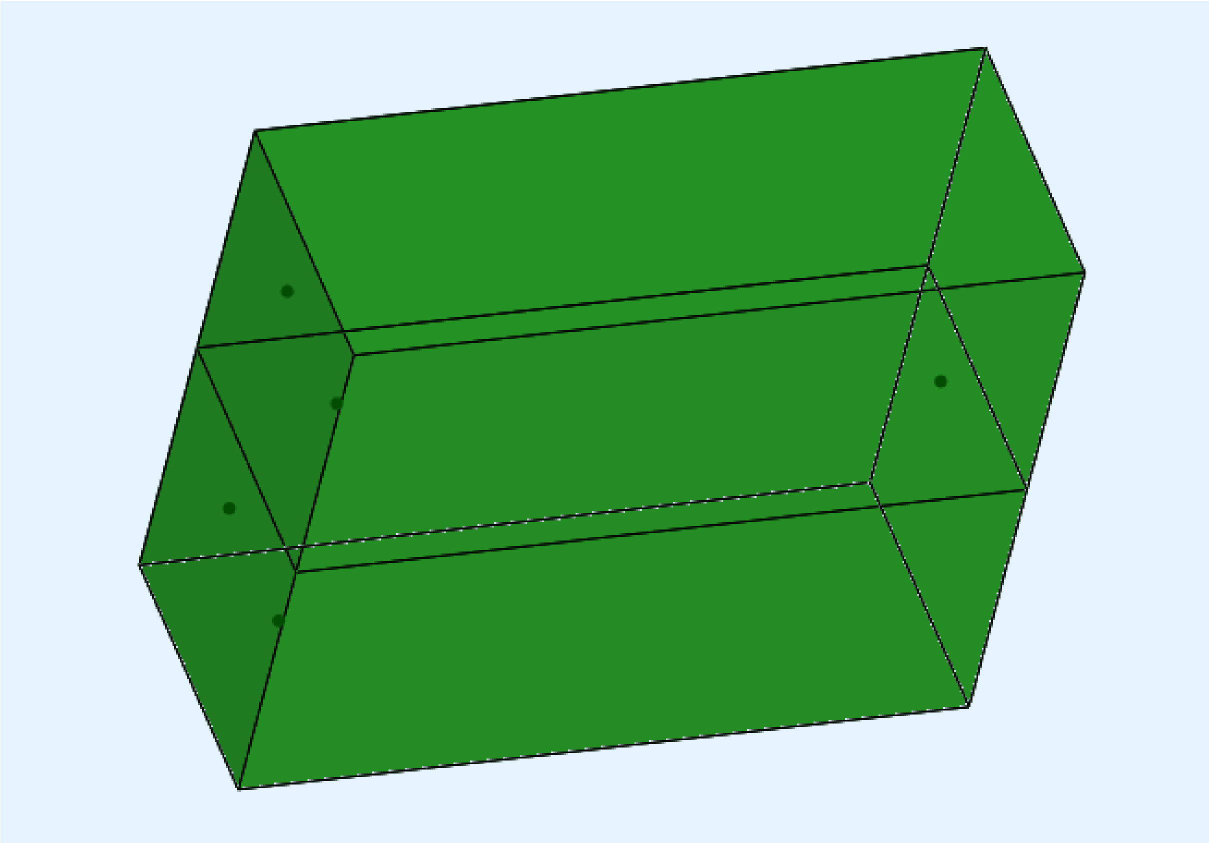
The rear grid was cut in half and the subwoofers were positioned at ½ of the room height.

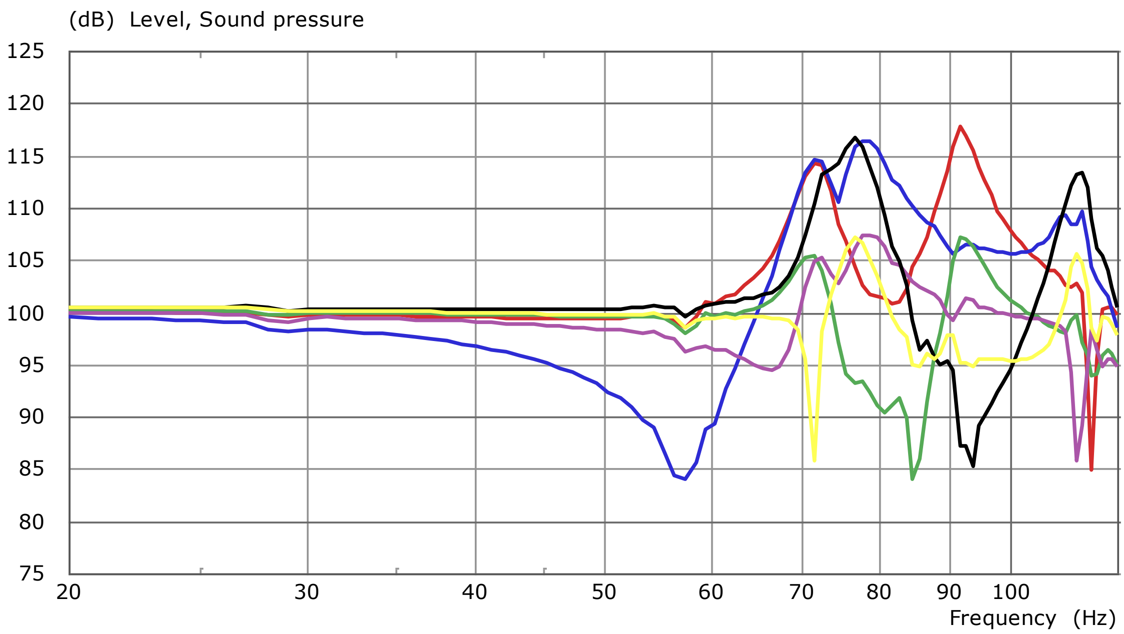




4.3. 4 drivers at the front, 1 at the rear

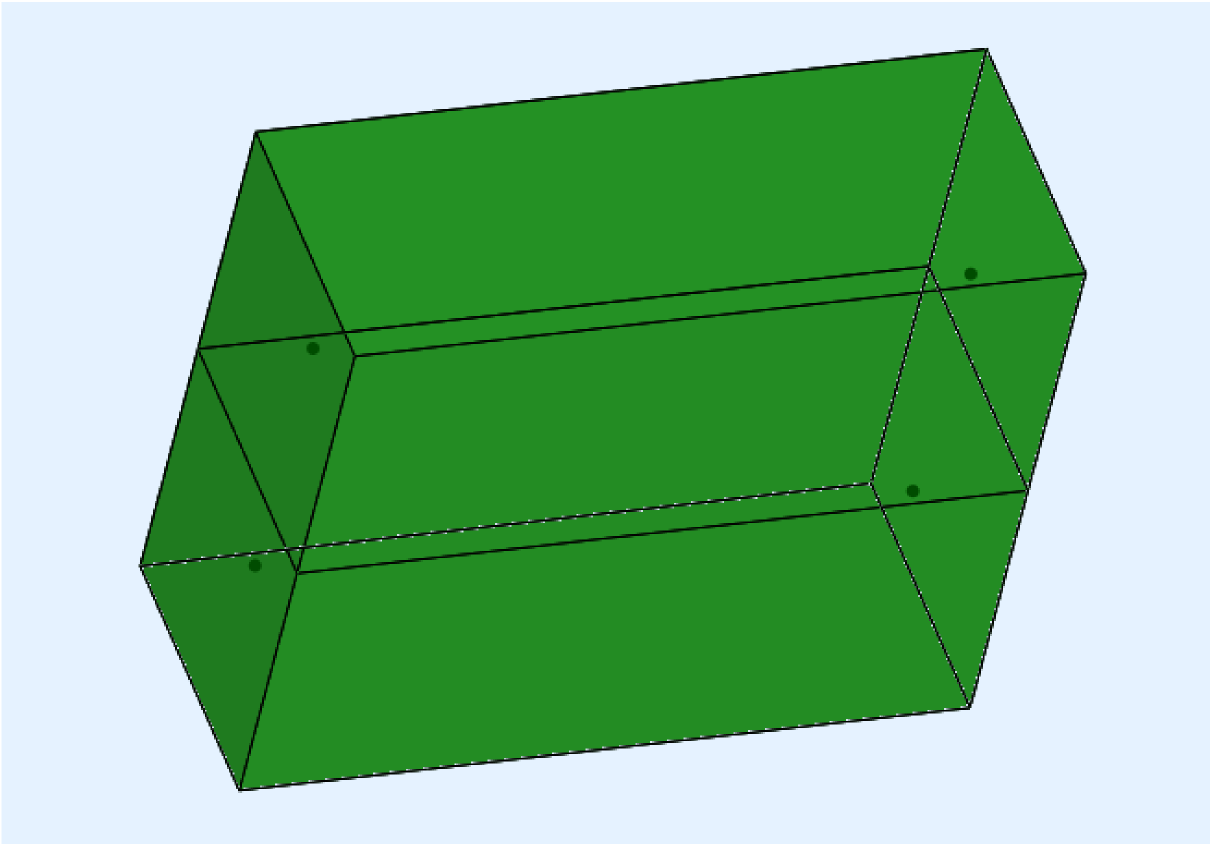
The rear grid has been further reduced to one driver, which is located at ½ of the wall width and height.

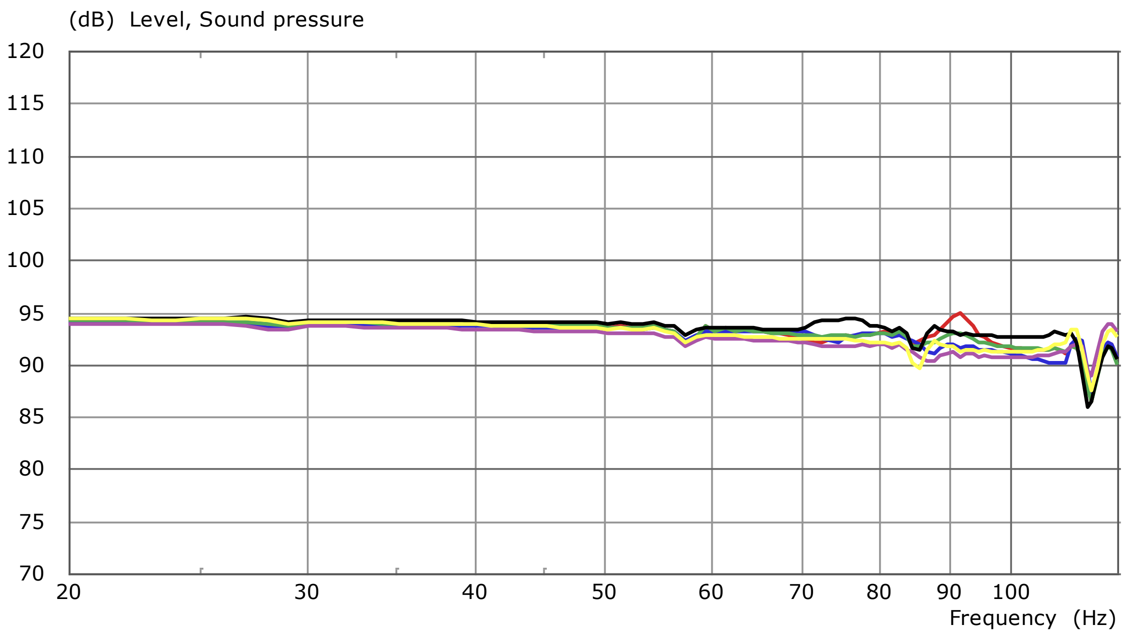




4.4. 2 drivers per grid at ½ of the height

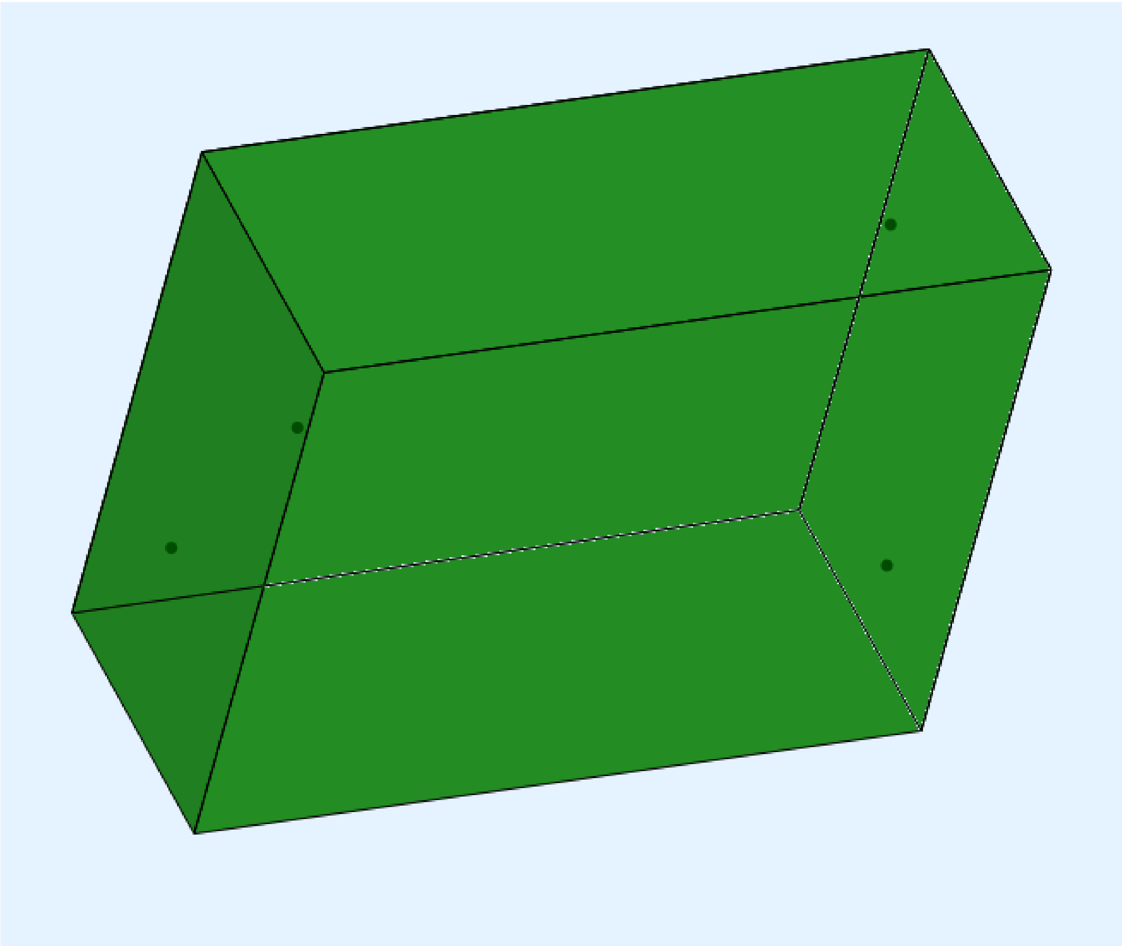
Both grids were cut in half and the drivers were positioned at ½ of the room height.

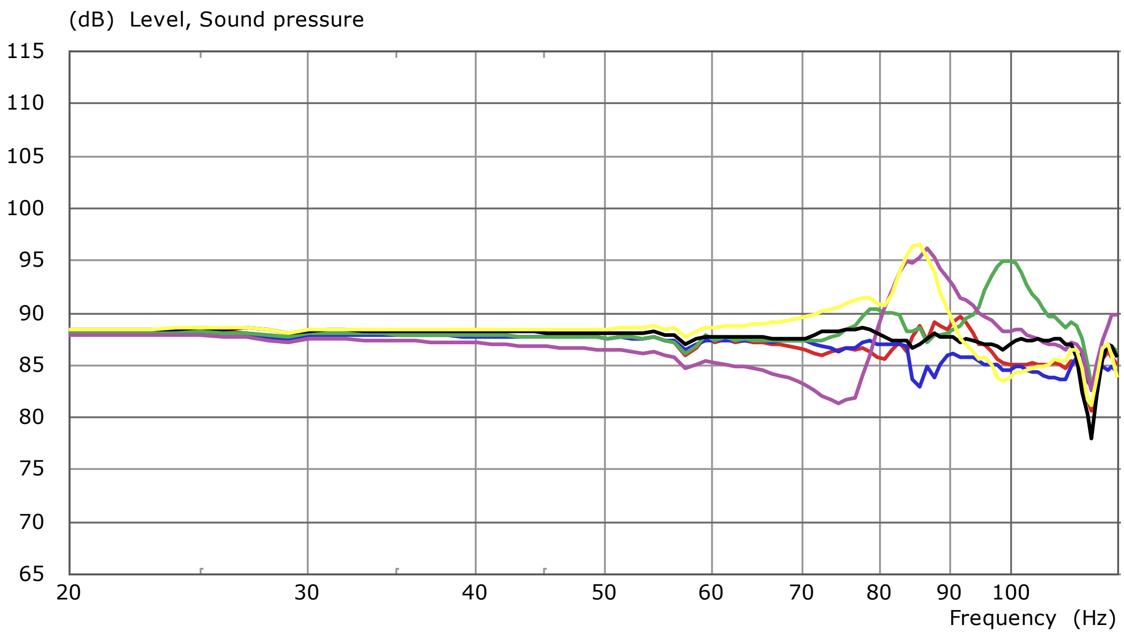




4.5. 2 drivers per grid on ¼ and ¾

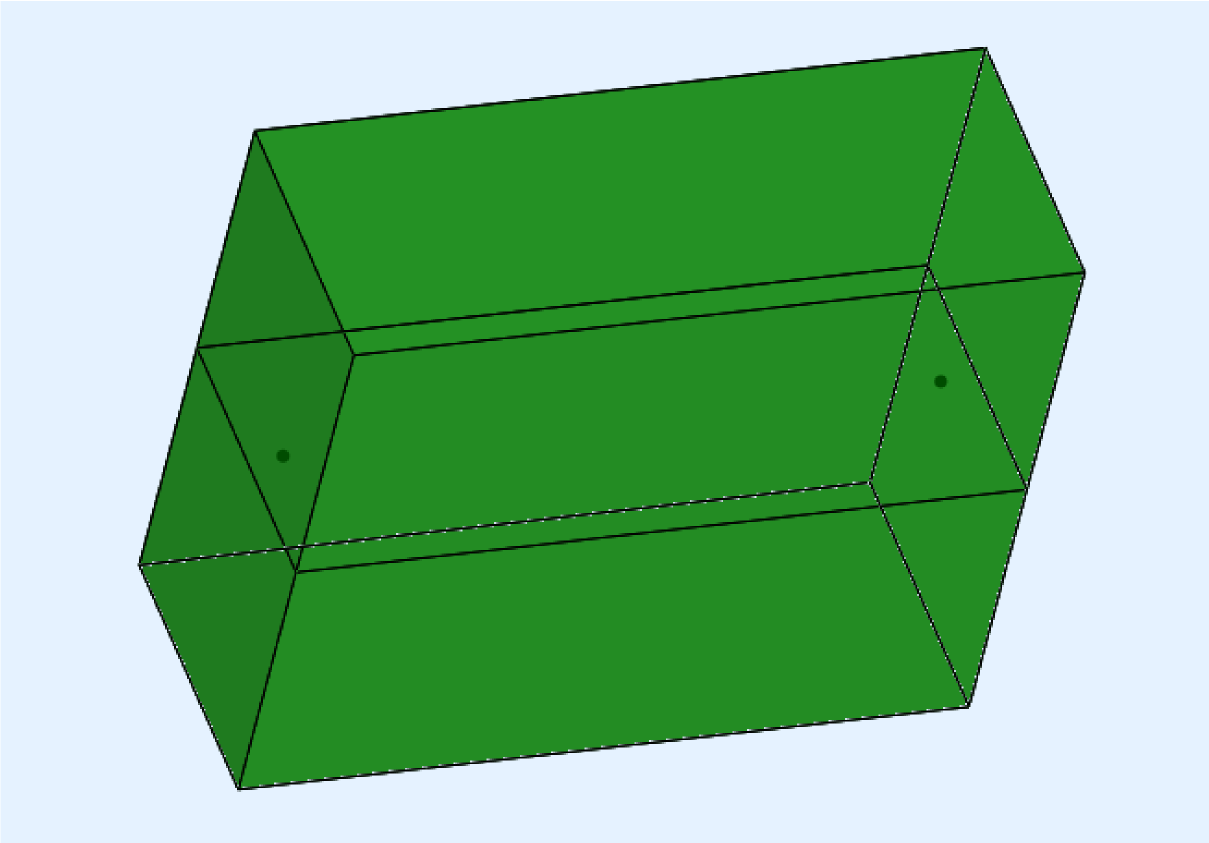
Now the drivers are mounted at ¼ and ¾ of the width and height of the room. The rear grid is point-symmetrical to the front one.

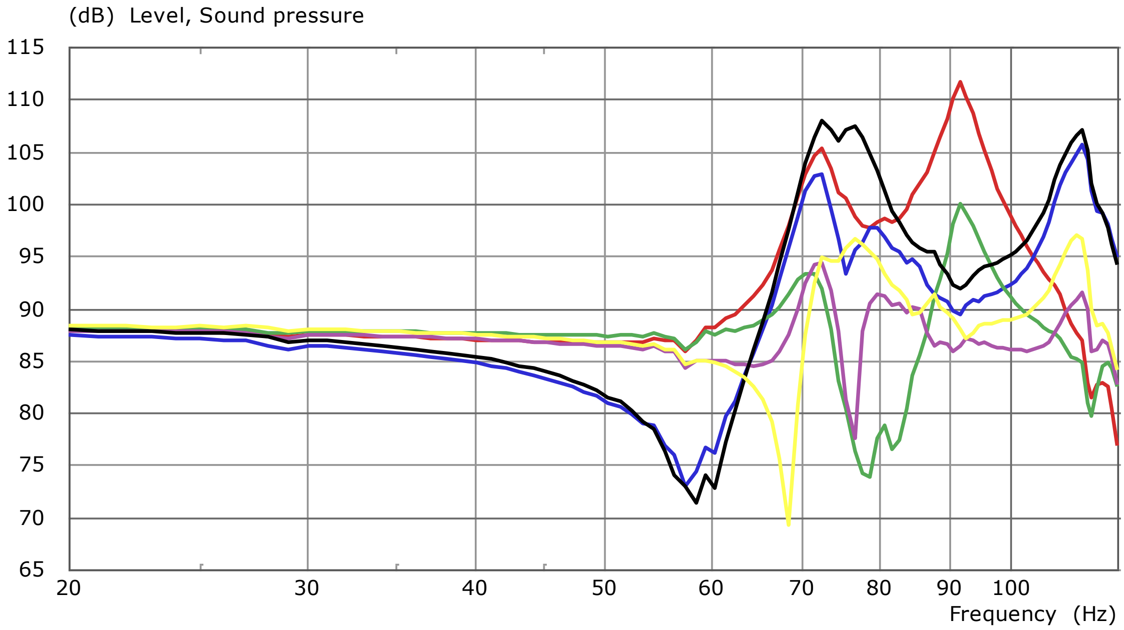




4.6. 1 driver per grid in the middle of the wall

Both grids have been reduced to one driver, which is located at ½ of the wall width and height.





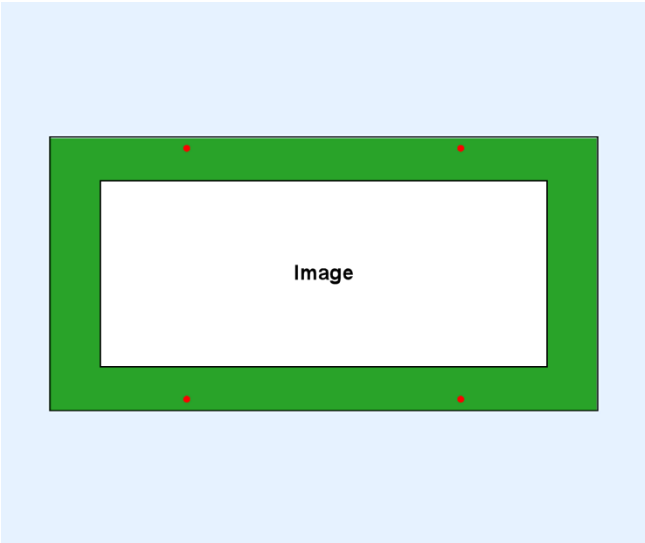
4.7. Variant for screens or LED walls

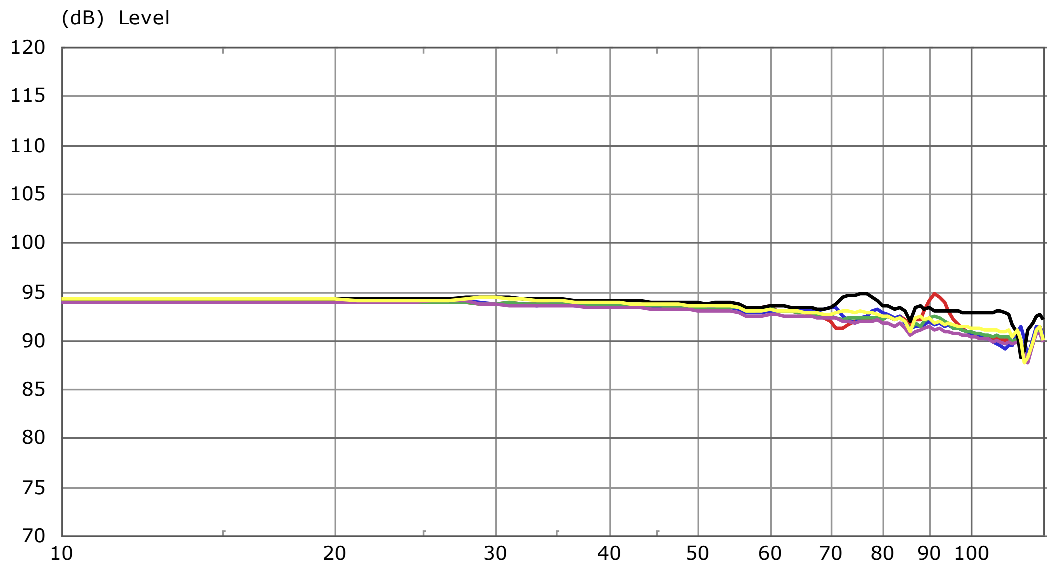
In the case of LED walls or acoustically non-transparent screens, the problem arises that the subwoofers of a DBA cannot be mounted at ¼ of the width and height of the room because the image takes much space on the wall. Luckily, that's not necessary. Because with a trick, a DBA also works in a slightly modified way.

The dimensions of typical home cinema rooms usually have the following relation:

Length > Width > Height

This means that the most likely compromises can be made in terms of height with regard to the subwoofer arrangement, because vertical modes are located higher in the frequency range. In the following, a DBA with 4 drivers per grid was simulated. The drivers are still located at ¼ and ¾ of the width of the room, but directly on the floor and under the ceiling. Since the picture usually does not take up the full height, there may be still space for the subwoofers.





Since the drivers are located directly on the floor and ceiling, they excite the vertical modes to the maximum. However, there is the following physical property, which is used here: **two drivers arranged opposite to each other completely cancel out the 1st mode.**

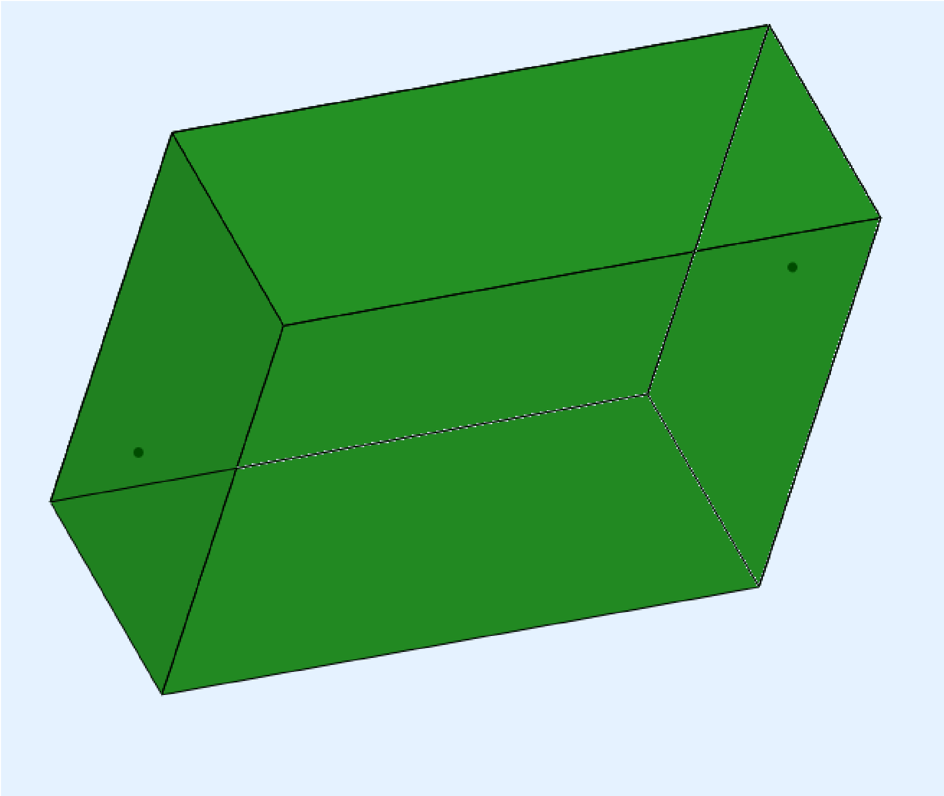
It doesn't work with the second mode. However, this is located in the range of 114 - 171 Hz for common ceiling heights and is therefore outside the usable range of a subwoofer or at its upper limit. Since the low-pass is already effective in this area, its signal level is significantly decreased.

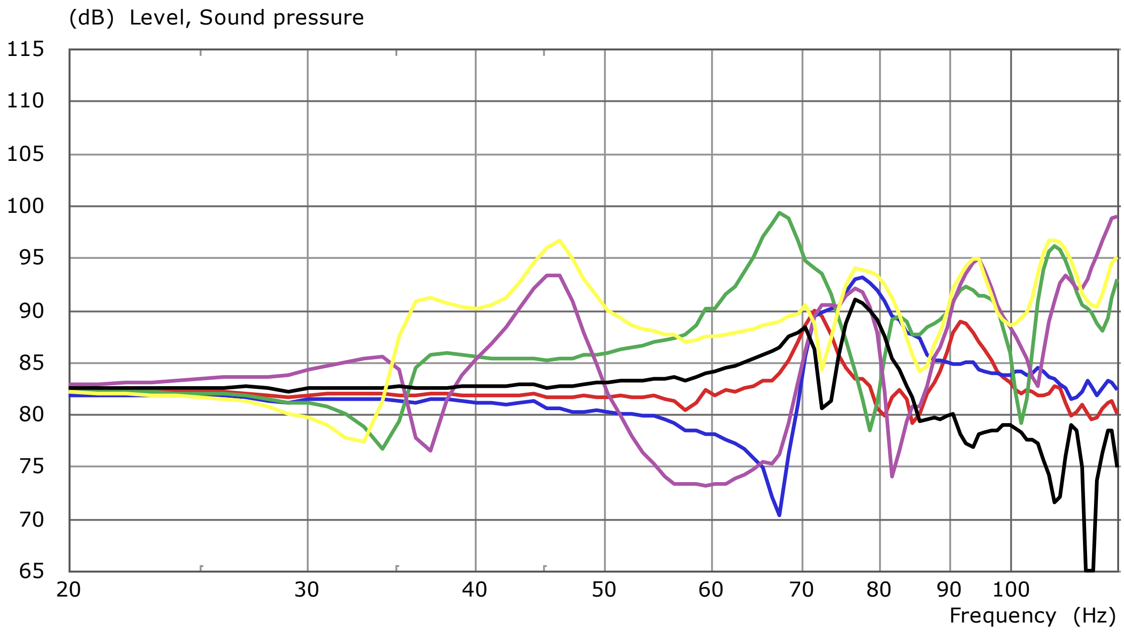
5. Stereo DBA

For stereo listening it can be useful to play the stereo bass as well. This is not possible with the arrangements that are optimized for a monaural bass. The following simulations contain only one driver per grid, which are arranged on one side with respect to width.

5.1. 1 driver per grid on ¼ and ¾

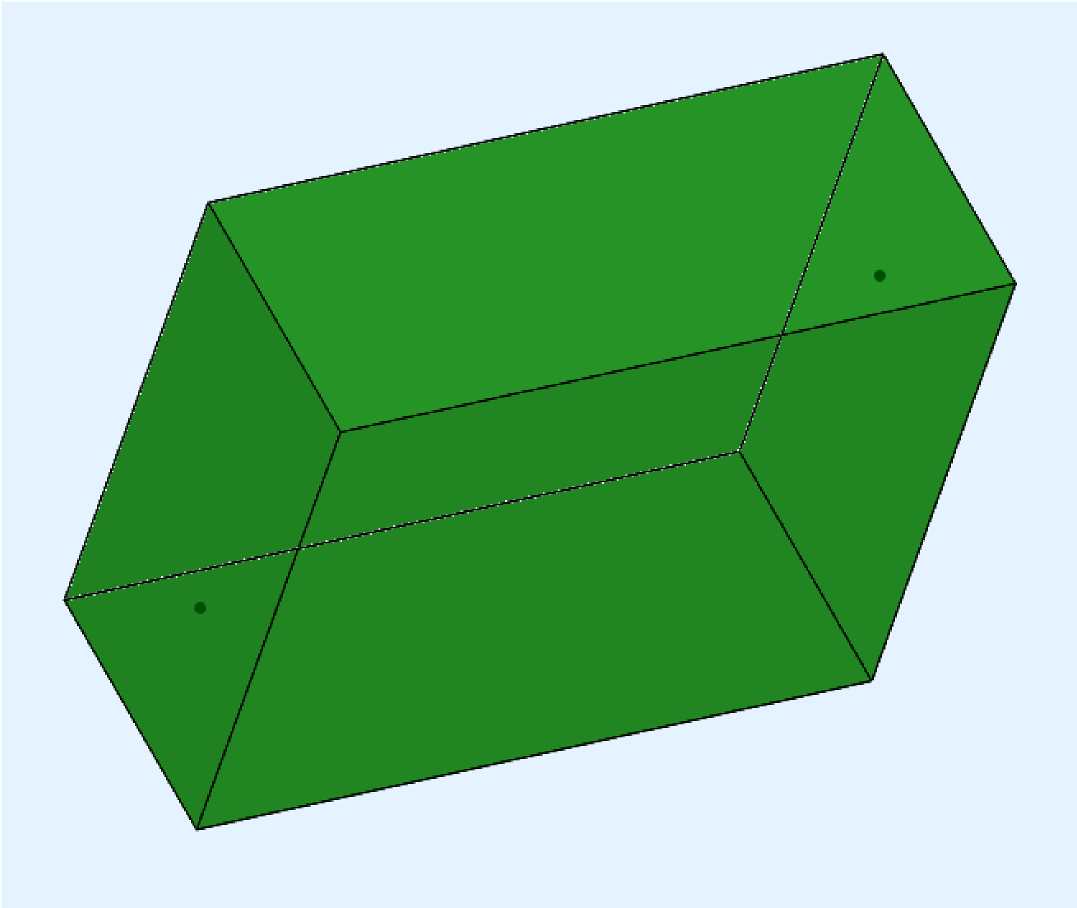
The two drivers are positioned at ¼ and ¾ of the room width and height. The rear grid is point-symmetrical to the front one.

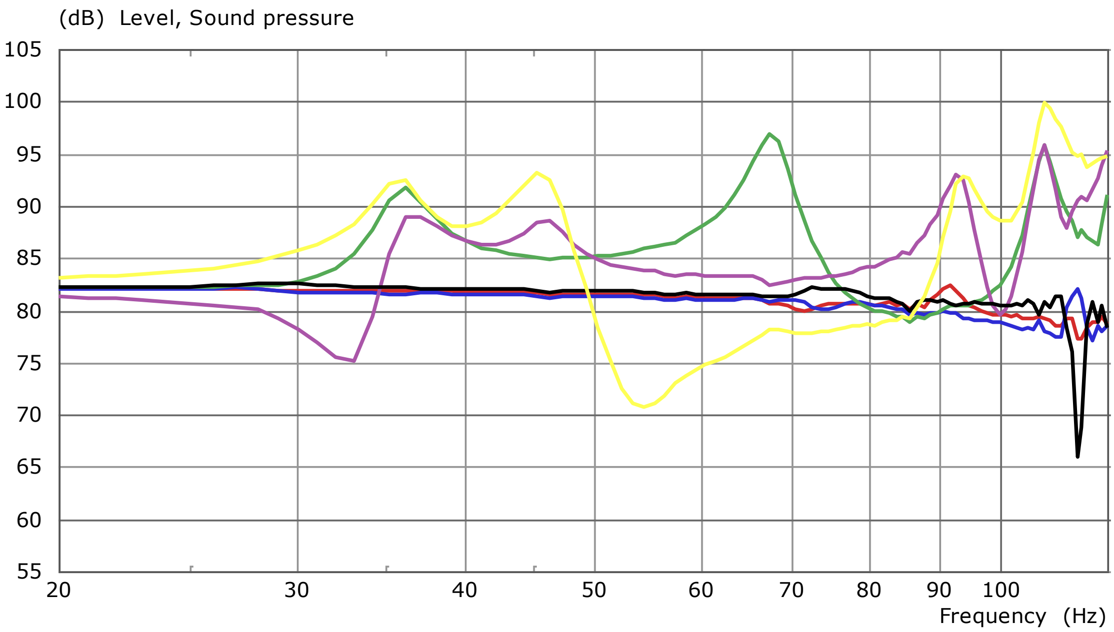




5.2. 1 driver per grid at ½ of the height

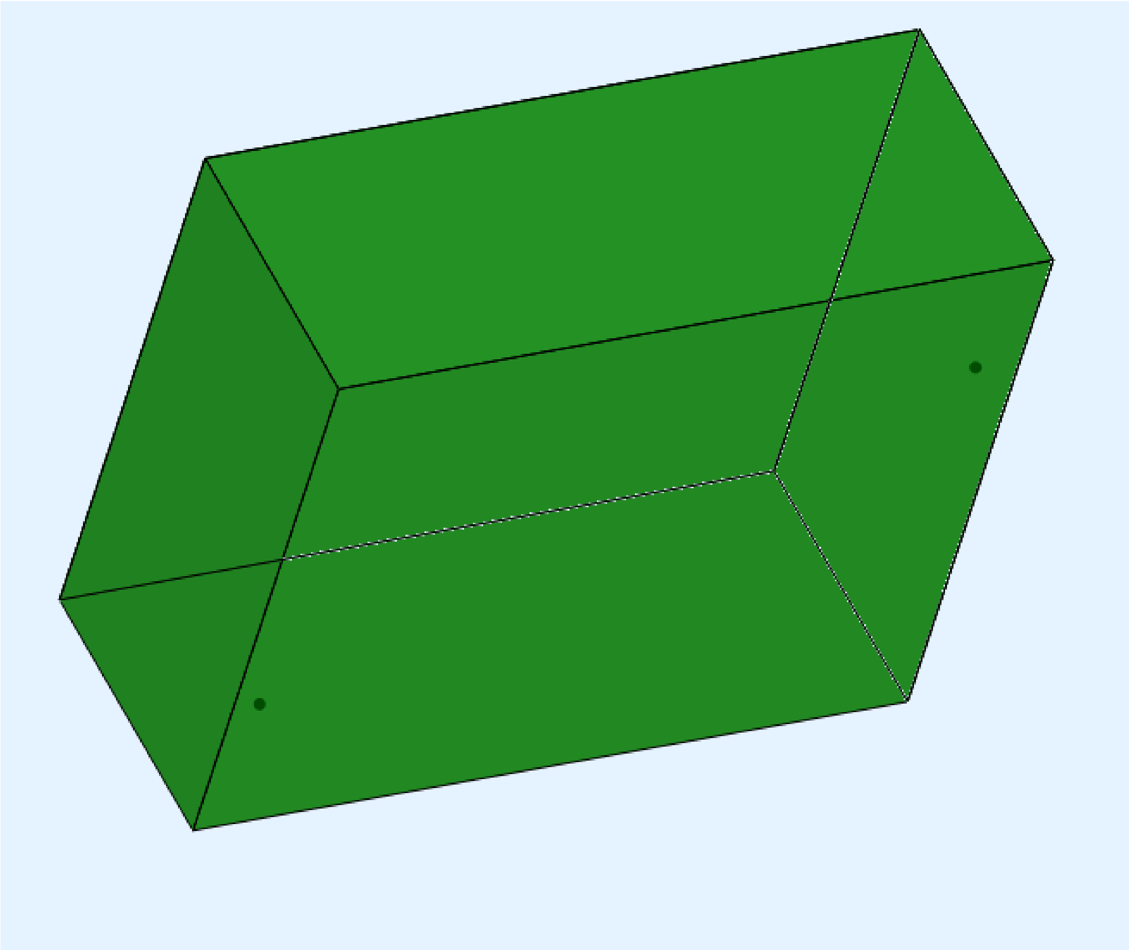
The two drivers are positioned at ¼ and ¾ of the room width and at ½ of the room height. So, there is a point symmetry with respect to the width. The corridor in which the DBA operates is very narrow. Outside the center line the linear distortions increase singificantly.

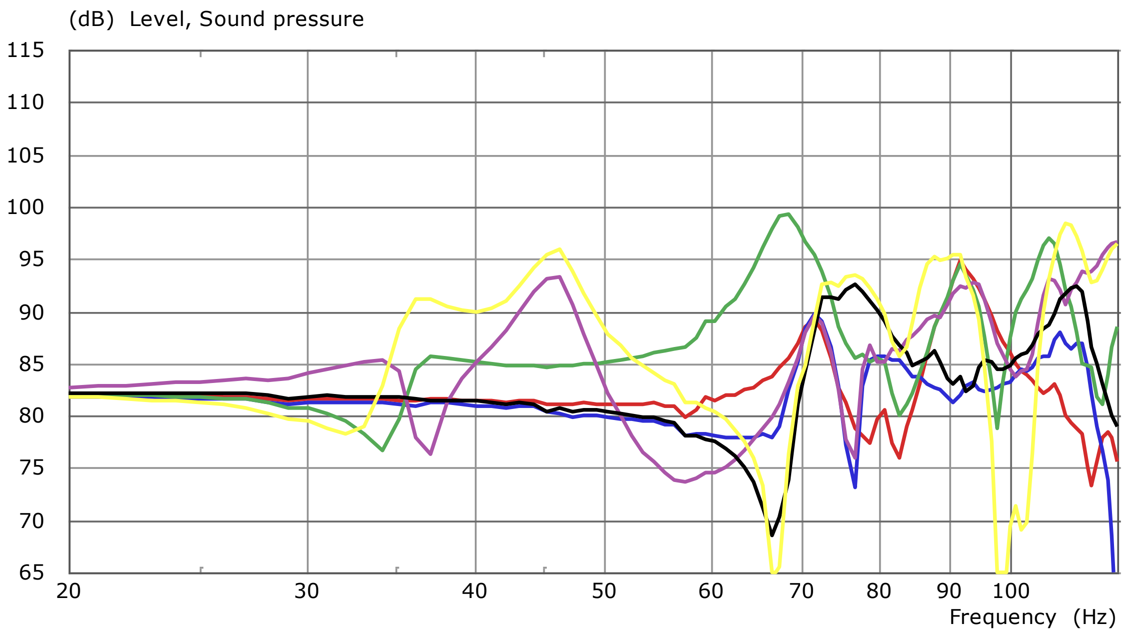




5.3. 1 driver per grid on the floor

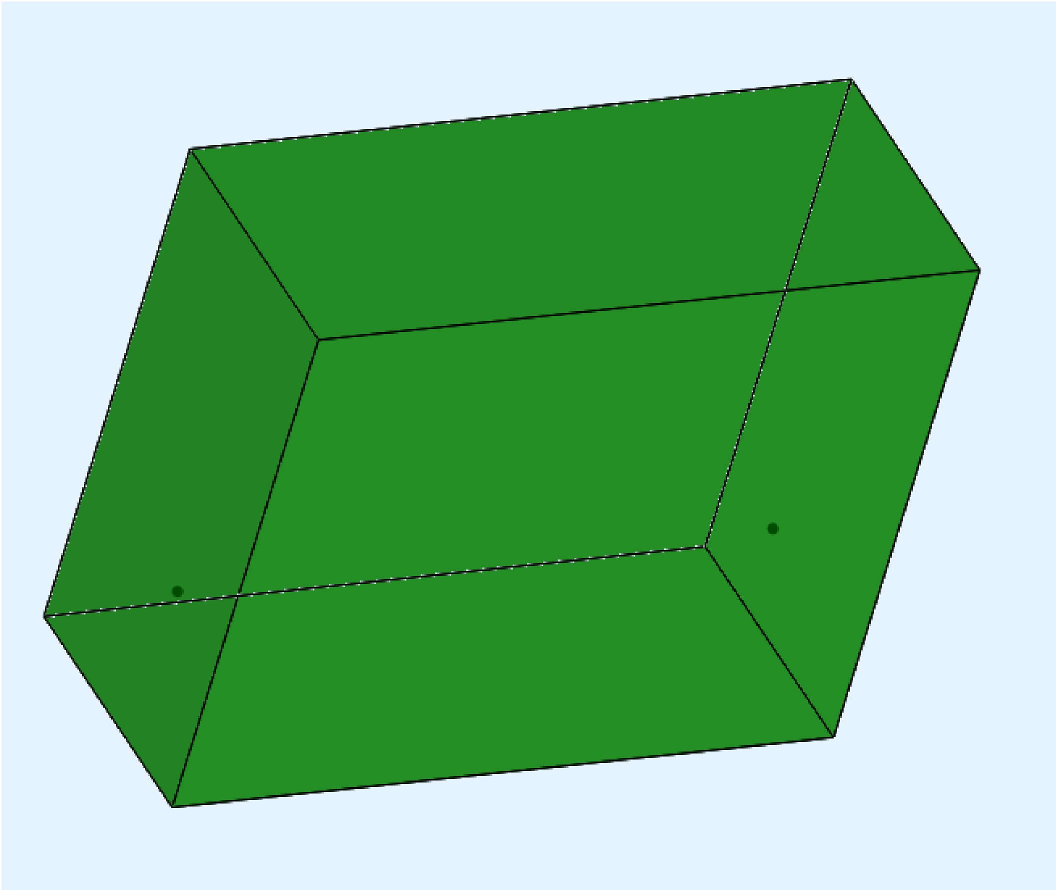
In the following both drivers are placed on the floor and ¼ and ¾ of the room width.

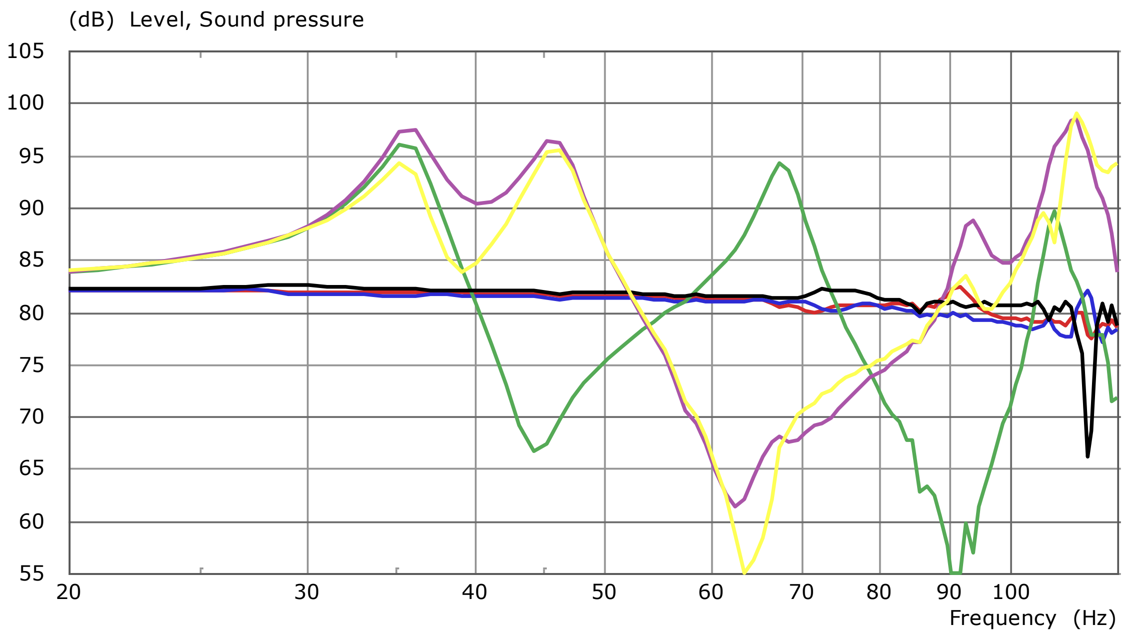




5.4. 1 driver per grid on ¼ and ½

In the following both drivers are located at ½ of the room height and ½ of the room width. Both drivers are placed in the same half in terms of width. The corridor in which the DBA operates is very narrow. Outside center line the linear distortions increase significantly.





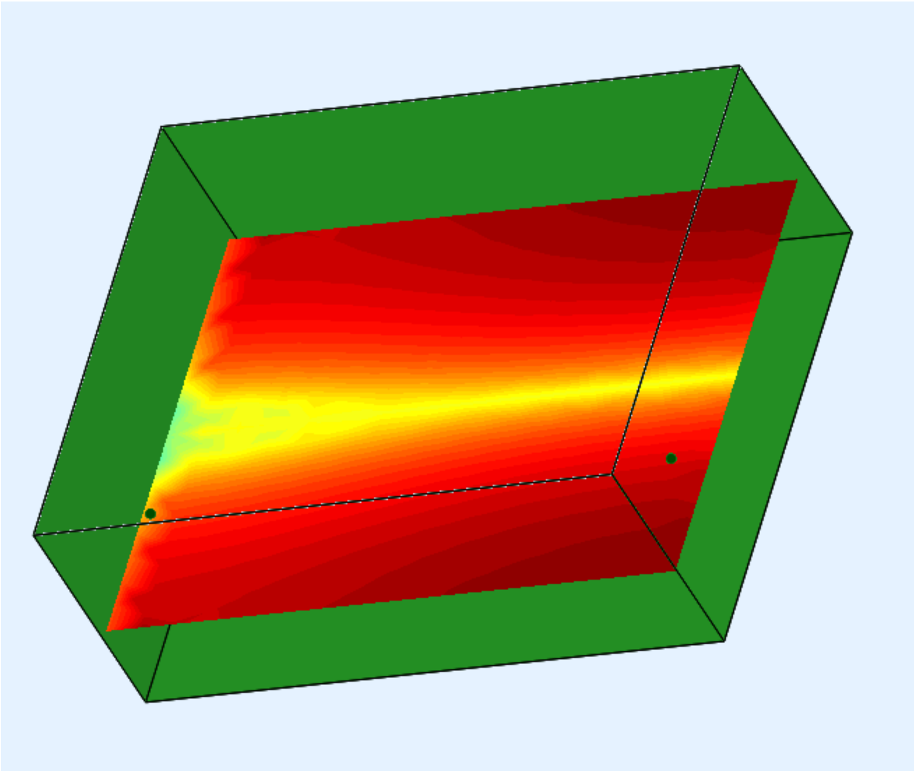


Figure 3: Sound pressure level at 35 Hz

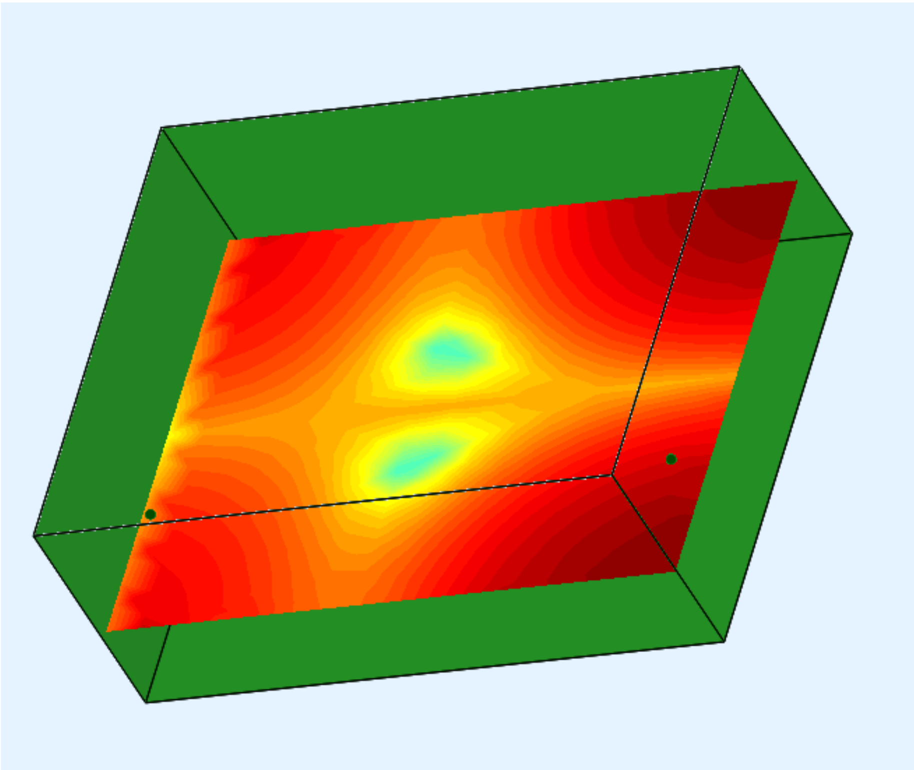


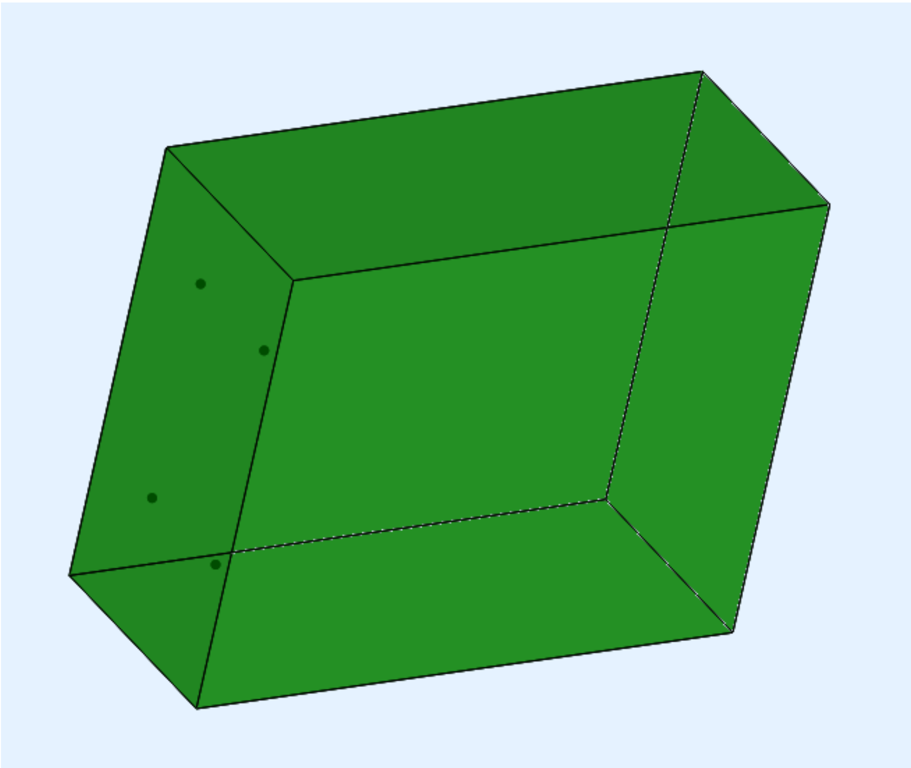
Figure 4: Sound pressure level at 40 Hz

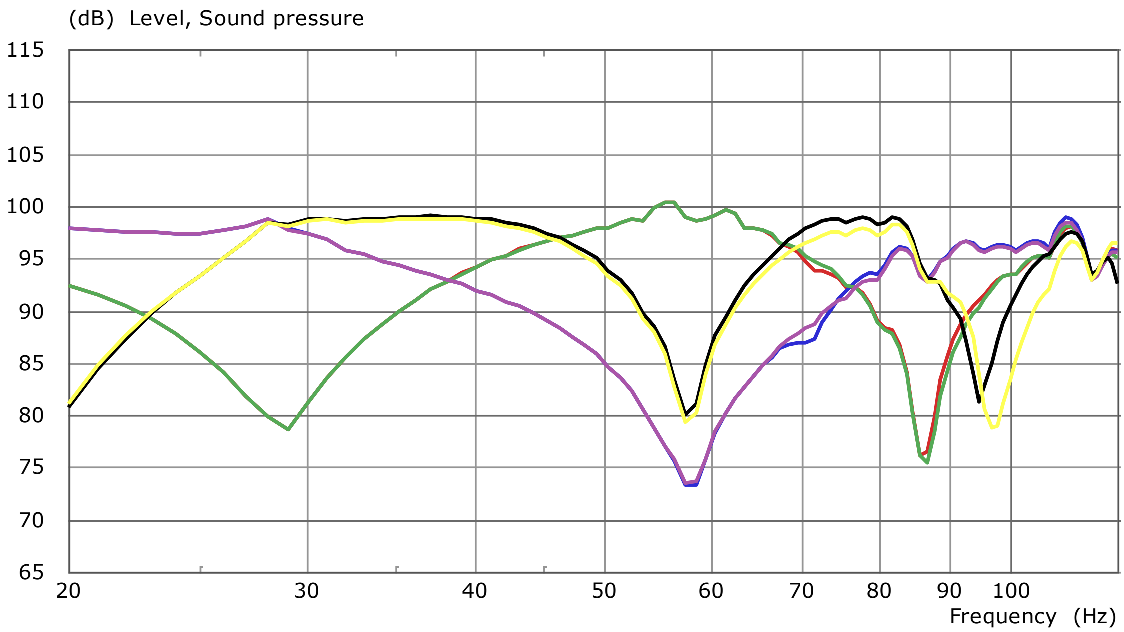
6. Pseudo-DBA with only one grid

6.1. Delay = 2 × room length

In the following only one woofer grid is used which cancels out the signal reflected on the rear wall when it arrives back at the front. This means that the second, inverted signal is fired at a time delay time that corresponds to twice the length of the room.

The idea is to save half of the drivers. Unfortunately, this does not work very well, because the reflected sound passes through the listening position once and thus interferes with the direct sound. The amplitude response strongly depends on the longitudinal sitting position.





Subsequently, an additional measuring point was placed on the rear wall. As you can see, the principle works here, because due to the non-existent propagation time difference, no comb filter can be formed between direct sound and reflection.

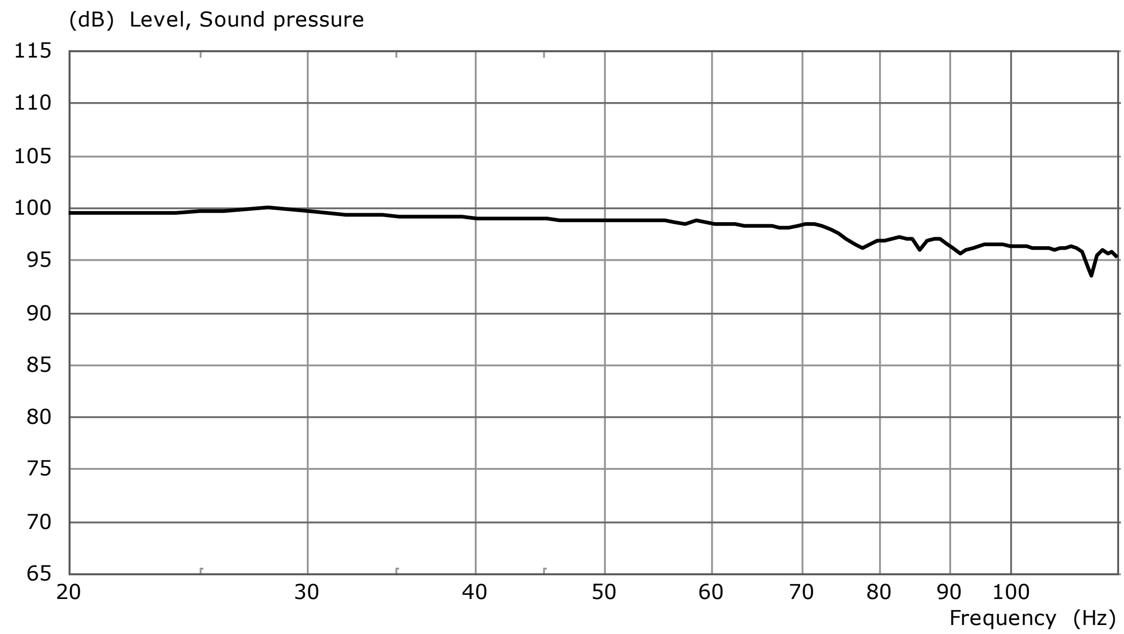
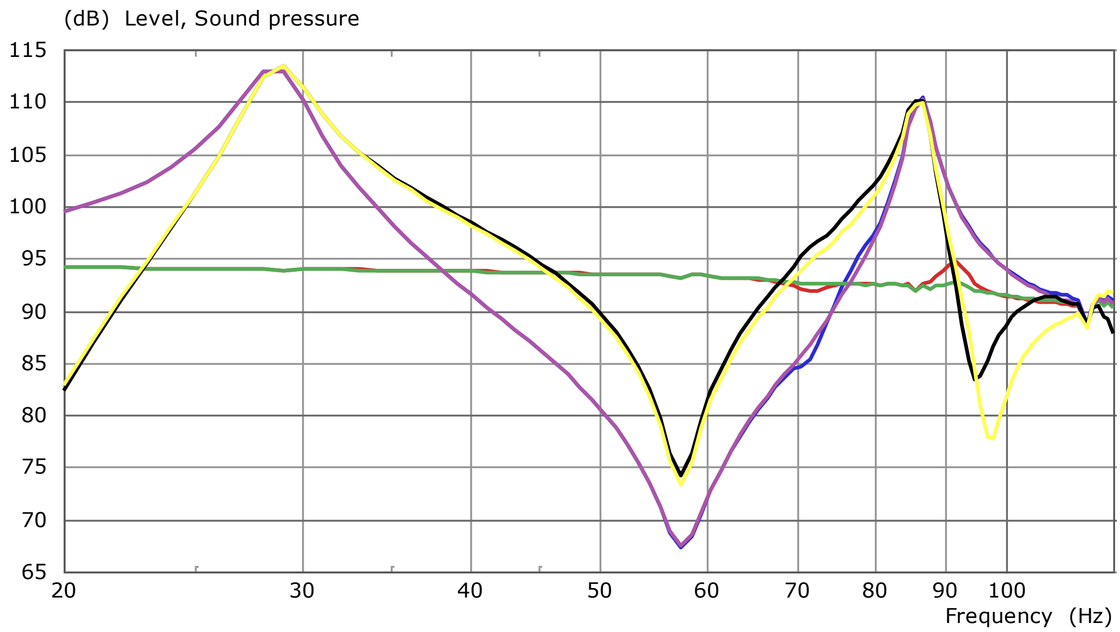


Figure 5: Measuring point on the rear wall

6.2. Delay = 1 × room length

If the delay is equal to the single length of the room, all modes are cancelled out in the center line. In the rest of the room, on the other hand, they are maximally pronounced.


(dB) Level, Sound pressure
115
110
105
100
95
90
85
80
75
70
65
20
30
40
50
60
70
80
90
100
Frequency (Hz)

7. Efficiency-optimized DBA

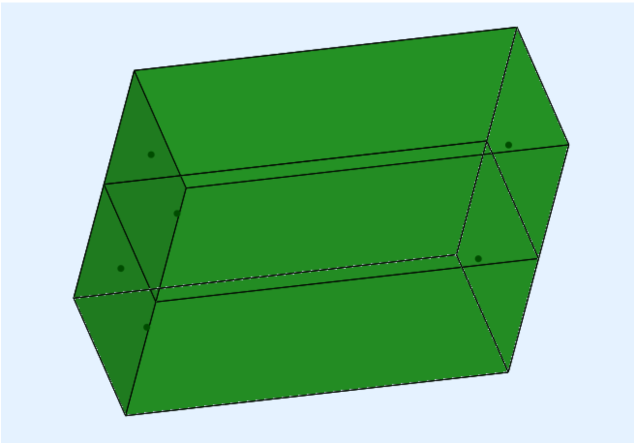
In the following, the reduced DBA arrangement corresponds to 4.2, but both grids are assigned compensation signals. So, it's a mixture of DBA and pseudo-DBA. The rear grid only partially compensates for the modes. The front one compensates for the rest.

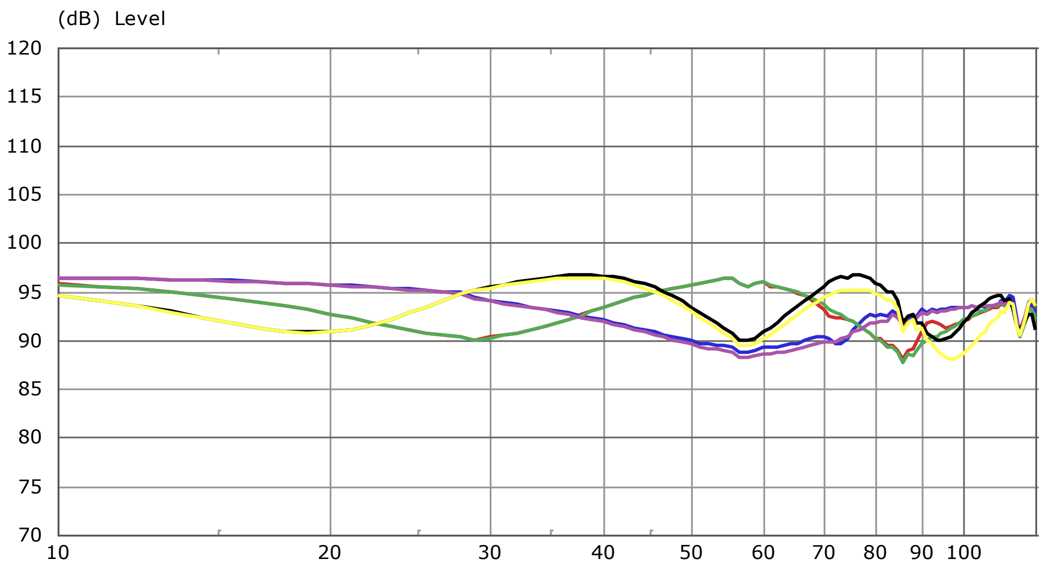
Front grid (4 drivers):

- Wanted signal (0 dB)
- Compensation signal (level: -6 dB, delay: 2 times the length of the room)

Rear grid (2 drivers):

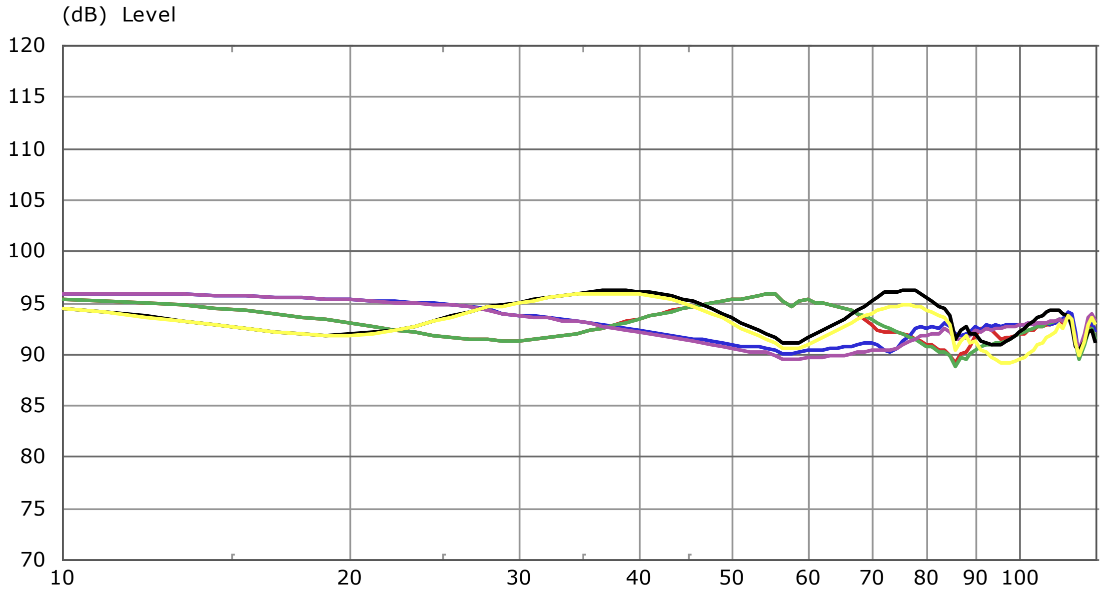
- Compensation signal (level: 0 dB, delay: 1 time the length of the room)





With this arrangement, the comb filter of the Pseudo-DBA is greatly attenuated, but remains present. The front grid must reserve up to 3.5 dB of the maximum level (limited by linear excursion) for the compensation signal. This makes it more efficient than the reduced DBA from 4.2, where the maximum level is reduced by up to 6 dB through the rear grid. However, the values can be somewhat lower in real rooms due to the damping.

It becomes even more efficient if both grids generate the same total level, i.e., limit at the same time. This is achieved by increasing the level of the rear grid by 1.75 dB and reducing the level of the front compensation signal by 1.75 dB accordingly. This results in a total loss of maximum level of up to 3 dB. The comb filter is slightly reduced by this measure.



8. Directionally optimized DBA for multi-channel systems

In multi-channel systems (surround) with speakers in "small" mode (i.e., redirecting the bass to the subwoofer), a DBA leads to the problem that the localization of the bass is always perceived from the direction of the primary grid. So usually from the front wall. This fits the localization direction of the three front speakers, but not that of the surround speakers.

To improve this, a second DBA can be created with the existing woofer grids. In this case, the primary grid is the rear one and the front one is responsible for the cancellation. The direction correlates much better to that of the surround speakers.

Note: in the following drawings for a 7.1 system, the woofer grids are not included, only the direction of the sound they produce.

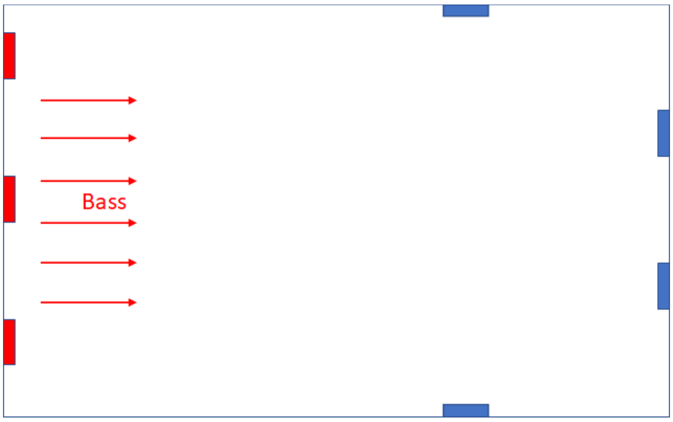


Figure 6: Direction of the woofer from the signal of the front channels

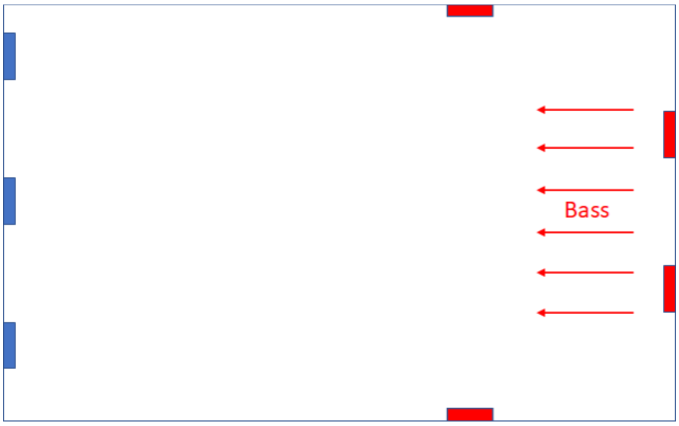


Figure 7: Direction of the bass from the signal of the surround channels

The signals for both DBAs can be generated and added together in a freely routable DSP. The summed signals are placed on the two low-frequency grids at the end.

Routing for the front DBA: L, C, R, LFE

Routing for rear DBA: SL, SR, SBL, SBR

Since the two DBAs can be active at the same time with appropriate source material, the problem arises that the addition is only purely constructive in one vertical plane. This is plane usually placed on the 1st row of seats in a home theater via the adjustment of delays. For all other planes, the two plane waves also create destructive interference. However, the problem is rather negligible, as the surround channels rarely contain bass with significant level. The advantage of the improved localization of the surround channels clearly outweighs the disadvantages.

9. Double DBA

The idea came up to separate both DBAs from chapter 8 for the entire bass to achieve a higher maximum level. However, the idea is subject to a flaw. This is because with a conventional DBA, the drivers in the rear grid have to create the same amount of excursion as those in the front. This means that the mechanical limit in terms of excursion is reached at the same time. There is no reserve. If the signal of the second DBA is added to this, the excursion also increases accordingly. In the worst case, it is an addition of +6 dB, which means a doubling of the excursion. Thus, the maximum level cannot be increased.

Furthermore, two opposing DBAs only create a purely constructive interference in one vertical plane. In a home cinema, this would correspond exactly to one row of seats. Before and after that, there are extinctions. Below are two examples of different delays of the rear DBA.

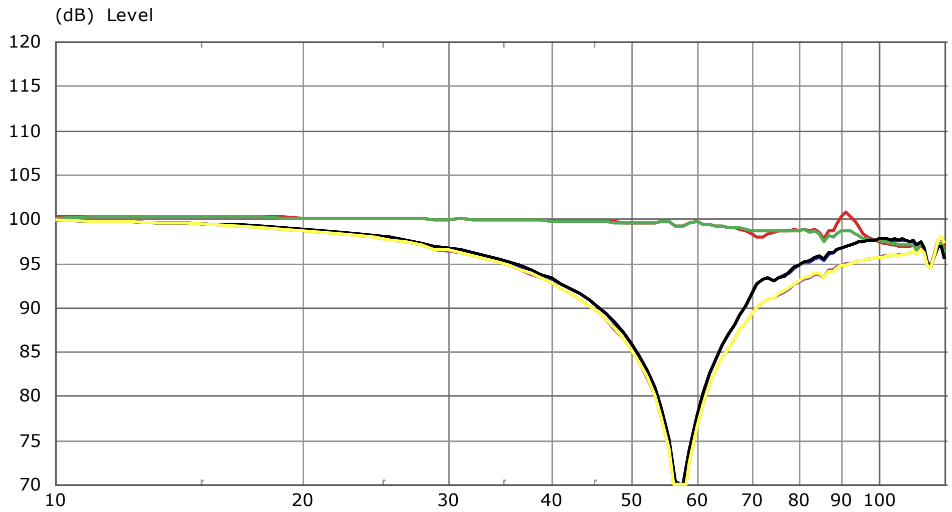


Figure 8: Delay for 1/2 of Room Length

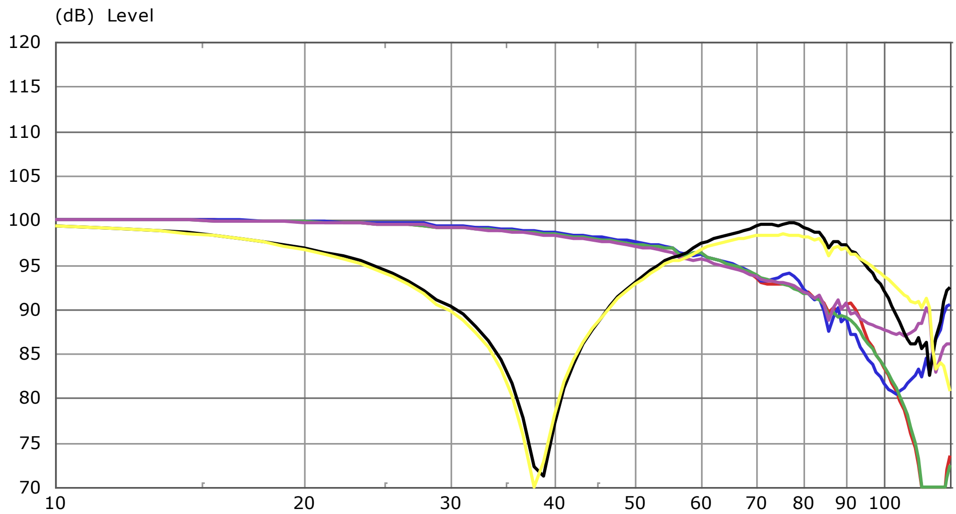
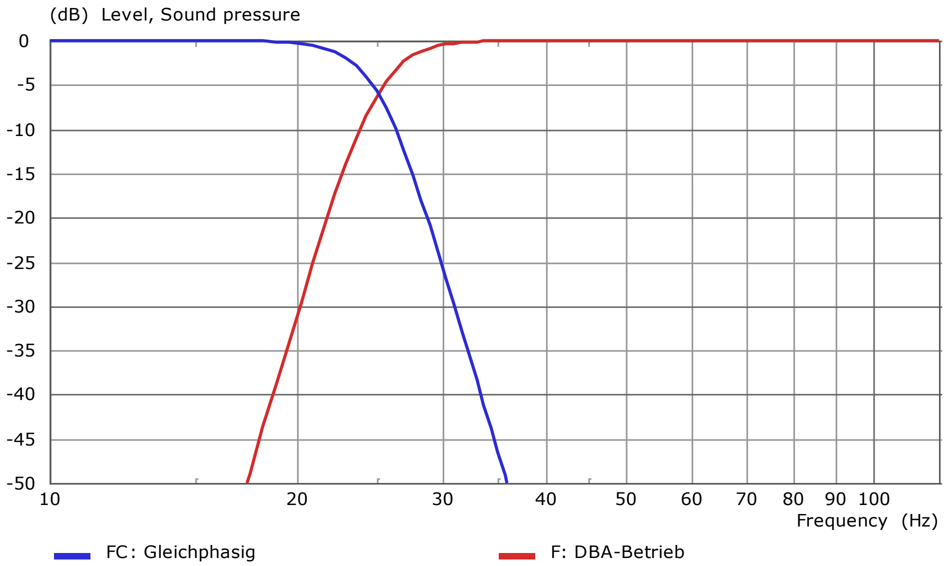


Figure 9: Delay for 3/4 of the room length

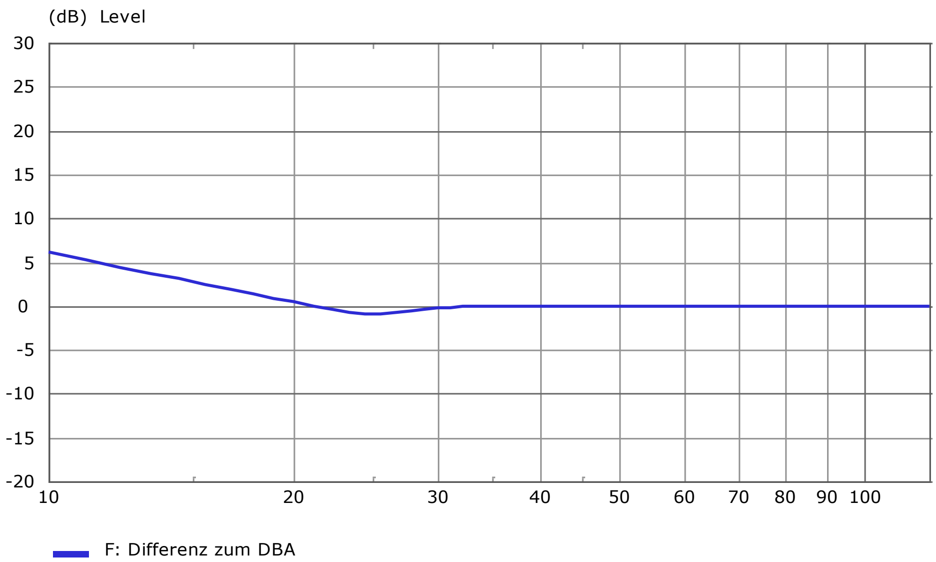
10. Optimized control below the 1st longitudinal mode

Below the 1st longitudinal mode, active cancellation on the rear wall is no longer necessary. The rear woofer grid can be operated in-phase and without delay in this frequency range. This has the advantage that the maximum level increases.

In the following, it was simulated that the rear woofer grid below 25 Hz is controlled in phase and without delay, and above 25 Hz it is used for active cancellation. Both signals were summed up and placed on the rear grid. The crossover's slope is realized with 8th order.



Subsequently, the difference curve to the standard DBA was generated at one of the measurement points. It turns out that the gain in sound pressure level only starts from about 20 Hz and increases towards low frequencies. At 10 Hz, approximately +6 dB is achieved compared to the full DBA. Thus, the benefit in the relevant transmission area is limited.



11. Result

The 1st longitudinal and broad modes are completely obliterated by all arrangements.

Reduced arrangements 4.2 and 4.4 work almost as well as the complete DBA arrangement. This means that very good results can be achieved with just two drivers per grid.

For stereophony and a single seat along the longitudinal axis of the room, very good results can be achieved with just 2 drivers. Here it seems that 5.2 outside the longitudinal axis.

For multi-channel systems, a possibility was shown to improve localization in small operation.

Furthermore, the rear grid density may be lower than the front one. Since the level of the rear grid can be lowered in many real living spaces anyway, the costs of the overall arrangement can thus be optimized.