Edge Diffraction: Rounding vs. Bevel

Content

Motivation

The edges of the baffle of a loudspeaker create a diffraction and thus secondary sound sources that overlap with the direct sound and creates an interference pattern. This interference pattern influences, among other things, the dispersion of the speaker. This is usually counteracted with rounding or beveling.

Rounding and beveling are usually treated as equivalent. This document will deal with the effects of both methods and compare them.

To illustrate the effects, a small sound source in the middle of a circular baffle with a radius of 10 cm was simulated by BEM. The small sound source has the advantage that it acts as a full-space radiator in the transmission range. The circular baffle ensures that the interference effects fall on the same frequencies from all directions, making it much easier to analyze.

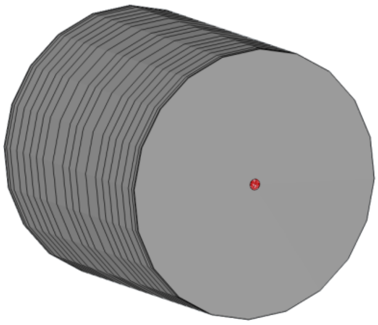
The amplitude response at 0° and the dispersion at infinite distances are shown.

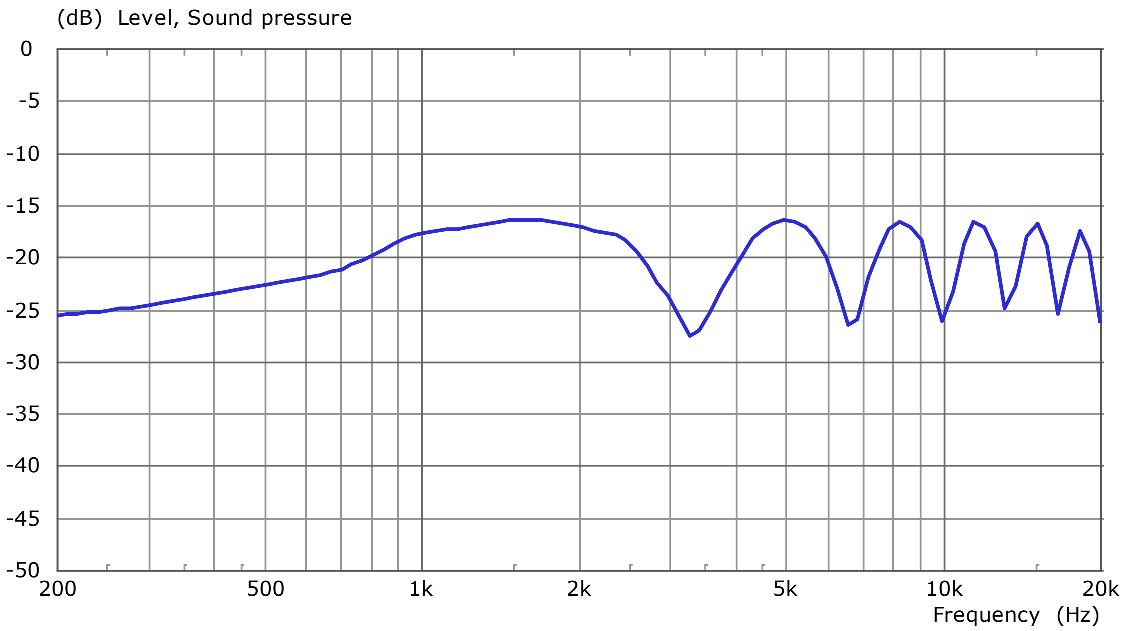
Simulations

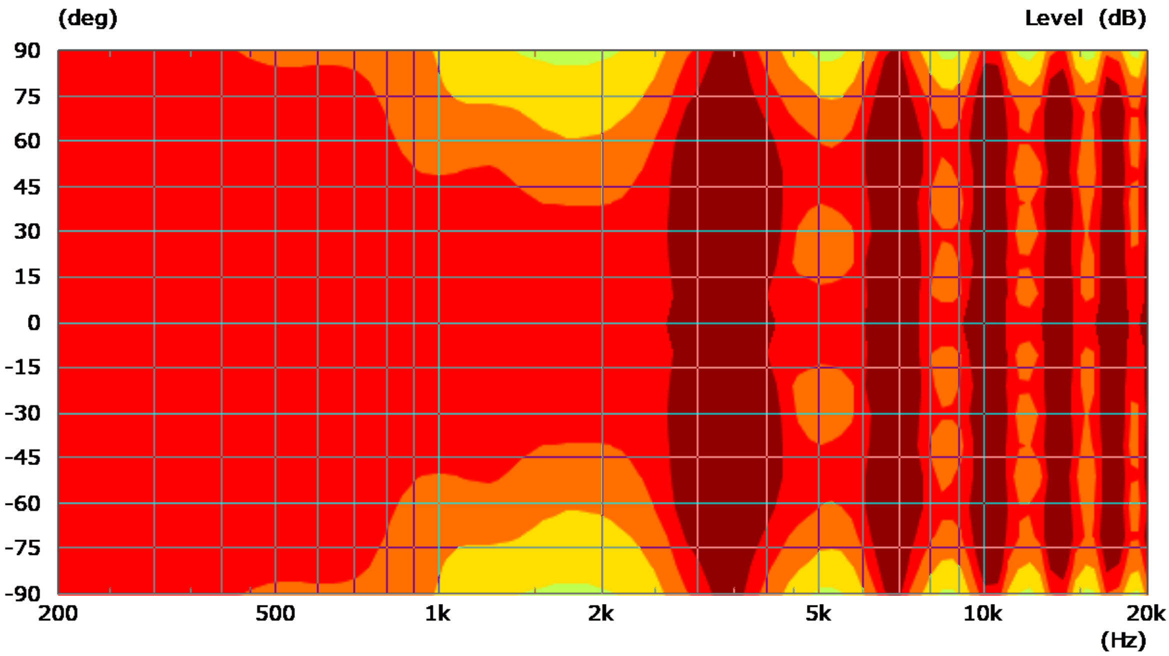
Sharp edge

The sharp edge creates a strong interference pattern. The secondary sound source overlaps with the direct sound at 0° in such a way that the sum fluctuates by +/- 6 dB.

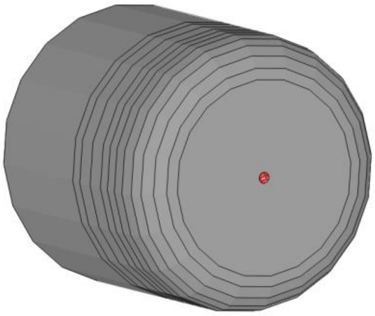
The first maximum occurs in the frequency range whose half wavelength corresponds to the distance between the center of the sound source and the edge (i.e., the radius of the baffle).





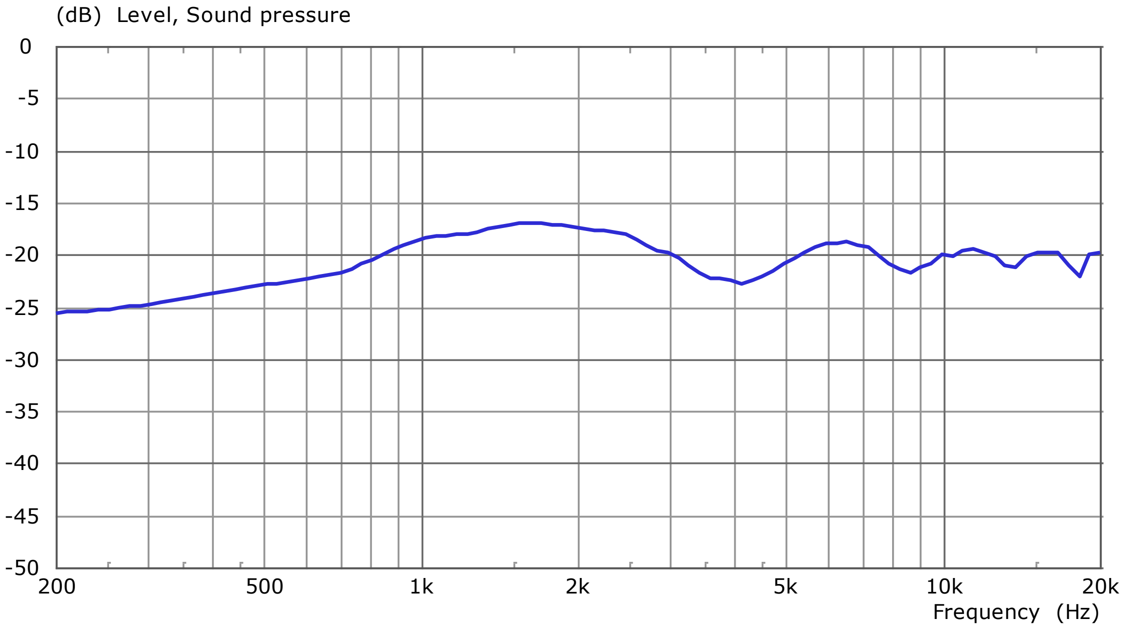


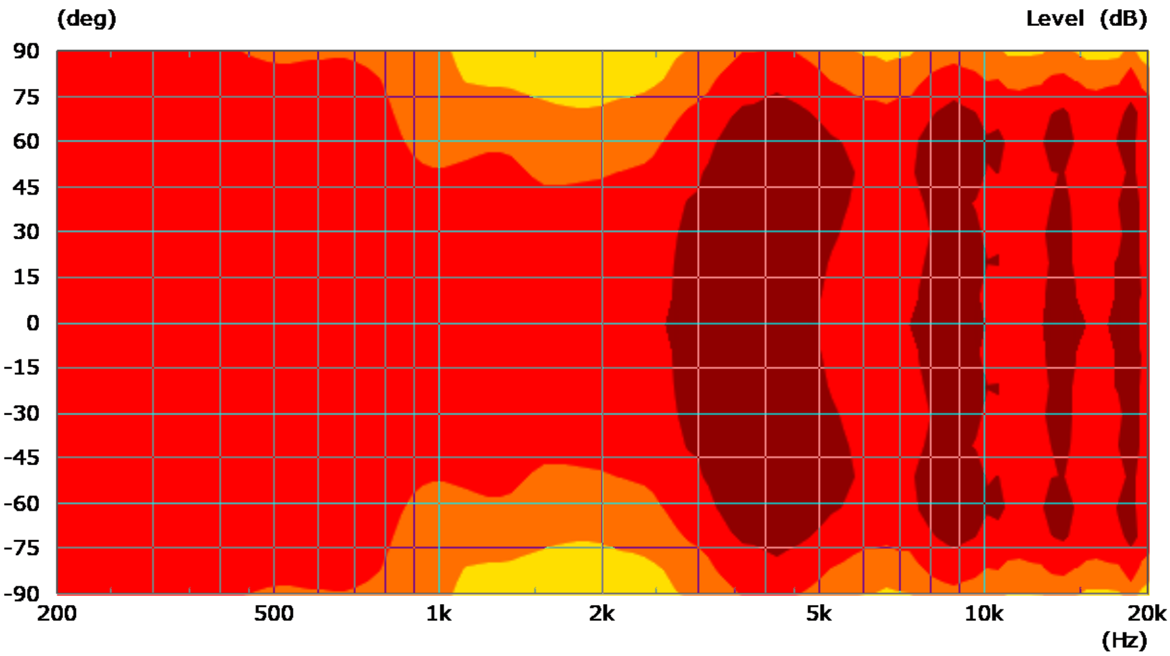
Rounding



The first thing one notices is that the rounding shifts the secondary sound sources slightly upwards in the frequency range. The baffle is therefore reduced in size in terms of interference.

Furthermore, the amplitude of the secondary sound sources is greatly attenuated, especially in the upper frequency range. In the lower range, the attenuation is lower because the radius of the rounding is too small in relation to the wavelength. The fact that the secondary sound source in the highs is not completely eliminated could be due to the approximate rounding of the 3D model. This was not investigated further.

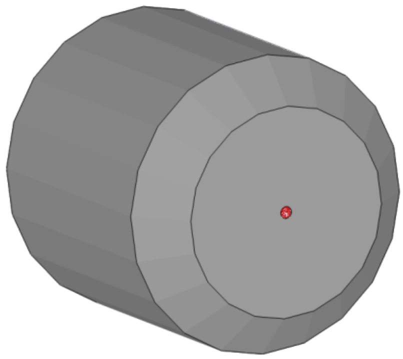


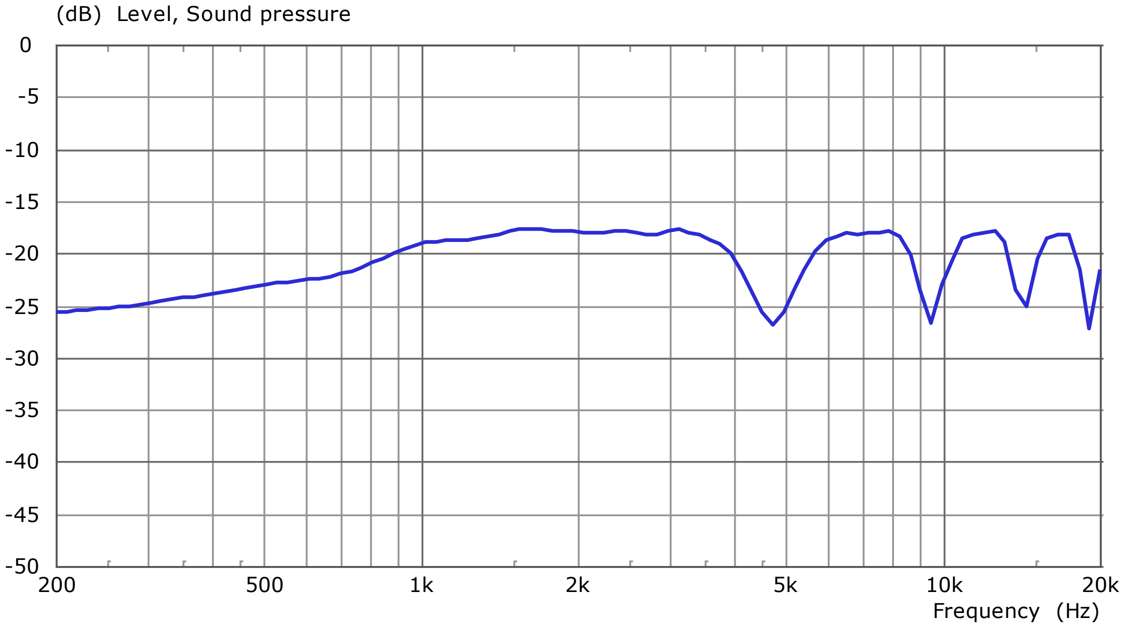


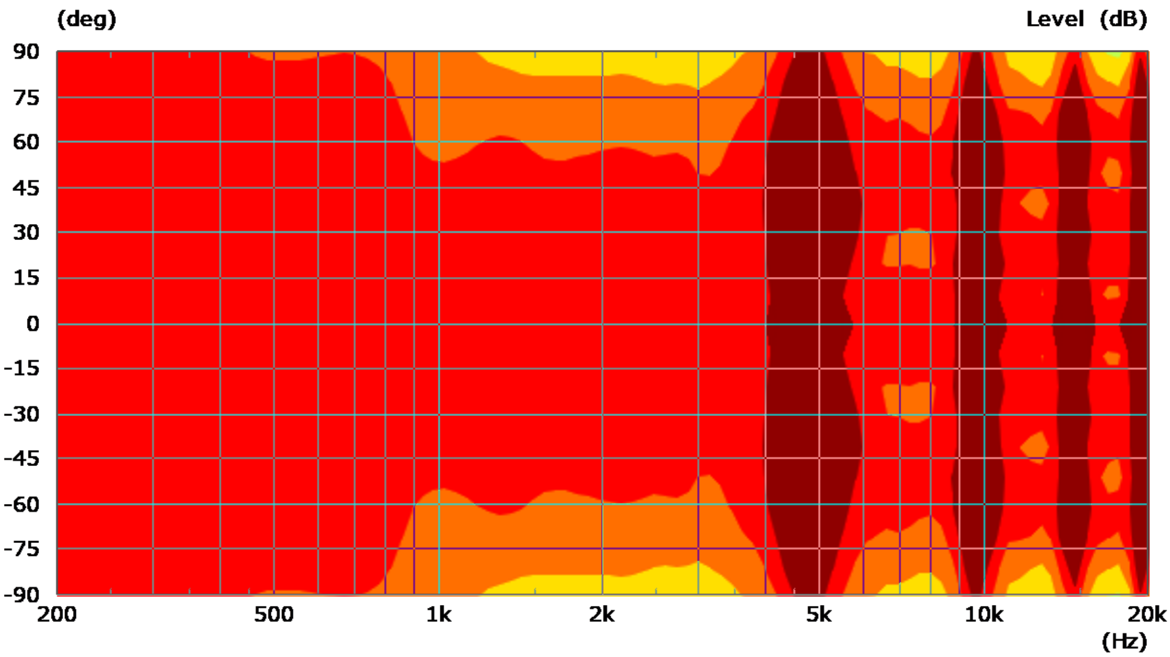
Bevel

In the case of beveling, on the other hand, the amplitude of the secondary sound sources is not attenuated. The bevel ensures that the baffle is reduced to the inner edge (r_1). As a result, the interference pattern shifts upwards in the frequency domain.

Furthermore, the outer edge (r_2) creates a tertiary sound source. In other words, there is a secondary sound source of the secondary sound source which in turn overlaps with the direct sound.



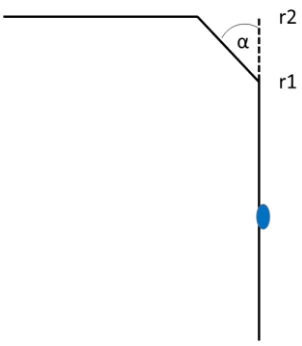




If r_1 and r_2 are chosen in such a way that the transit times of the secondary and tertiary sound sources are identical to their primary sound sources, the maximum take the form of a plateau. Thus, a relatively large frequency range (almost three octaves) is created in the area of the first maximum which has an almost constant directivity. This is the case with a ratio of $r_1 = \frac{r_2}{\sqrt{2}}$.

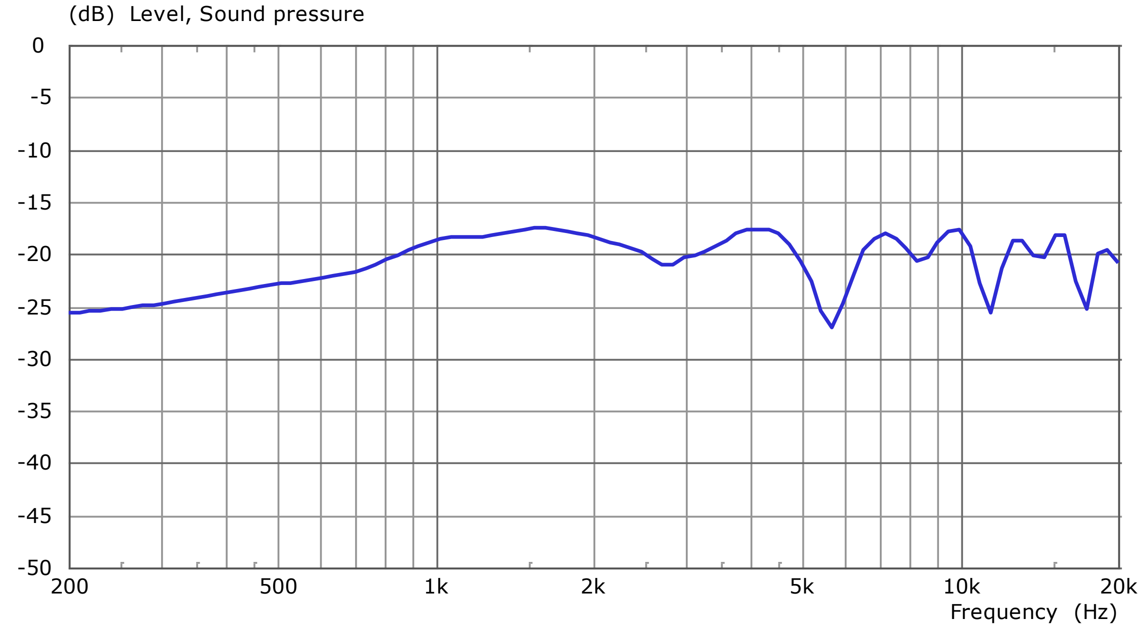
This particularly favorable ratio can also be applied to rectangular baffles with a centrally placed sound source, but to a lesser extent. With more complex baffles and acentric driver positions, however, this no longer works so trivially.

Variation of angle

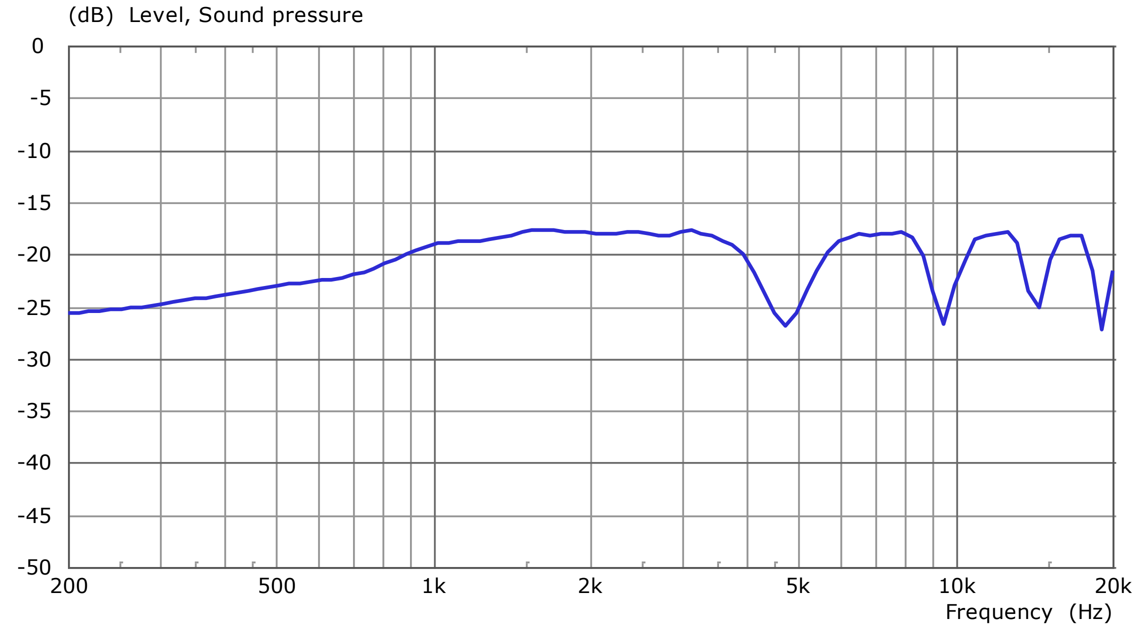


In the following, it was investigated whether the angle has an influence on the dispersion. For this purpose, the outer radius (r_2) and the propagation time difference between the secondary and tertiary sound source were kept constant. As a result, the inner radius (r_1) varies. The propagation time difference has been set in such a way that it is identical to the runtime between the primary and secondary sound source.

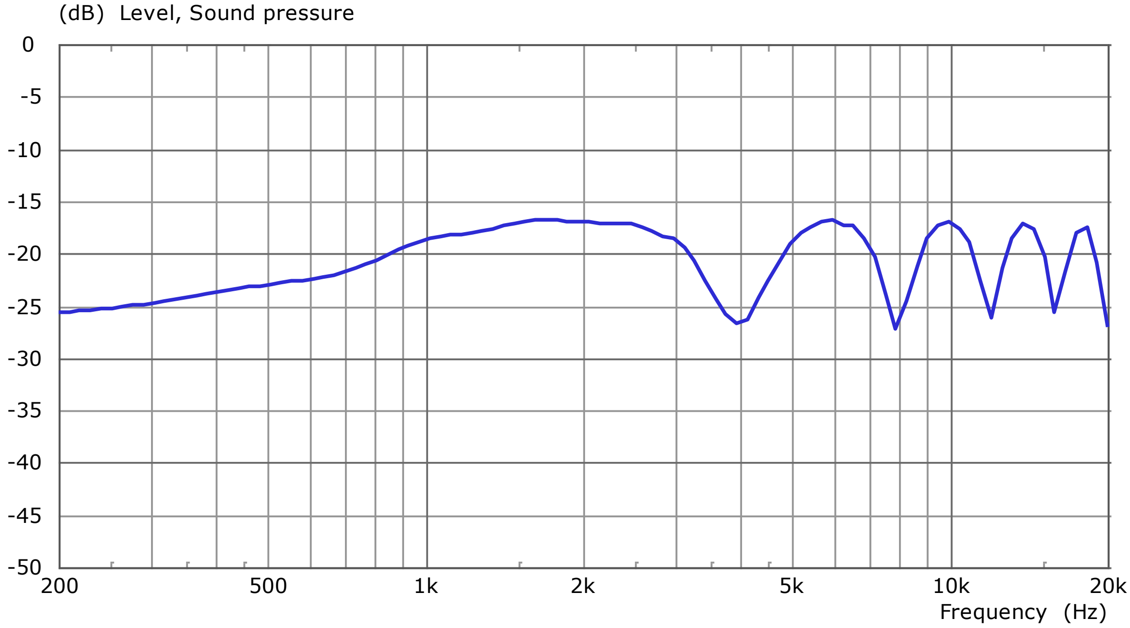
α = 20°, r_1 = 58.8 mm:



α = 45°, r_1 = 70.7 mm:



α = 70°, r_1 = 85 mm:



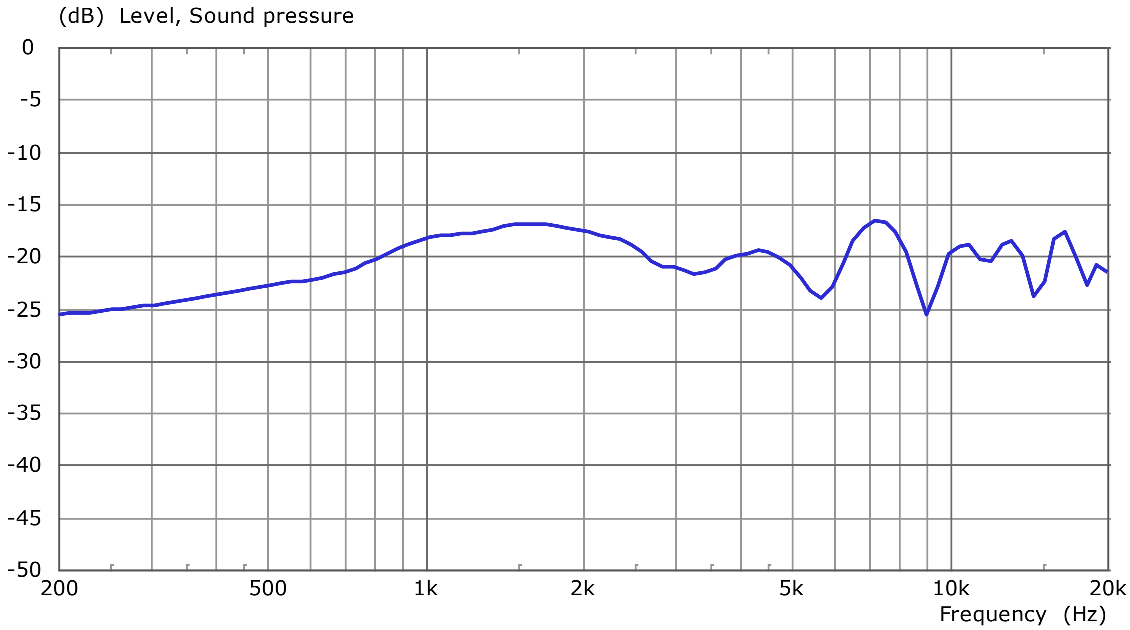
The interference pattern is virtually the same at all angles. There is no attenuation. This means that the angle itself has no significant effect on the amplitude of the secondary sound source. However, in these examples, the ratio between the radii r_1 and r_2 and thus the wavelengths at which the minima and maxima occur changes.

There seems to be an ideal ratio between the radii. At approx. 45° there is the largest range of almost constant directivity. Larger distances (shallower angles) produce a dip at 0° (i.e., a widening in the radiation behavior) and smaller distances (steeper angles) have the opposite effect.

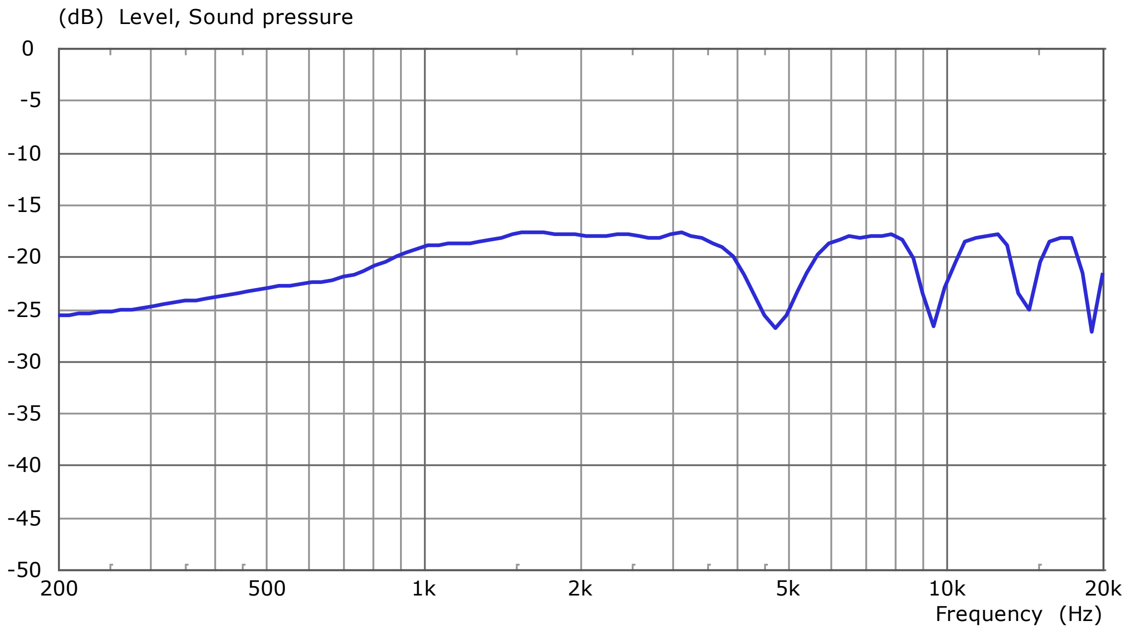
Variation of the runtime

Subsequently, the radii r_1 and r_2 were kept constant and only the angle was changed. As a result, the transit time difference between the secondary and tertiary sound source varies. The ratio between the radii was $r_1 = \frac{r_2}{\sqrt{2}}$ chosen.

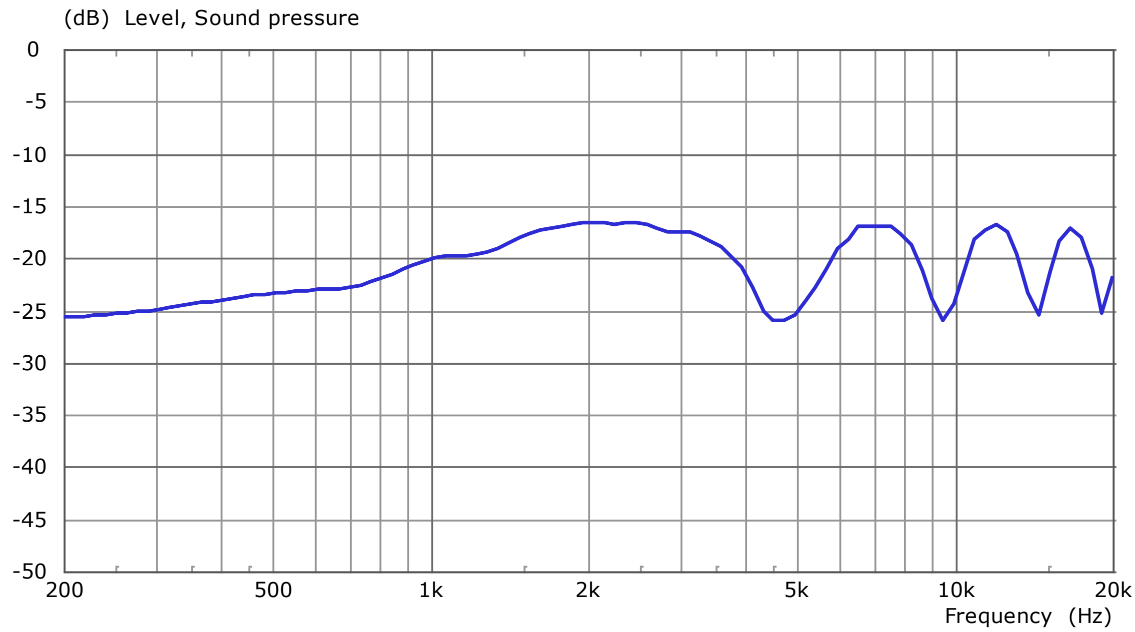
α = 20°, t_{12}/t_{23} = 1.7:



α = 20°, t_{12}/t_{23} = 1:



α = 70°, t_{12}/t_{23} = 0.43:



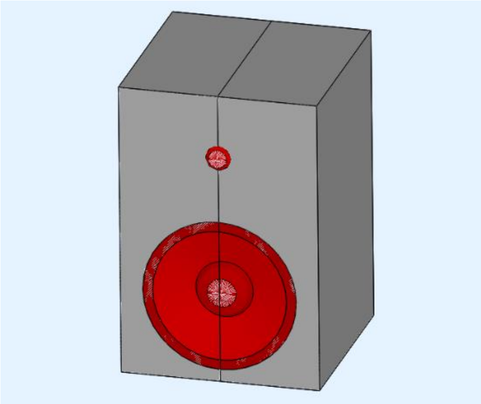
An optimal ratio seems to exist with identical runtime differences.

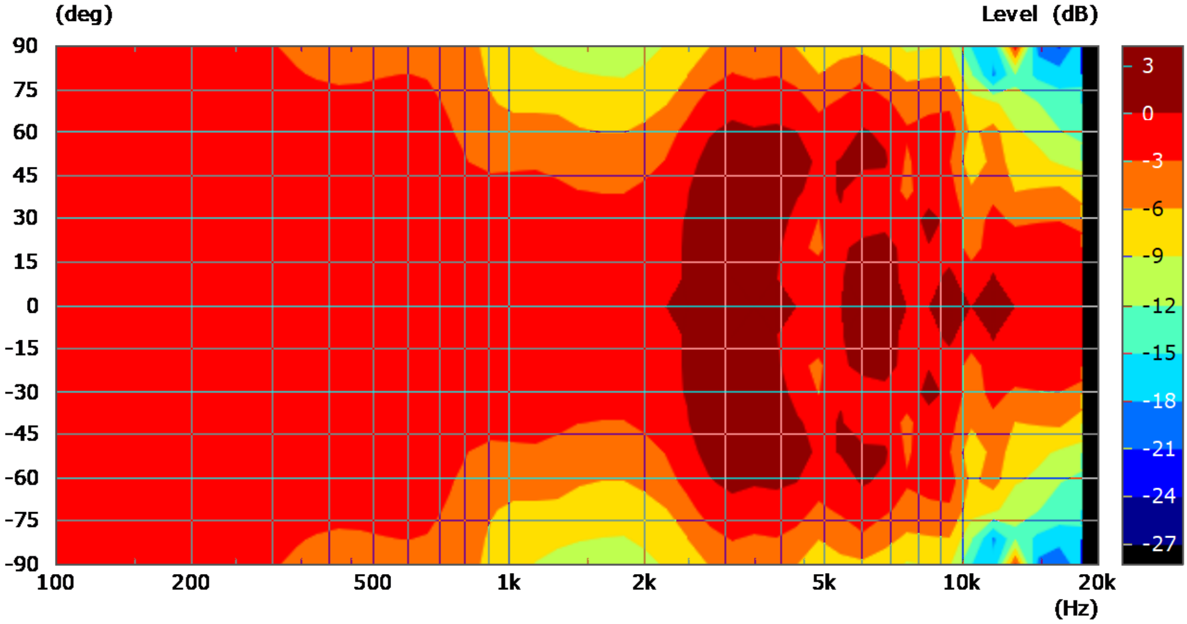
Example using a 2-way speaker

In the following, a 2-way spaker with 6" woofer and 1" tweeter was simulated. The enclosure dimensions were 20x30x20 cm (WxHxD). The crossover frequency was chosen to 1.8 kHz. The filter characteristic was Linkwitz-Riley 4th order.

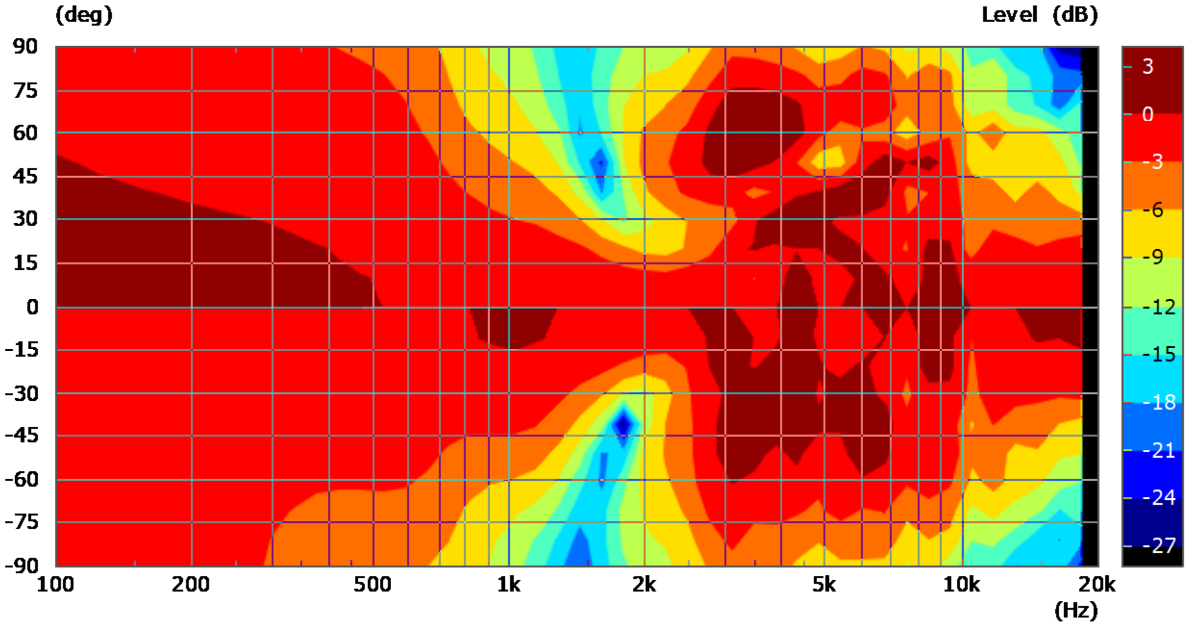
The horizontal and vertical dispersion characteristics are shown.

Sharp Edge



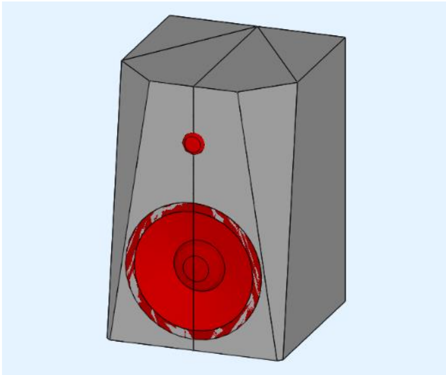


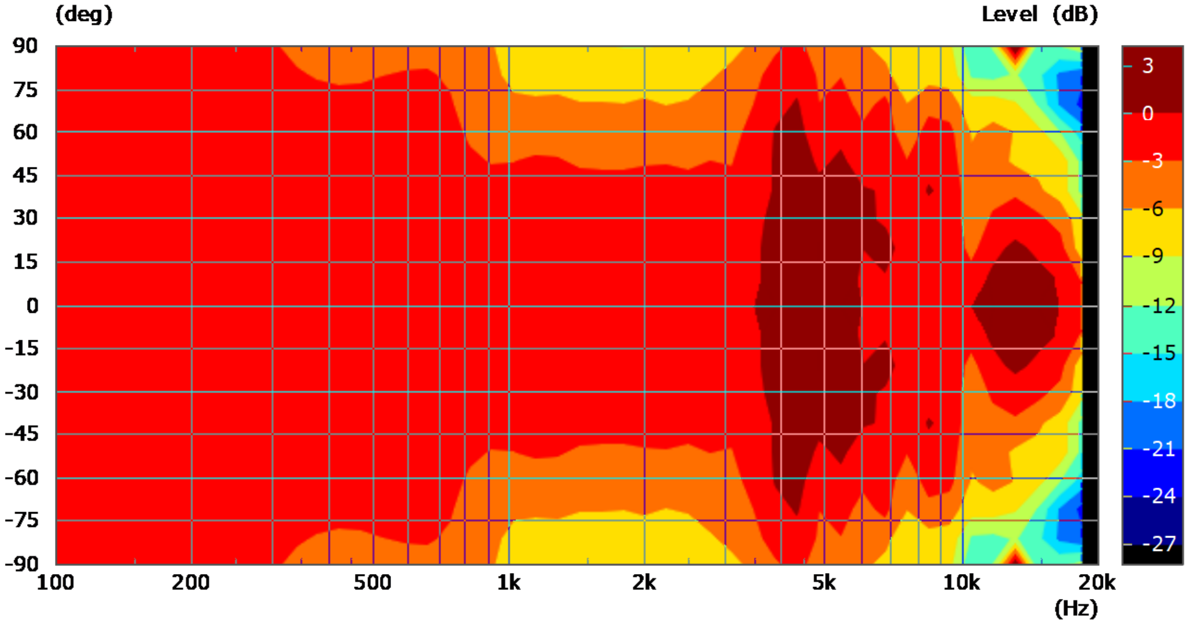
(deg)
Level (dB)
90
75
60
45
30
15
0
-15
-30
-45
-60
-75
-90
100
200
500
1k
2k
5k
10k
20k
(Hz)
3
0
-3
-6
-9
-12
-15
-18
-21
-24
-27



(deg)
Level (dB)
90
75
60
45
30
15
0
-15
-30
-45
-60
-75
-90
100
200
500
1k
2k
5k
10k
20k
(Hz)
3
0
-3
-6
-9
-12
-15
-18
-21
-24
-27

Bevel





(deg)
Level (dB)
90
75
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1k
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(Hz)
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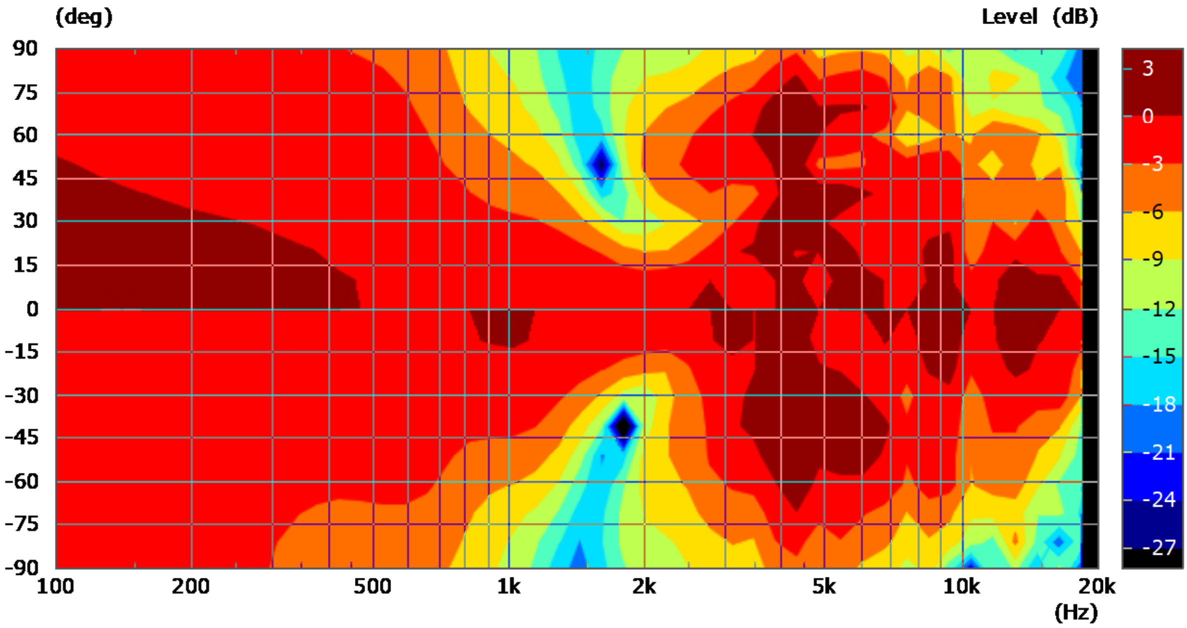

(deg)
Level (dB)
90
75
60
45
30
15
0
-15
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-45
-60
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-90
100
200
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1k
2k
5k
10k
20k
(Hz)
3
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-21
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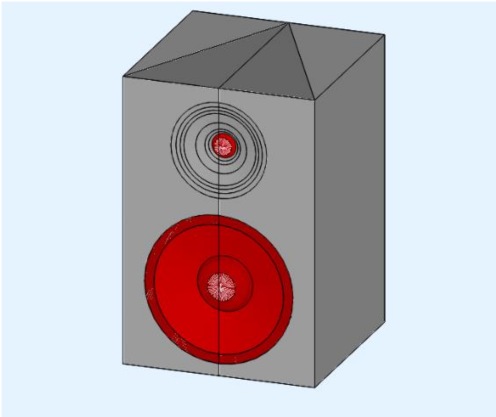
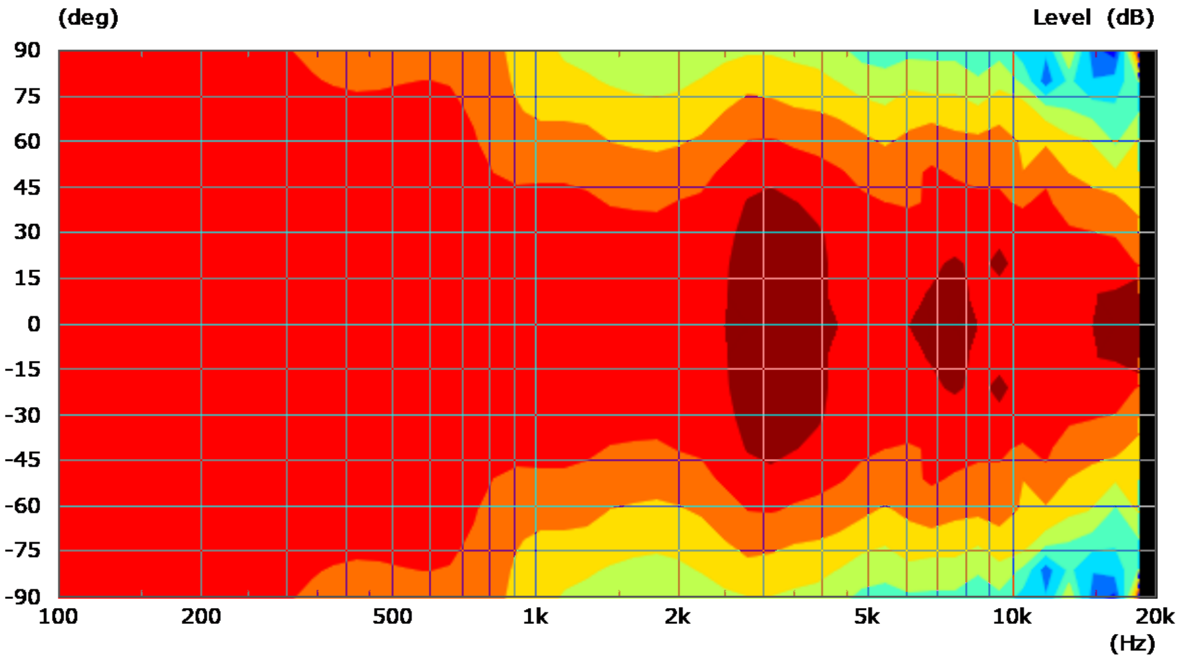
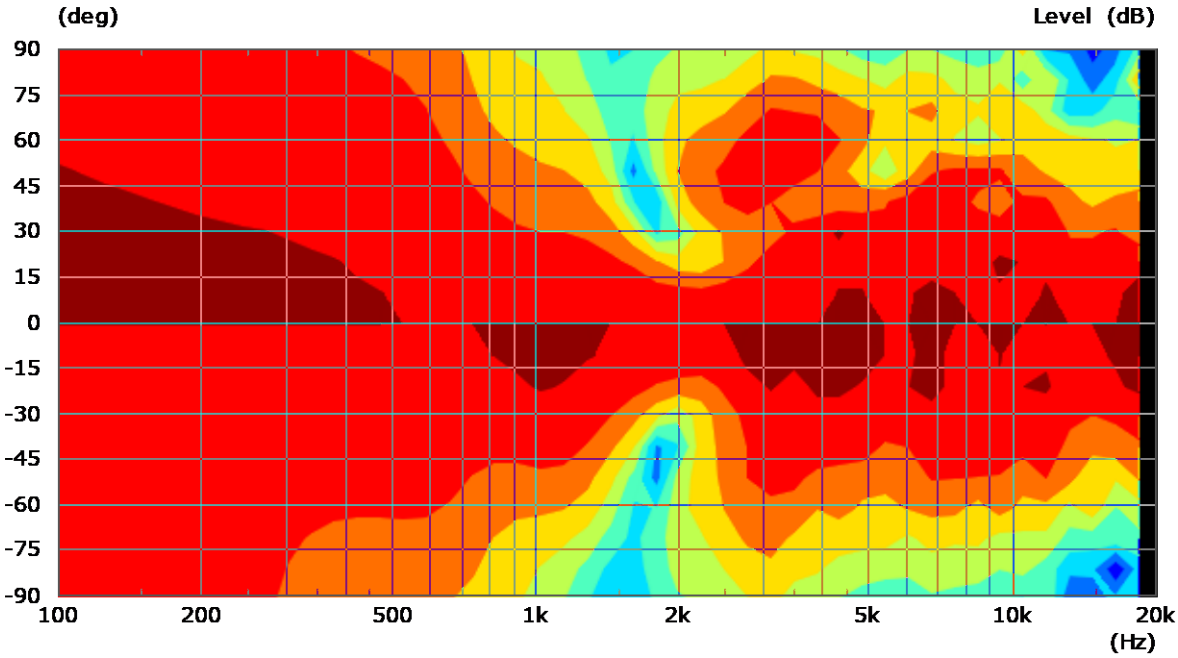
-27

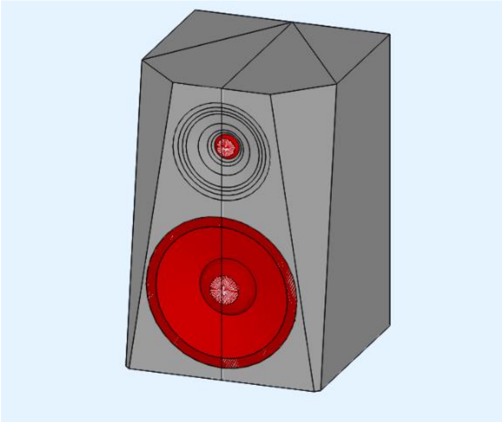
Waveguide and sharp edge

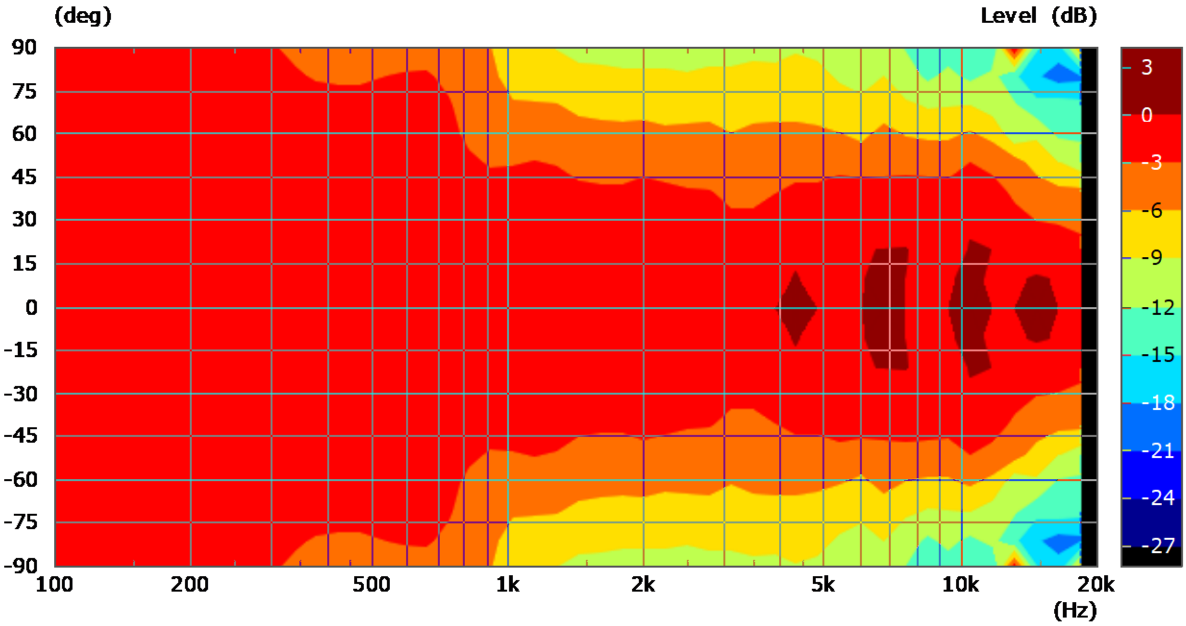


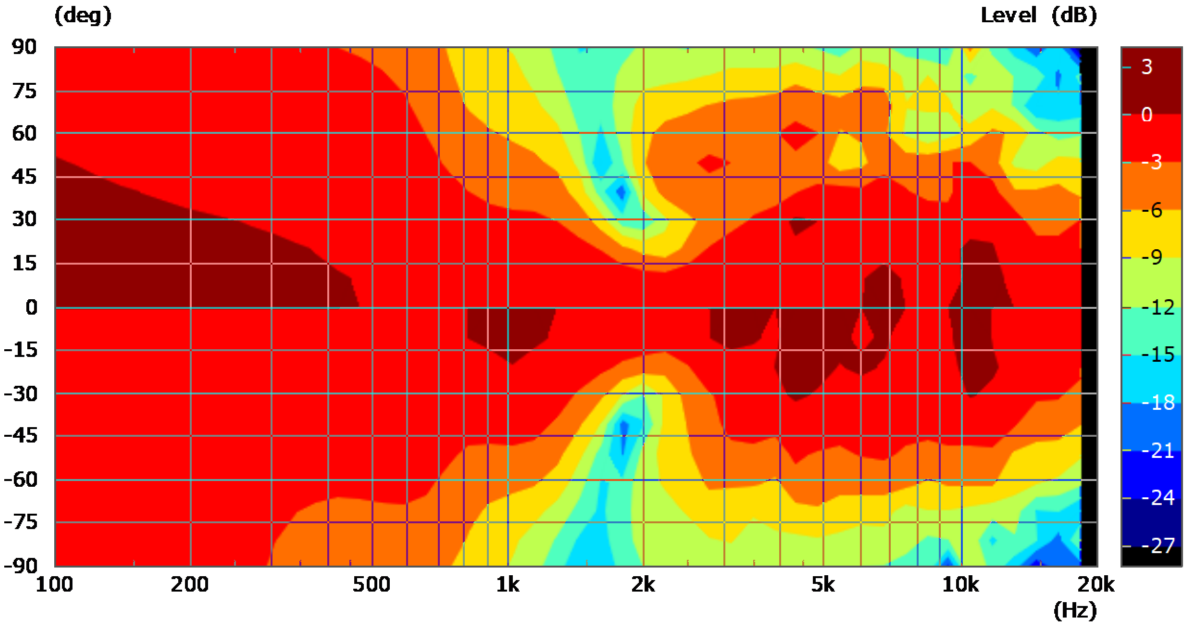




Waveguide and bevel







Result

While both the rounding and the bevel reduce the effective size of the baffle, this effect is much more pronounced with the bevel. Furthermore, only the rounding attenuates the amplitude of the secondary sound sources and thus the interference. It is therefore always necessary to examine exactly which method is better suited for a particular concept.

The effects of sound sources with a narrow directivity (large diaphragm or horn/waveguide) have not been considered in this document. However, it should be said that these are very effective in attenuating secondary sound sources.