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Investigation of the depth of field in acoustic maps and its relation between focal distance and array design

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ABSTRACT

Most of today's established beamforming systems use planar microphone arrays. This is a popular and easy choice because these arrays have a great depth of field and seem robust against false focus. In cases of planar beamforming-array-measurements considering a false focus, sources are mostly mapped correctly and show only a minor loss of the source level. As the further development of the beamforming technology takes place, the 3D–arrays have been developed and used for several new applications. Especially room and building acoustics as well as car interior measurements seem to be some of these applications for such 3-dimensional-arrays. Here the simplest chosen way is to map on several 2D planes facing outwards from the spherical array and overlap the maps. The focus will only be accurate for a very small number of points in the map and leads to a dramatically false acoustic map. More advanced systems offer the implementation of common 3D CAD data in order to avoid calculation points with wrong focal distance. These CAD models represent a correct display of reality in its proportion and when mapping on such models no wrong focus can occur. This paper will show the impact of the array design on the depth of field and the mapping capabilities of 3D Beamforming through simulations and practical measurements. It identifies some of the earlier proposed methods as not applicable and unmasks the misleading ones. A simple way to prevent false results through wrong focus distances will also be presented.

1 INTRODUCTION

Current commercial beamforming systems, among them the Acoustic Camera, use a rectangular virtual image plane in order to calculate the run times between microphone array and measurement object. This way the surface of the device under test is approximated, and the z-axis of the array is usually oriented perpendicularly to the image plane. Subdividing the image plane into rows and columns results in a finite amount of rectangular display details (pixels). The area centers of these pixels are used to calculate the delays. Figure 1 shows this mapping principle. For mapping car interior or rooms several system providers introduced 3D-spherical microphone arrays. To solve the problem of the mapping surface some manufacturer use up to 12 built-in video cameras. So they get up to 12 mapping surfaces (pictures) in a defined distance to the array. Sound sources which are placed on a three dimensional device surface will be localized and mapped on a big two dimensional plane. This proceeding causes errors. First, by mapping the calculated sound sources on a two

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dimensional plane we will get distortions of the mapping. Sound sources will be localized incorrectly. In most beamforming applications these effects are negligible but for mapping of interior rooms these effects are noticeable [1]. Second, the focus of the beamformer is incorrect for most pixels.

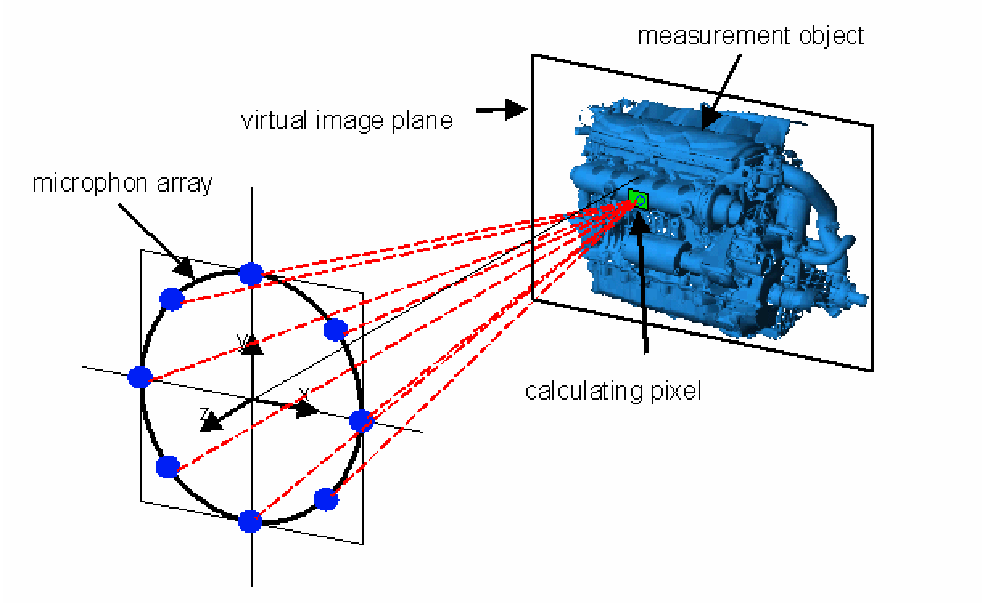

Figure 1 conventional beamforming and mapping onto a 2D virtual image plane

Especially in the case of car interior we have a very complex situation. Figure 2 shows a typical measurement setup in a car interior.

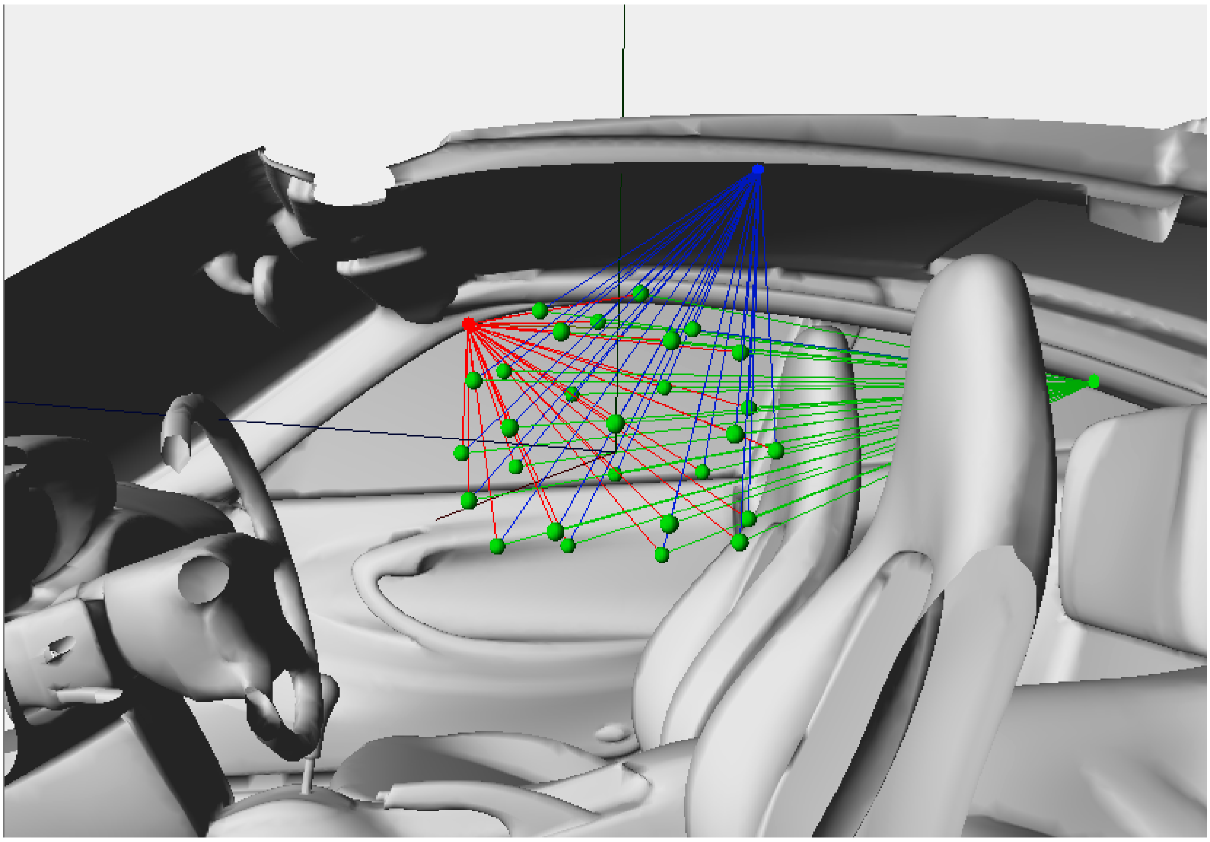

Figure 2 typical measurement setup in car interior

The distances to the emitting surfaces differ in a wide area from some 10cm (e.g. near the roof, blue lines) up to some meters (to the back or to the floor, red and green lines). Using only one focal distance requires a wide depth of field in acoustics sound pressure maps of the used arrays. Therefore we have to investigate the depth of field of the possible microphone arrays.

2 DEPTH OF FIELD OF DIFFERENT MICROPHONE ARRAYS

In the first part a source of broadband white noise was put in front of the array at a distance of 1 m. Figure 3 shows the decreasing of the source noise level depending on the focus used for calculation. For the measurement a spherical array containing 48 microphones having a diameter of 35cm was used (Sphere48_35cm). The calculations for the different frequency bands were made using white noise results and corresponding frequency filter.

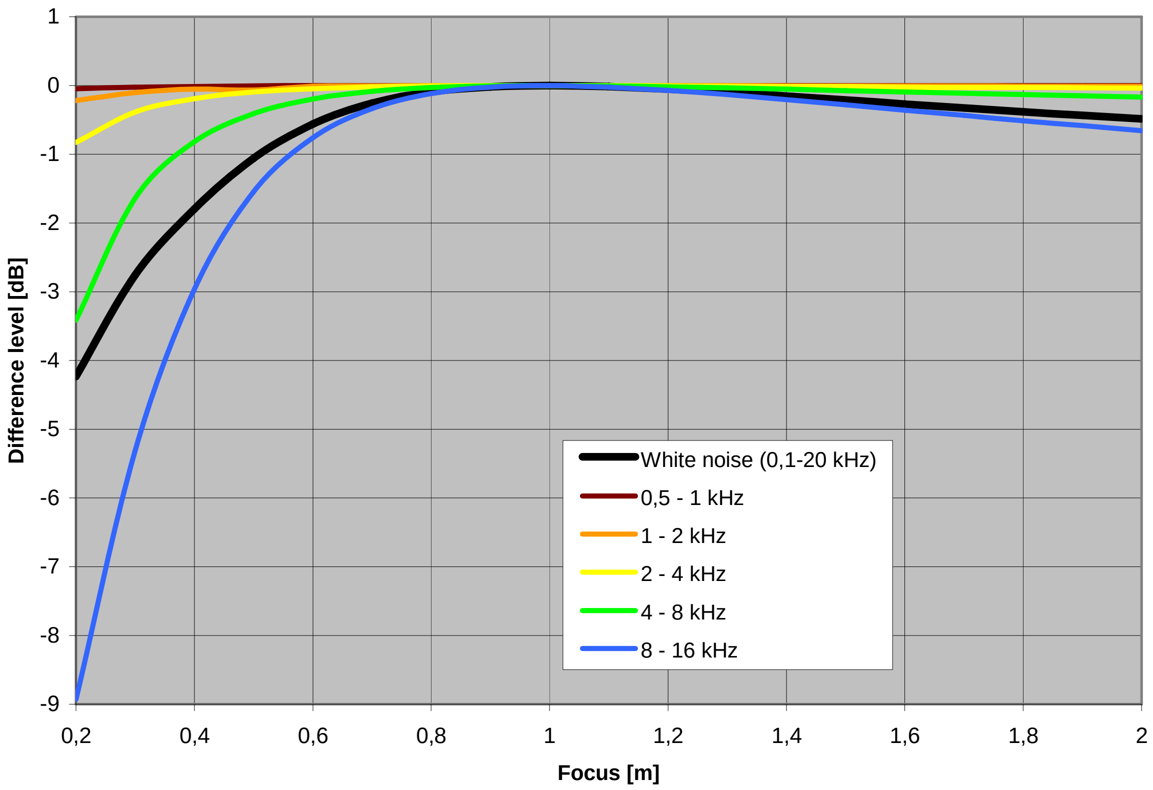

Figure 3 difference sound pressure level depending on specific focus distance used for calculation for Sphere48_35cm

Figure 4 shows the results for this spherical array and a white noise source in 0.5m distance. The dependency on the focus distance is much stronger.

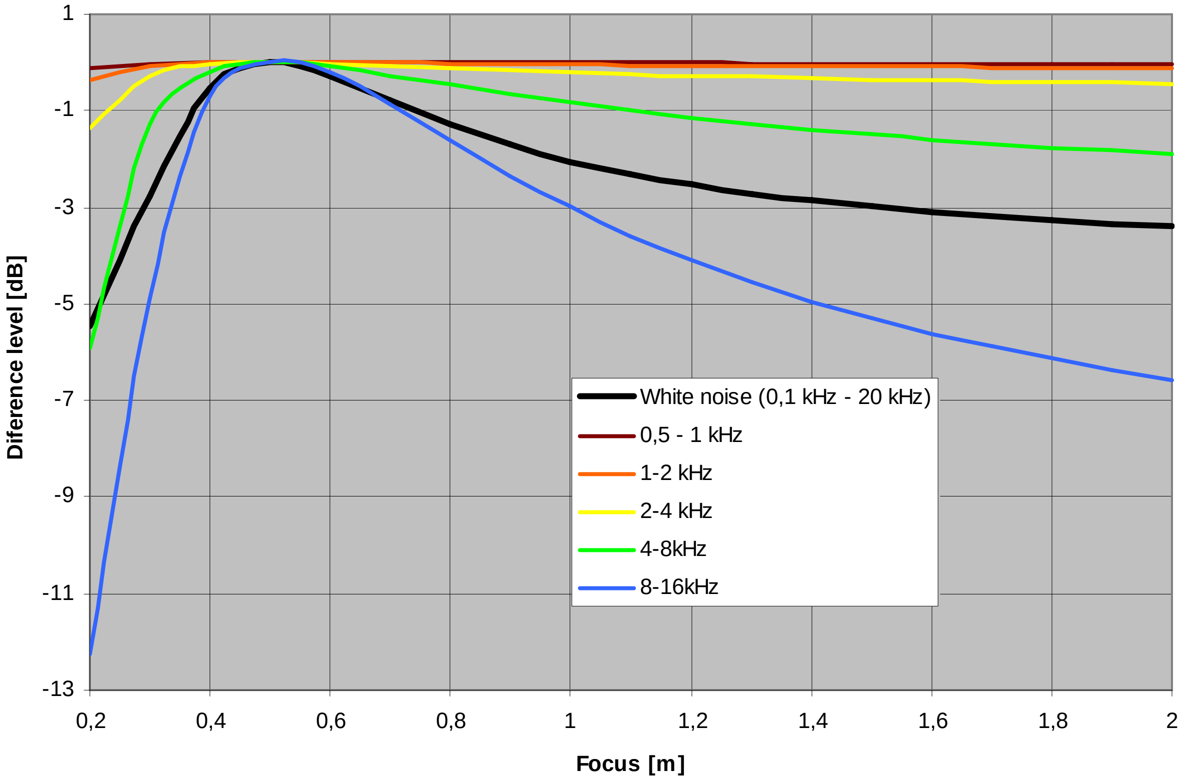

Figure 4 difference sound pressure level depending on focus distance used for calculation, Sphere48_35cm, 0.5 m focus

Figure 5 shows the analogous results for a spherical array containing 120 microphones and 60cm diameter (Sphere120_60cm). Figures 6 to 8 show the dependency of the source sound level on the chosen focus for a ring array with 48 microphones and 70cm diameter (Ring48_70cm), for a planar spiral array with 48 microphones and 70cm diameter (Spiral48p_70cm) and for a folded (30 degree) spiral array with 48 microphones and 70 cm diameter (Spiral48f_70cm).

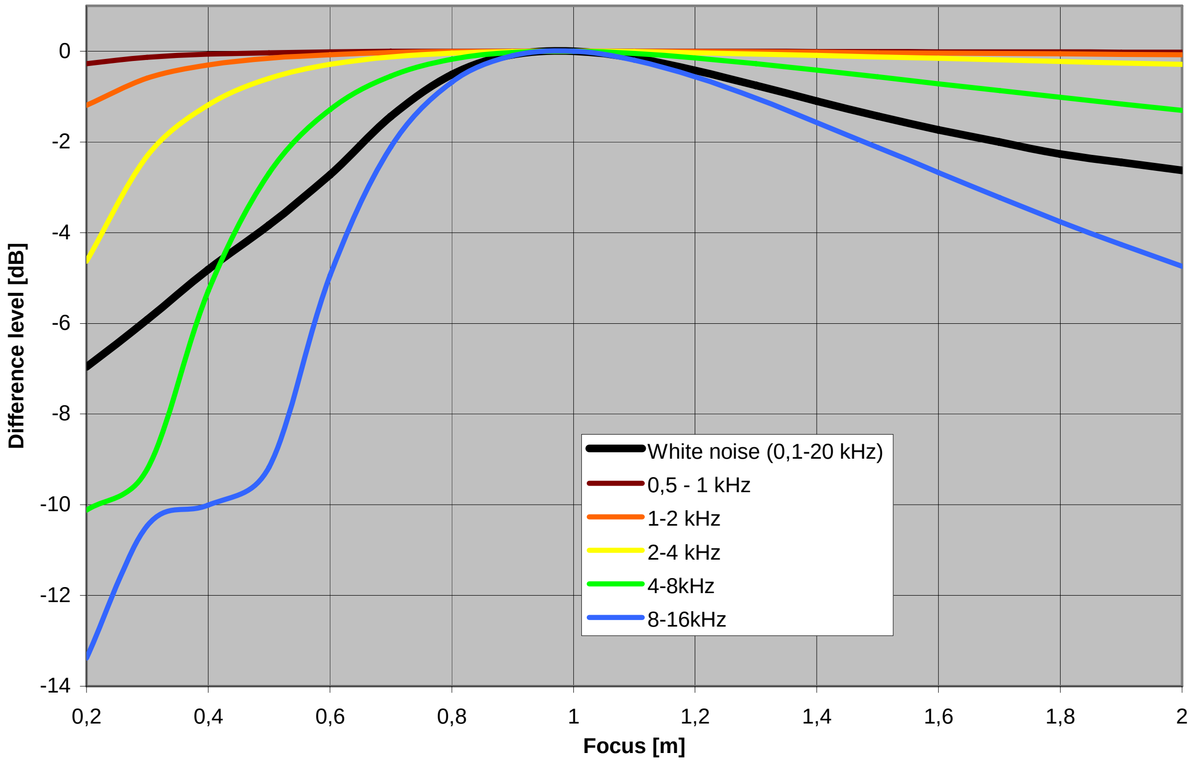

Figure 5 Difference sound pressure level depending on selected focus distance, Sphere120_60cm, focus 1m

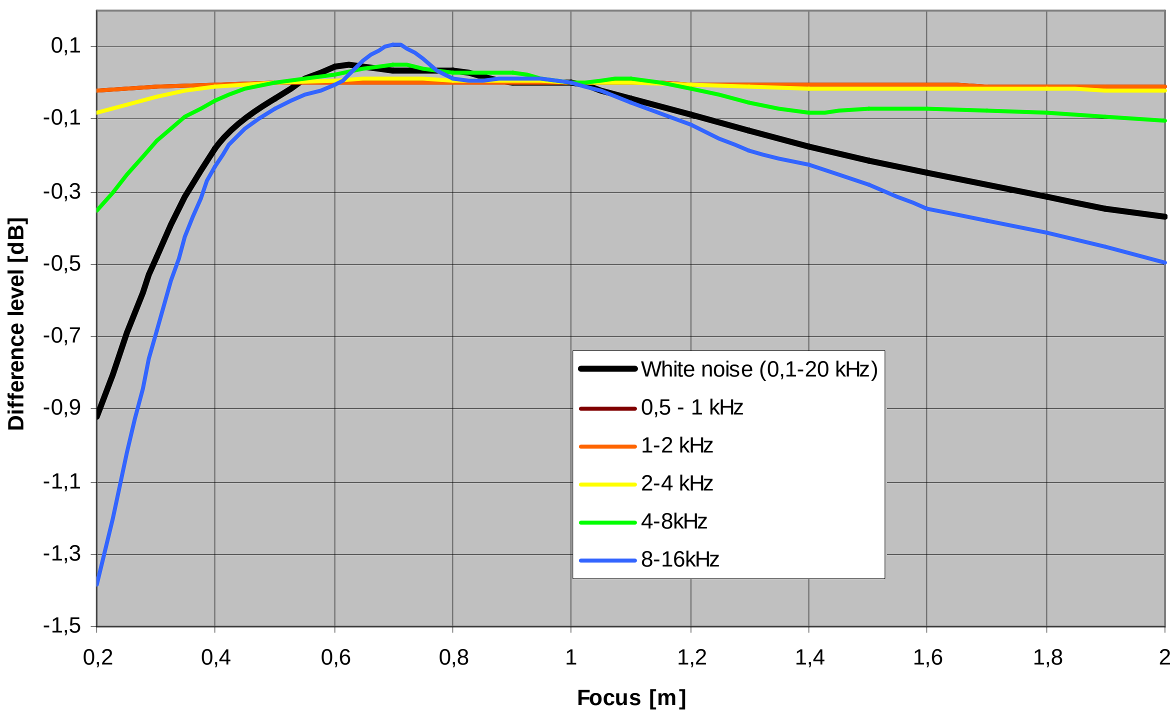

Figure 6 Difference sound pressure level depending on focus distance, Ring48_70cm, focus 1m

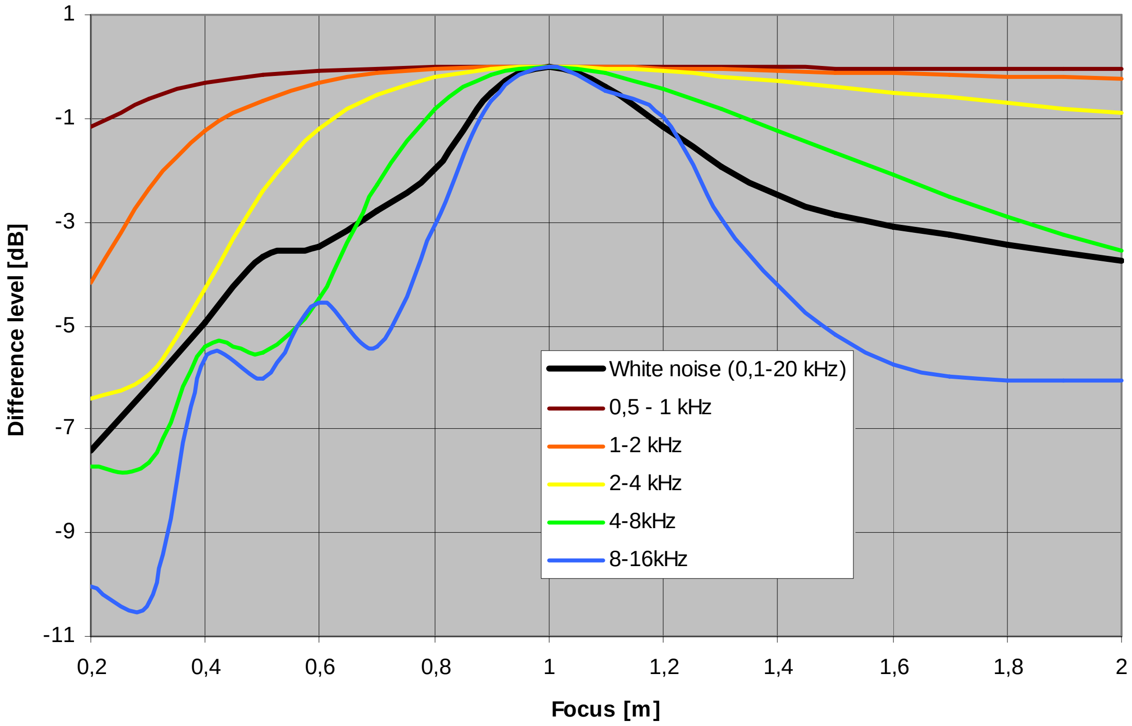

Figure 7 Difference sound pressure level depending on focus distance used for calculation, Spiral48p_70cm, focus 1m

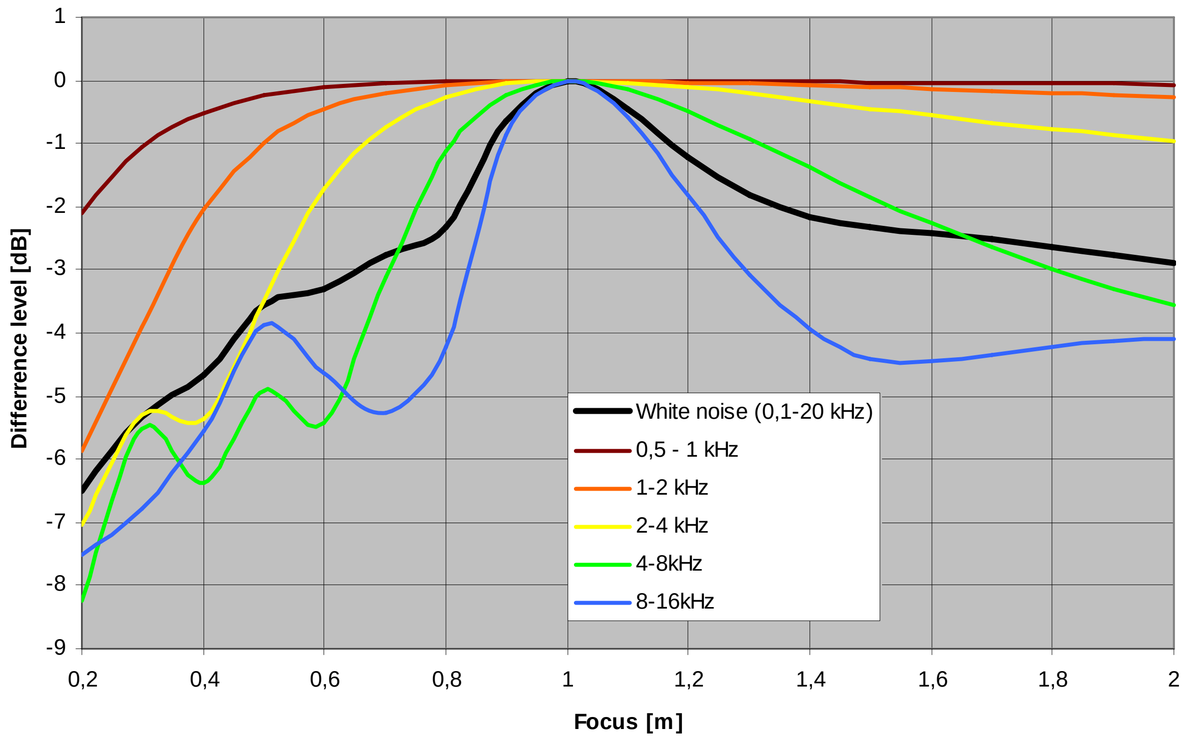

Figure 8 Difference sound pressure level depending on focus distance used for calculation, Spiral48f_70cm, focus 1m

3 CONCLUSIONS

All the investigated arrays show a remarkable dependence of the mapped noise source sound pressure level on the real focus distance. This behaviour is caused by the 3-dimensionality of the array patterns. The 2-dimensional array patterns are well known from standard beamforming solutions [3]. Various deconvolution methods (DAMAS, CLEAN etc.) [4] have been tried in order to reduce the impact of such aliasing. However, the 3-dimensionality of the aliasing patterns has not been considered so far. Consequently, focus errors have led to a significant decrease of the calculated sound level. This is the stronger the higher the frequency band is. For most of the arrays these differences become permanent for long distances (distances much longer then the array dimension). Figure 9 shows the dependence of the noise source level on the focus for white noise in 1m distance for the investigated arrays. Apparently, the planar ring array is the most stable array. It has the widest depth of field of all test arrays. Surprisingly the spiral arrays depend strongly on the real focus distance as all the 3D-spherical arrays do.

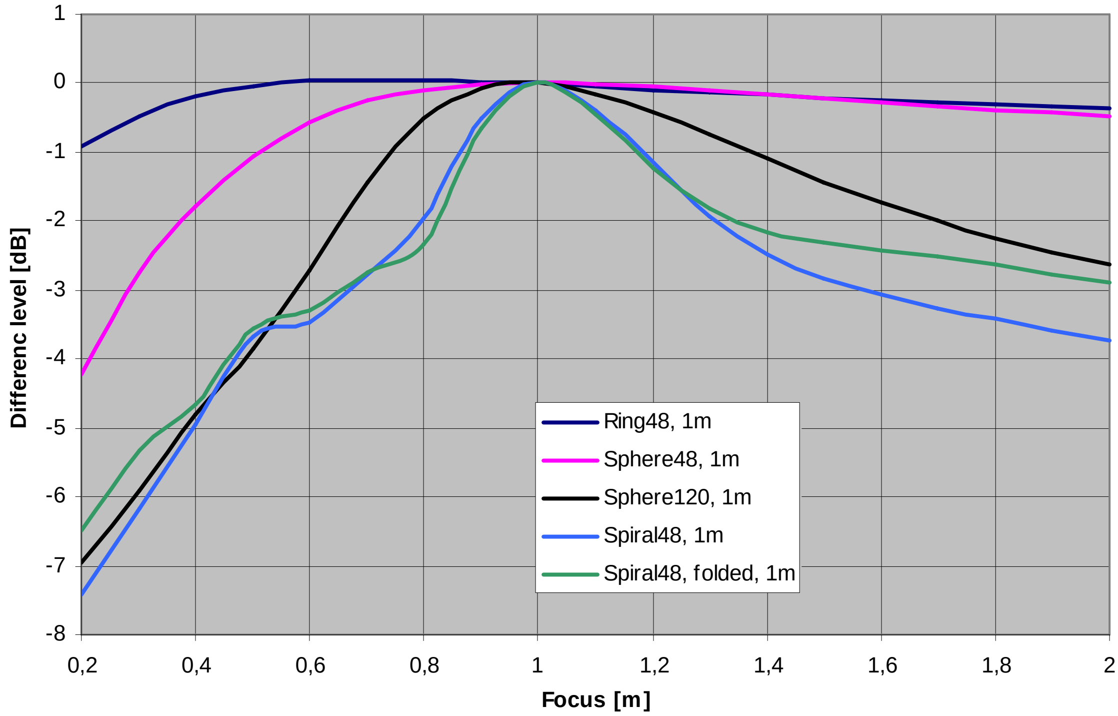

Figure 9 Difference level for the different arrays for white noise

Finally figure 10 shows 2 acoustic photos of two white noise sources in a distance of 0.3 m and 0.5m calculated for the distance of 0.3m, and 0.5m measured with Sphere48_35cm.

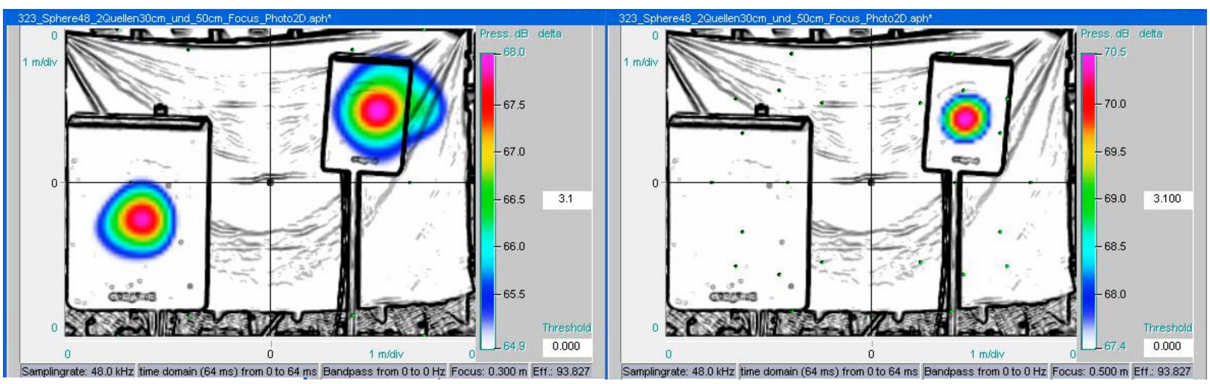

Figure 10 Acoustic photos calculated for focus 0.3m (left) and 0.5m (right)

For the focus distance 0.5m the sound level of the source in 0.3m decreases considerably and disappears for the chosen sound pressure level resolution. All the results show that it is necessary to work with the true focus distance. For interior measurements, this effect has more relevance than for measurements under free field conditions. The contrast (dynamic range) of the beamforming map in complex interior is limited because there are many reflections and diffractions. If we get an additional decrease of source levels by using a wrong focus, sources cannot be located. That means for car interior we have to map onto the (small) triangles of the 3D-CAD-model to get the true distances to the emitting surfaces as shown in figure 11.

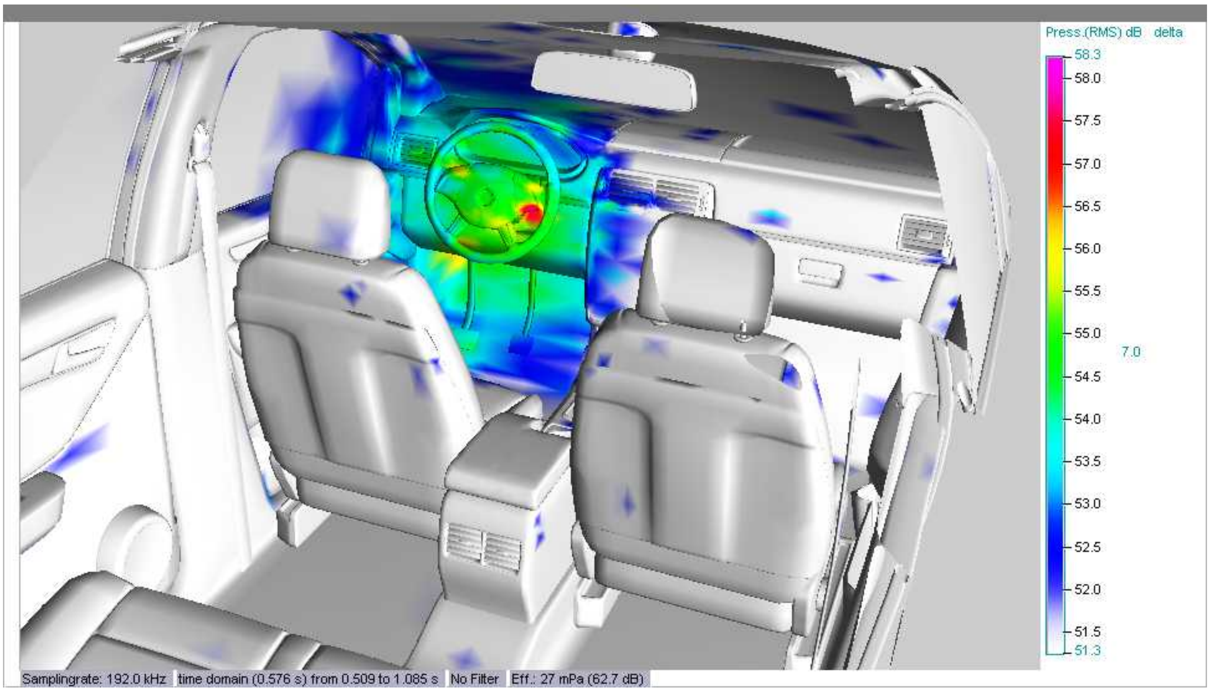

Figure 11 acoustic photo 3D of a car interior on a shaker

4 REFERENCES

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