Phase Decomposition for Loudspeaker Analysis

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Abstract

The sound pressure level from a loudspeaker at a distance is determined mainly by the vibration of the cone(s). It is however difficult to make a direct correlation between the displacement on the radiating surface(s) and the resulting sound pressure. In order to establish insight into this correlation some kind of decomposition of the vibration is advantageous. The so-called phase decomposition described by Klippel [1] splits the displacement into an in-phase, an anti-phase and a quadrature component, with each component contributing differently to the pressure. The decomposition requires that the pressure be calculated via the Rayleigh integral. Klippel provides software which can perform the analysis for a measured displacement pattern, but it was desired to have the phase decomposition done within COMSOL Multiphysics®. The Rayleigh integral and the phase decomposition technique were successfully implemented, and have been applied to vibrating cones and vibrating cabinets.

Certain assumptions have to be made when constructing a sensible phase decomposition. Here, it is assumed that the vibrating surface is flat and that this surface is situated in infinitely large and flat baffle. Also, that there are no obstructions in the pathway between the surface and the observation point. With these assumptions only a single displacement direction needs to be considered and there are no diffraction contributions.

An example illustrates the functionality implemented in COMSOL Multiphysics: Consider a flat disc with radius a of 0.1 m in an infinite baffle. On its surface the disk has a total force applied in the direction of the baffle normal of F_z=e^(-2/a √((x-a/5)^2+(y-a/5)^2)) N.

The resulting distinct displacement pattern can be used for illustrating the phase decomposition technique.

In Figure 1 the total displacement is shown for a frequency of 1.6 kHz. Two distinct displacement bulges in opposite phase are seen. The displacement was phase decomposed relative to an observation point on-axis in a distance of 1 m above the disk. All displacement components are depicted using the same amplitude scale as in Figure 1. The in-phase component is shown in Figure 2. It can be seen that the in-phase part is simply the larger of the two displacement bulges.

The anti-phase shown in Figure 3 is the smaller of the displacement bulges. Since the total displacement only has two phase values, this has to be case, since the anti-phase component can never be larger than the in-phase component.

Finally, the out-of-phase displacement is shown in Figure 4. This component is essential zero. For the total displacement pattern shown in Figure 1, the out-of-phase component can only be non-zero on-axis if the observation point is located close to the surface.

Reference

[1] W. Klippel and J. Schlechter, Measurement and Vizualization of Loudspeaker Cone Vibration, www.klippel.de (2016)

Figures used in the abstract

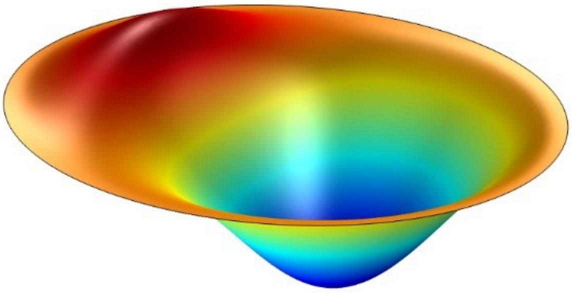

Figure 1: Figure 1. Total displacement of the vibrating disc at 1.6 kHz.

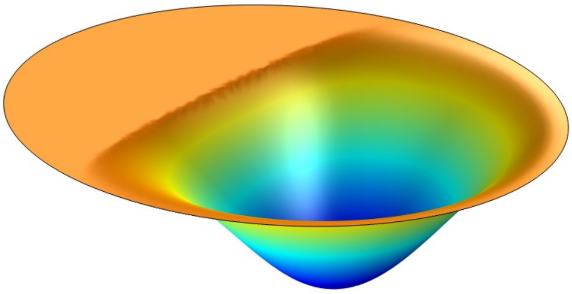

Figure 2: Figure 2. In-phase displacement component of the vibrating disc at 1.6 kHz.

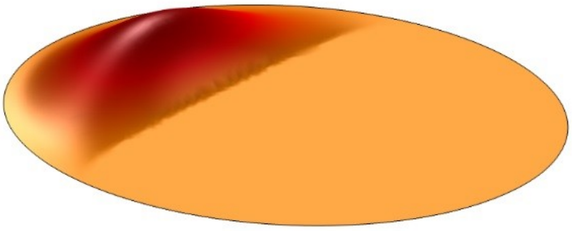

Figure 3: Figure 3. Anti-phase displacement component of the vibrating disc at 1.6 kHz.

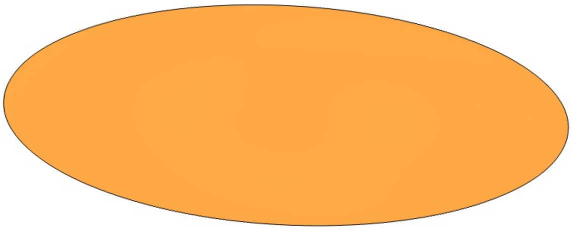

Figure 4: Figure 4. Out-of-phase displacement component of the vibrating disc at 1.6 kHz.