Loudspeaker positioning in rectangular rooms

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Introduction

Sound fields in rooms are essentially diffuse [1,2]. Yet, at low frequencies, modes are prevailing, and loudspeakers respond differently when they are moved through a room. The reason is that modes play a dominant role in an otherwise diffuse field, and that the position of the loudspeaker determines how much each mode is excited. Another view of the same effect is given by the image sources of the loudspeaker, that are moving, too, when the loudspeaker is moving through the room. Thus different sound filed patterns are created, that correspond to the modes.

Image sources in rectangular rooms

In rectangular rooms, image sources are regularly clustered by groups of 8 – or by group of 4 in 2 dimensions as shown in Figure 1.
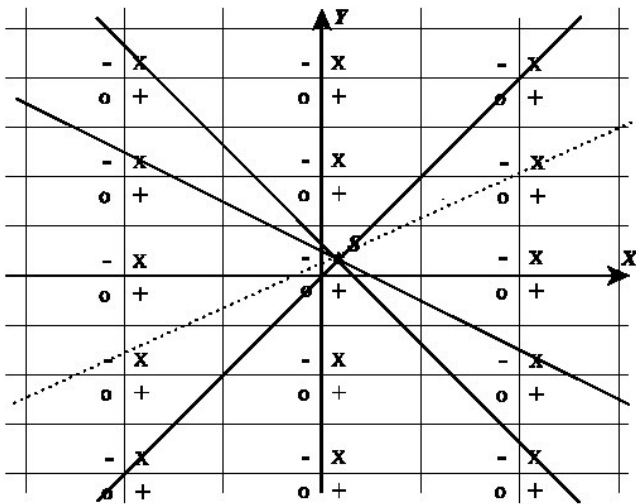

Figure 1: Image source distribution in a rectangular room.

One of the sources in each cluster corresponds to an even number of reflections on each wall, the other add a further reflection on at least one wall. It can be shown that image sources obtained from even reflections on all walls correspond to close orbits [3-5]: rays issued from the real source in their direction cross a new image source at regular intervals. No such regularity exists for the other image sources, except accidentally if they happen to lie on a close orbit. The regularity makes it possible to treat the cluster of image sources globally, with a close form for the sources on the periodic orbits, corrected by perturbation terms for all the other image sources.

Thus, the field created by a source at its own position can easily be computed by finding out all the directions in which closed orbits can be constructed. This pressure field represents the acoustical load seen by the source. For a point source, the imaginary part of this field diverge for the image source coinciding with the real source, and only the real part is convergent: it is represented with broken line in Figure 2 for a source located at the reference position located 0.6m from the end wall and 1.0m from the side wall of the room of Figure 1. It compares well with the load measured at the same position with the ABC system [6] - continuous line.
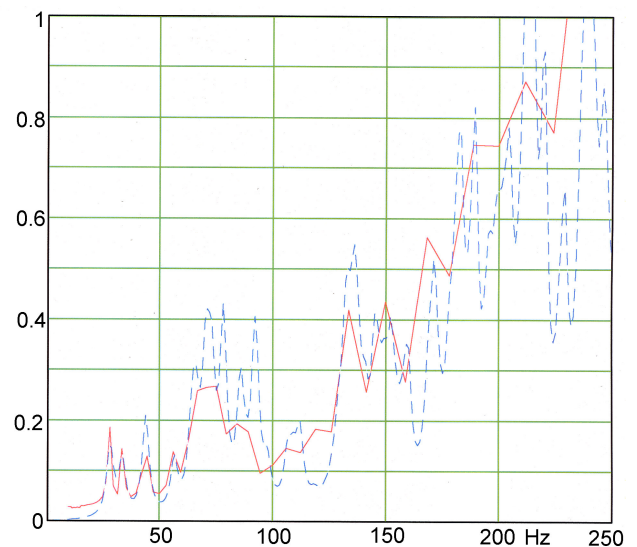

Figure 2: Load measured (continuous line) and computed (broken line) at reference position

Field correction

A field correction must be applied to a loudspeaker system when it is moved to another position, in order to recover the same sound field as in the original position. This makes it possible to optimise the system for one position in the room, then correct the signal fed to it when it is moved so that the response becomes independent of the position.

The basic idea for field correction consists in determining the acoustic load at some position and compare it to the acoustical load at a reference position at which the response of the speaker system has been optimised. Such a correction is presented in Figure 3, based on the loads computed for a point source at the reference position (see above) and at the corner position located at 0.4m from the end wall and 0.4m from the sidewall.

Despite the crude approximation – the loudspeaker is approximated by a point source, the loudspeaker box is ignored, and phase shifts at the reflections on the walls are ignored – the simulated correction compares well with corrections measured with the ABC system [6] for the same

loudspeaker positions (Figure 4). The orders of magnitude are correct. The main discrepancy concerns the position of the maximum, which is shifted toward higher frequencies in the simulation, due to the fact that the real loudspeaker is not a point source.
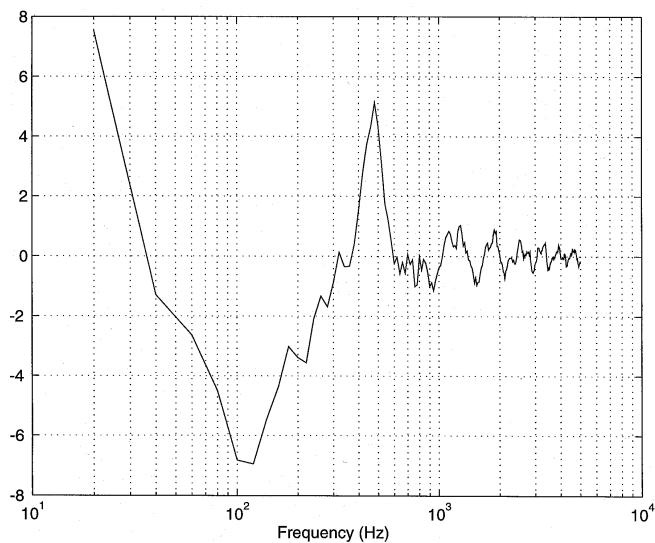

Figure 3: Correction computed when moving a point source from reference to corner position

Attempts to take into account the finite size of the loudspeaker and diffraction around the loudspeaker box have not been successful yet.
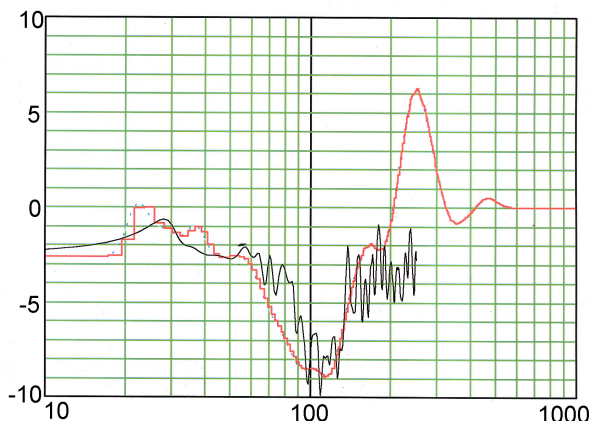

Figure 4: Correction measured when moving a point source from reference to corner position

Measuring the radiation impedance

In order to check the theory, it is necessary to develop a technique for measuring the acoustical load seen by the loudspeaker, that is, its radiation impedance. Using the flat piston approximation for the radiation of the loudspeaker membrane, it is possible to develop the pressure radiated on axis as a function of the distance to the membrane.

Measuring the pressure on axis at 10 different positions in front of the membrane makes it possible to derive both the pressure on the membrane by regression and extrapolation, and the velocity of the membrane by the finite difference approximation to the gradient. The radiation impedance thus derived in a damped room corresponds well to the theory
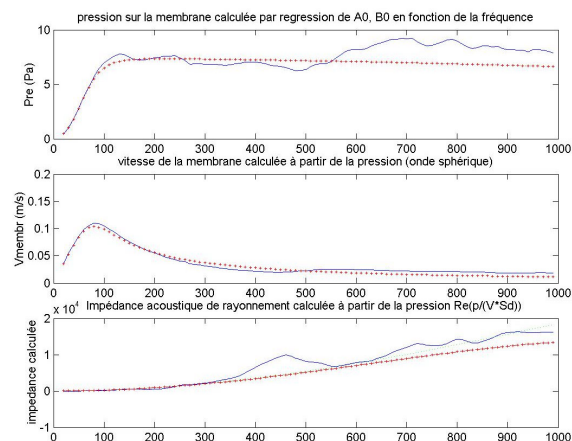
(Figure 5).

Figure 5: Pressure on the membrane, velocity of the membrane and radiation impedance derived from pressure measurements on axis in a damped room (continuous lines), compared to theory (dotted lines).

However, to fully check the theory, measurements should be carried out in a highly reverberant rectangular room. The lack of such a room has postponed those measurements.

Conclusion

The present work can be seen as a first attempt toward explaining room correction when a loudspeaker is moved from one position to another, in the same or in different rooms. But work remains to find efficient ways to take into account the finite size of loudspeaker and diffraction around loudspeaker box.

References

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