Simulation of a Piezoelectric Loudspeaker for Hearing Aids and Experimental Validation

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Abstract

1. Introduction
The use of piezoelectric materials in hearing aid loudspeakers, also called receivers, presents technical and economic advantages such as reducing the number of parts of the system and its manufacturing cost. However, the performance of such systems is still not competitive when compared to traditional electrodynamic loudspeakers. In order to achieve an appropriate performance, one option is to apply optimization techniques to these systems. In optimization procedures, it is convenient to use efficient models to quickly evaluate the system performance, so that the evaluation can be repeated several times. Therefore, the aim of this work is to develop and validate an efficient multi-physical model of a hearing aid piezoelectric loudspeaker so that the model may be used in an optimization procedure.

The performance of a hearing aid loudspeaker is usually evaluated through an experimental set-up where the loudspeaker is connected to a standard microphone coupler which simulate the ear canal impedance and provides an approximation of the incident sound pressure at the ear drum. An overview scheme of the model used to simulate this experimental set-up can be visualized in Figure 1, where the loudspeaker is represented by a multi-physical Finite Element (FE) model and the acoustic coupler as a Transfer Matrix Method (TMM) model [1] to reduce the computational cost of the analysis. With this model, the system frequency response function is evaluated by taking the average sound pressure level (SPL) at the microphone surface position for an unit input spectra of the electric potential at the loudspeaker electrode surface.

2. Use of COMSOL Multiphysics® software
Figure 2 presents the domains and boundary conditions (BC) applied to the loudspeaker FE model. As the piezoelectric loudspeaker has a cylindrical shape, to reduce the computational cost, a 2D axisymmentric FE model was used in COMSOL. The analysis was performed using the Acoustic-Piezoelectric Interaction, Frequency Domain interface. The TMM model is coupled to the FE model by means of the acoustic impedance BC.

The acoustic model of the small cavities of the loudspeaker accounts for thermal and viscous effects on the acoustic propagation. These effects may be modeled by the Thermoacoustics physics interfaces in COMSOL, but this approach is computationally expensive. Therefore, these effects are included in a simplified form using the Low Reduced Frequency (LRF) [2,3] model by using Pressure Acoustic physics interfaces of COMSOL.

3. Results
The FE model of the loudspeaker was experimentally validated through tests with a prototype designed and built with dimensions larger than those of a hearing aid loudspeaker designs to allow its construction. Figure 3 shows the SPL results compared with experimental result measured in [4] and two commercial hearing aid loudspeakers (Knowles) measured with the same acoustic coupler.

4. Conclusions
This paper has presented a multi-physical model to analyze the performance of piezoelectric loudspeaker for hearing aid application. The model was simplified to increase its efficiency and to allow the application of optimization procedures. Despite the model simplifications, it was experimentally validated showing good agreement with the experimental results.

Reference

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Figures used in the abstract

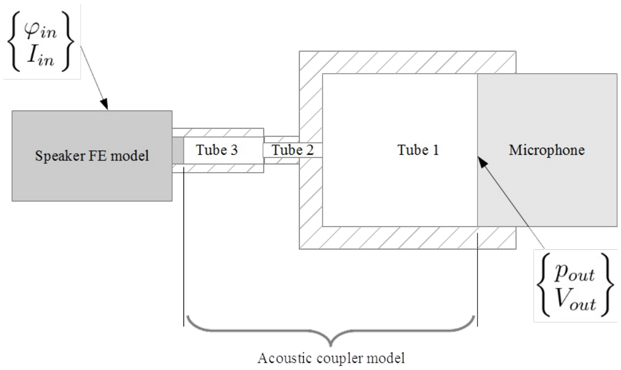

Figure 1: Overview scheme of the speaker performance analysis model.

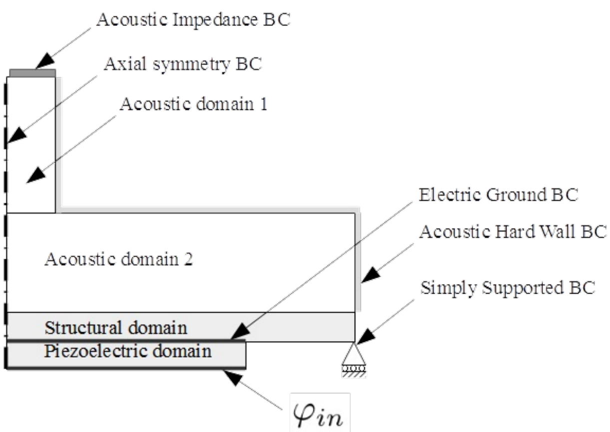

Figure 2: Multi-physical loudspeaker FE model set-up.

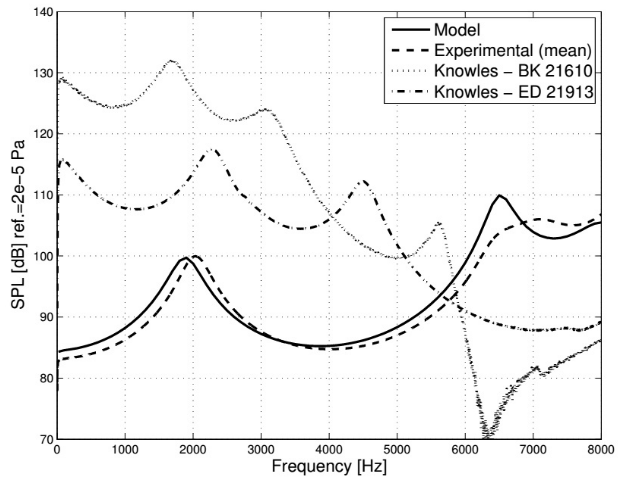

Figure 3: Comparison of numerical and experimental SPL of a piezoelectric prototype and two commercial hearing aid speakers (for an unit input spectra of electric potential).