Investigation of internal feedback in hearing aids

There are many aesthetics and structural design requirements to modern hearing aids and their size has been reduced considerably during the last decades. This has led to designs where the receiver (loudspeaker) and microphones are placed closely together. As a consequence, problems with vibroacoustic transmission from the receiver to the microphones often occur during the use of hearing aids. This transmission causes feedback at certain critical gain levels where it produces a loud uncomfortable squealing. Consequently feedback often constitutes the limiting factor for the maximum obtainable gain in the hearing aid and it therefore represents a critical design problem. Feedback in hearing aids is usually divided into external and internal feedback. External feedback is caused by the leakage of sound from the ear canal whereas internal feedback is due to transmission of sound and vibrations internally in the hearing aid. As a result of reducing the size of hearing aids, manufacturers have experienced an increase in internal feedback problems. The main objective of the present thesis is therefore to examine the vibroacoustic mechanisms responsible for internal feedback in hearing aids. This is approached by the development of a full vibroacoustic 3D-model of a so-called “behind the ear” hearing aid manufactured by Widex A/S. The 3D-model is developed using finite element analysis and it is capable of simulating the so-called “open-loop” transfer functions. These open-loop transfer functions relate the microphone output voltages and the receiver driving voltage when the receiver and microphones are electrically disconnected. The main scientific part of the thesis consists in the study and extension of a relatively recent method. This method is the "Theory of fuzzy structures" and it is intended for predicting the vibrations of a deterministic "master" structure with one or more attached complex "fuzzy" substructures with partly unknown dynamic properties. An important part of the theory regarding the modeling of fuzzy substructures attached to the master through a continuous interface is thoroughly examined and reformulated in a more simple form. Such fuzzy substructures are modeled by including spatial memory in the fuzzy boundary impedance. The main effect of an attached fuzzy substructure is the introduction of high damping in the vibration response of the master structure, but, it is shown that spatial memory reduces this damping. The method of including spatial memory is hereafter extended such that it also comprises modeling of fuzzy structures with a two-dimensional interface. Furthermore, a novel experimental method for estimating the fuzzy parameters of complex substructures is developed by the author. Using this method the damping of the structural fuzzy is estimated and the fuzzy parameters are subsequently derived. The developed method is finally utilized for estimating the fuzzy parameters of certain internals in the considered hearing aid. The estimated fuzzy parameters are experimentally validated and they reveal a high spatial memory in the fuzzy boundary impedance. Different methods are used for determining the properties of the remainder components in the hearing aid. The determined properties include the stiffnesses of the rubber suspensions, vibration forces of the receiver and the vibration sensitivity of the microphones. Moreover, the sound pressure in the tube system from the receiver to the ear canal is simulated and validated experimentally. All the determined properties including the fuzzy parameters are incorporated into the full 3D-model. Simulated results for the open-loop transfer functions show good agreement with measurements on the hearing aid considered. By analyzing the simulations results, it is revealed that feedback is caused by local pressure generated by the vibrations of the shell close to the microphone inlets. These vibrations are mainly caused by the reaction forces from the high pressure in the tube system of the hearing aid.

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