Modeling Acoustic Waveguides for Ear Impedance Measurements

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Abstract

The otoacoustic emissions (OAEs) are acoustic signals emitted by the inner ear as a consequence of the activity of a nonlinear feedback mechanism capable of amplifying the signal near to the hearing threshold level. The otoacoustic emissions can be used as an acoustic imaging of the cochlear functionality. They are used in clinics for screening purposes but due to the extreme variability between one subject and another is it very difficult to design a diagnostic system for hearing threshold based on the otoacoustic emissions registration. One of the sources of the intersubject variability of OAEs is thought to be due to the variability in the middle ear transmission properties. It could be so very important to classify the subjects on the basis of their middle ear characteristics to the aim at normalizing the OAEs signal. The middle ear input impedance can be measured by a miniaturized probe inserted in the ear canal following a methodology proposed in [2]. The probe which is equipped with a microphone and a loudspeaker, can be sketched as a pressure generator and can be described in term of its Thevenin parameters, equivalent pressure P0, and equivalent impedance Z0. A load impedance is applied to this generator. In the described case, this load is the unknown input impedance of the middle ear. The equivalent circuit is shown in Figure 1
With the purpose of characterizing the Thevenin parameters of the probe, different loads with known impedance have been applied and a linear equations system has been solved. Different acoustic wave guides have been used at this purpose. The impedances of acoustic wave guides of different diameter and length have been calculated by means of COMSOL Multiphysics.
In the numerical simulations a thermoacoustics model has been implemented. The results of the simulations in the case of cylindrical wave guides have been validated by means of the analytical solution given in terms of Bessel functions. A comparison between the simulated and calculated impedance is shown in Figure 2. Once the numerical code has been validated, the impedance calculation has been extended to wave guides of different geometry. This preliminary work will be the basis on which a technique for measuring the middle ear input impedance and for diagnosing hearing pathologies related to the transmission of the acoustic signal from the ear canal to the cochlea.

Reference

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Figures used in the abstract

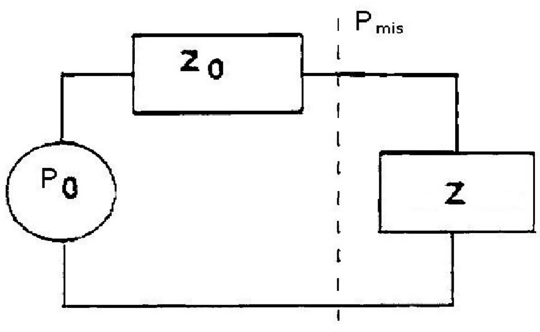

Figure 1: Equivalent Thevenin circuit for the measure of the ear input impedance.

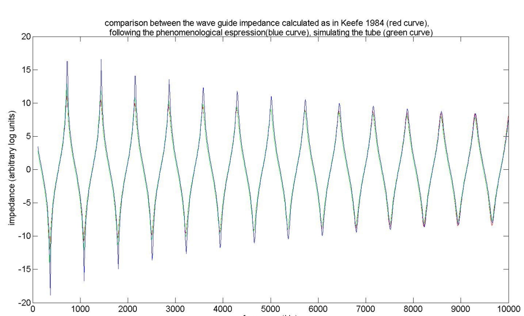

Figure 2: Comparison between the impedance calculated analytically as in Keefe [3], calculated following a phenomenological expression and numerically simulated.