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Sub-cutaneous cochlear implant: analytical modelling of an acoustic receiver behind the skin

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ABSTRACT

Cochear implant users have to support the maintenance cost of their hearing aid every two months. One of the maintenance concerns the change of the miniaturised microphones located in the outer part. A solution to this problem is the fully-implanted hearing aid. This paper presents the modelling of an implantable, biocompatible microphone including a commercial MEMS microphone and its enclosure, comprising a membrane loaded by a thin fluid film and small acoustic elements connecting this fluid layer to the MEMS microphone. An analytical model of the acoustic transfer function for such an enclosure is proposed, taking into account both thermal and viscous damping in the boundary layers. This model, relying on the Stokes-Navier equation, takes into account the strong coupling between the skin membrane, the fluid film between the skin and the enclosure membrane, the fuid film loading this latter membrane and the small acoustic elements (tube and cavity) ducting the pressure towards the MEMS microphone.

The displacement field of the housing membrane is developped as power series expansion of the eigenmodes. The acoustic pressure in the fluid film is then computed on the same eigenvector basis with a non-slip condition on the walls so the normal component of the acoustic velocity vanishes. As the film thickness is very small, the acoustic pressure is assumed constant regarding the thickness of the fluid film. The opening connecting the fluid film to the tube towards the microphone is taken into account as a negative volume flow source in the right hand side of the equation. The cavity of the MEMS microphone packaging is supposed to be small, i.e. the pressure is assumed to be constant inside. The pressure on the MEMS microphone is then calculated using acoustic impedance conditions for the tube and the cavity.

The global transfer function of the enclosure is plotted between 100 Hz and 100 kHz. A lower order approximation of this modelling leads to a generalised constants equivalent electric circuit which may be useful for a quick analysis of the system. This model enables scaling the dimensional parameters of the enclosure in order to meet given acoustic specifications for the implanted microphone.