Modelling Internally Coupled Ears

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Abstract

Hier steht eine maximal einseitige Zusammenfassung der Dissertation.

Dies ist ein neuer Absatz.

Chapter 1

Introduction

Chapter 2

The ICE Model

Our goal is to model the middle-ear of the vertebrates in question in the simplest possible way while ensuring an accurately replication of its main properties. The main components of such a system are the mouth-cavity, the two tympani and the two extracollumellar footplates (one on each tympanum). In general, the shape of the mouth-cavity is highly irregular and therefore not conducive to an analytical treatment. Moreover, the system corresponds to a pair of second-order PDE's with moving boundaries. For this reason we will need to make further approximations for the sake of expediency.

2.1 Description

In the earlier treatment of the ICE model, the mouth canal is modelled as a simple cylinder closed at both ends by rigidly clamped (baffled) circular membranes. As shown in [1], The length of the cylinder was chosen to be equal to the interaural distance. The advantage of using a cylindrical cavity model for the mouth cavity is that the pressure distribution inside the cavity is easy to calculate - something that is even more important at higher frequencies as the pressure distribution inside the cavity is highly non-uniform.

The problem with this description is the fact that the volume of the model's cavity is an order of magnitude smaller than that of the mouth-cavity in the corresponding animal with similar tympani and a the same interaural distance. In general, a smaller volume results in a stronger coupling - both in terms of an increased iTD and an increased iLD. For this reason, the earlier model overestimates the iTDs at low frequencies and the iLDs at high frequencies respectively.

2.2 Internal Cavity

We assume that the air inside the cavity obeys linear acoustics (described briefly in A). The pressure distribution inside the cavity is therefore given by the 3D acoustic wave-equation in cylindrical polar coordinates,

$$\frac{1}{c^2}\frac{\partial^2 p(x,r,\phi,t)}{\partial t^2} = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial p(x,r,\phi,t)}{\partial r}\right) + \frac{1}{r^2}\frac{\partial p(x,r,\phi,t)}{\partial \phi^2} + \frac{\partial p(x,r,\phi,t)}{\partial x^2} \tag{2.1}$$

where c is the sound propagation velocity.

2.3 Vibration of the Membrane

As a preliminary exercise, we will first derive expressions for the free and force-driven vibrations of a circular membrane. We will then use our results to move on to the sectoral membrane which corresponds to the tympanum loaded by the extracollumella.

2.3.1 Circular Membrane

The equation of motion for a rigidly clamped circular membrane of radius a is given by,

$$-\frac{\partial^2 u(r,\phi,t)}{\partial t^2} - 2\alpha\frac{\partial u(r,\phi,t)}{\partial t} + c_M^2\left(\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u(r,\phi,t)}{\partial r}\right) + \frac{1}{r^2}\frac{\partial u(r,\phi,t)}{\partial \phi^2}\right) = \frac{1}{\rho_m d}\Psi(r,\phi,t) \tag{2.2}$$

subject to the boundary condition $u(r,\phi,t)|_{r=a} = 0$.

2.3.2 Sectoral Membrane

Chapter 3

Analysis of the ICE–Model

Chapter 4

Conclusion

Appendix A

Acoustic Theory

Hier steht der erste Anhang.

Appendix B

Second Appendix Chapter

Hier kommt der zweite Anhang.

Bibliography

[1] V. Christine: *Auditory Information Processing in Systems with Internally Coupled Ears*. Technische Universität München, Dissertation, 2010.

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Danke.