Intelligent Venting-Systems for Hearing Instruments

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Introduction

Hearing instruments are available as In-the-Ear-(ITE) or Behind-the-Ear-devices (BTE). Although these instruments have a different housing, both close the ear canal, at least partly. The ITE directly sits in the ear, for BTE instruments an ear mould, an olive and acoustic tubing is used to conduct the sound to the ear canal. This closure is beneficial to avoid feedback arising due to the amplified sound contributions emitted by the hearing instrument, being radiated from the ear canal back to the hearing aid microphone.

On the other hand it would hardly be accepted by users to have their ear canals completely sealed over a longer period of time. The ear canal needs to be ventilated to the outer environment. In case of a total seal moisture would be increased. This provides a good base for bacteria and fungus growth linked with skin irritations or inflammations. On the other hand occlusion effects would appear that distort the own voice recognition considerably and lower the hearing comfort. In the hearing aid world the so-called ventings are used. Typically a canal connects the ear canal with the outer environment. In the application the design of the venting is determined by the trade-off between a minimized likelihood for feedback and a high ventilation and occlusion reduction.

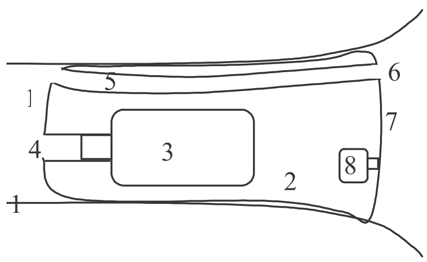

Figure 1: Schematic view of an ITE-hearing instrument

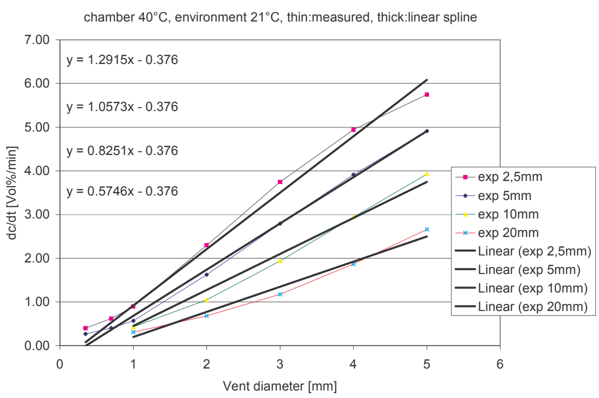

Figure 2: Diffusion related propagation time constants of the ventilation as function of the venting diameter and length

This paper reports on the investigation of the physical effects of ear canal ventilation in the hearing aid application. In addition to measurements of ventilation the acoustic behaviour of this acoustic leakage is considered and improved. The challenge is to design a venting that provides a better acoustic and ventilation behaviour as well.

In Figure 1 a typical set-up of an ITE-hearing instrument is shown. Apart from the active components microphone (8), amplifier and receiver (3) a venting (5) is usually integrated in the hearing aid housing.

Ventilation

In a first approach let us assume the ear canal being a rigid cavity. This cavity at a time t=0 was filled with 100% nitrous oxide; the ventilation is observed using a gas sensor for concentration measurements over time. The result as shown in Figure 2 demonstrates the propagation parameter of this diffusion procedure dependent on the venting set-up. It must be pointed out that for typical ventings the diffusion is relatively low, only a very little ventilation is achieved.

An important factor boosting the ventilation is obvious, when the pressure deviation within the ear canal due to a jaw/ear canal movement is measured.

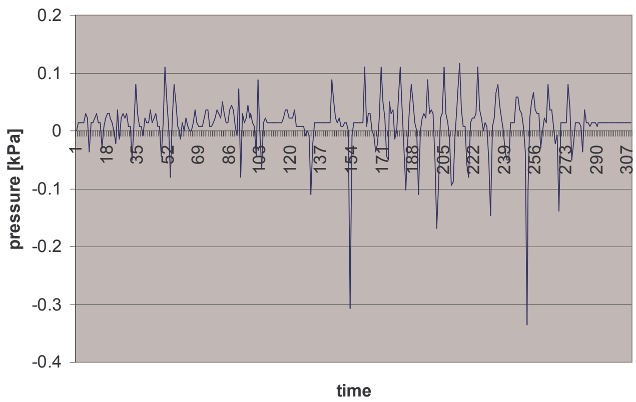

Figure 3: In-situ pressure deviations in a closed ear canal caused by jaw motion

As demonstrated in Figure 3 obtained on an average ear distortions of the ear canal shape due to jaw motion etc. cause a considerable pressure deviation. Peaks might go up to 450Pa. Assuming an adiabatic behaviour within the canal, the medium flow through the venting exceeds the volume of the vent. Thus this physical effect is fundamental for the ventilation of ear canals closed by a hearing aid. Here of course the venting geometry is essential, since a smaller vent diameter provides a higher viscous flow resistance. From the ventilation point of view it is desirable to build a venting as short and big as possible.

Venting acoustics

Acoustically, the venting behaves like an acoustic leakage enabling sound incidence from outside to pass this canal to the ear drum. On the other hand, sound can propagate to the outer environment, which causes feedback and distorts the frequency response. The transmission is important at low frequencies and, since the venting can be modelled as an acoustic transmission line (Figure 4) applying the electro-acoustic analogies, in the resonance frequency range of these transmission lines. Acoustic-wise, the venting should be small with resonance above the critical area. The input impedance of the venting branch of the circuit as seen from the ear volume must be maximized over the audio frequency range.

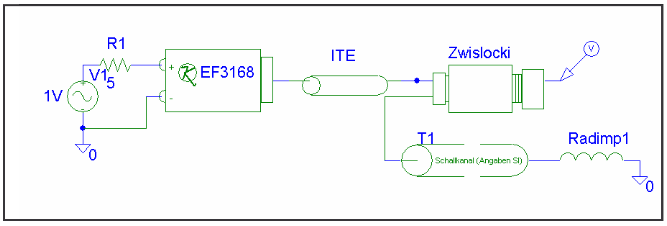

Figure 4: Acoustic propagation model with receiver, ear simulator and venting

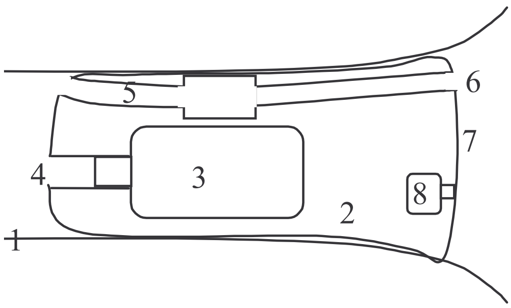

Figure 5: Modified venting with cavity

Regarding feedback in particular the frequency range above 4kHz is critical. Mainly resonance effects cause a sound propagation through the venting. In order to reduce this critical effect the resonance frequency of the venting can be shifted to higher frequency ranges. One possible way to do this is by applying a cavity in the venting. This adds additional acoustic reflections and reduces the resonance length. A typical set-up can be build as drawn schematically in Figure 5.

To obtain the result shown in Figure 6, a hearing instrument with venting was directly coupled to a Zwislocki-coupler. This is excited by reverse operation of the coupler microphone, while the sound transferred through the venting is measured with the external hearing aid microphone. Applying the cavity strongly reduces the acoustic transmission around the resonance frequency of 9kHz in this arrangement. The radiation is decreased by 50dB in the high frequency range, which is very important for wide band hearing instruments.

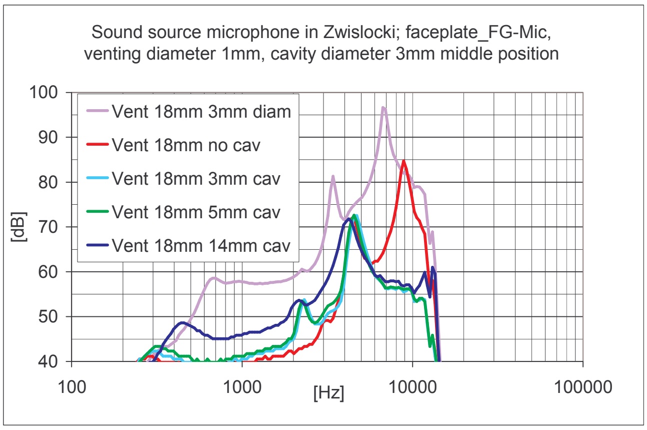

Figure 6: Radiated sound from the venting, Zwislocki-coupler excited in reverse by the microphone; signal picked up by the hearing aid microphone

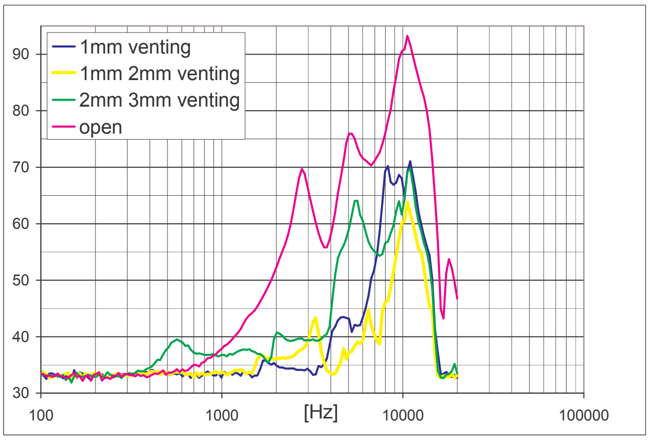

Figure 7: Venting sound radiation standard $\varnothing_v$=1mm (blue), as before but cavity $\varnothing_c$=3mm, l_c=2mm (yellow) and venting with $\varnothing_v$=2mm, cavity $\varnothing_c$=3mm, l_c=3mm (green)

In Figure 7 the signal transferred back to the hearing aid microphone is shown measured with a real ear mould and a hearing aid excitation. Very obvious is the reduction of venting transmission at the 8kHz resonance.

Summary

A venting is needed to make hearing aids more comfortable and acceptable. Apart from diffusion effects ventilation is dominated by volume changes of the ear canal. By adding a cavity in the venting, resonance effects and sound radiation of the venting can considerably be reduced. This results in reduced sound radiation of the venting with improved feedback behaviour. At the same time there is a minor increase of ventilation. For the application this means that the venting parameters can be chosen differently to either improve ventilation, acoustic performance or both.

Acknowledgements

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