Comparison of Transfer Functions in the Ear Canal for Open-Fitting Hearing Aids

Tobias Sankowsky-Rothe[1], Derya Dalga[2], Simon Doclo[2], Matthias Blau[1]
[1] Jade Hochschule Oldenburg, 26121 Oldenburg, Germany, Email: tobias.sankowsky@jade-hs.de
[2] University of Oldenburg, 26129 Oldenburg, Germany

Introduction

Open fittings, which leave the ear canal as open as possible, are very popular, mostly because they avoid the occlusion effect. On the other hand, an open fitting possibly lets unwanted background noise pass into the ear canal and increases the risk of feedback.

One possibility to reduce the background noise in open-fitting hearing aids is the use of active-noise-cancellation-motivated techniques for example like in [1], exploiting an ear canal microphone, which measures the sound pressure in the ear canal. In this context, a question is whether the sound pressure transfer function from the ear canal microphone of the hearing aid to the ear drum depends on the location of the sound source (outside at various positions versus inside, i.e. the hearing aid receiver).

In this contribution, sound pressure transfer functions were measured on both ears of 10 subjects in an anechoic room for different positions of the sound source.

Method

Sound pressure measurements were made in an anechoic room. The subject sat in the center of a horizontal circular array of 24 speakers, which were used as external sources. The sound pressure was measured with two probe microphones (Ethymotic type ER7c), at the inner face of the ear mold and at the ear drum, as depicted in figure 1. The hearing aid receiver was a dual balanced armature receiver (Knowles type TWFK 23991).

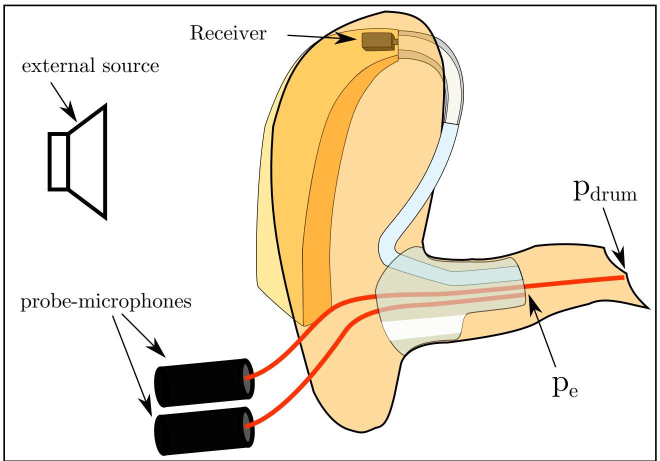

Figure 1: Sketch of the microphones, the receiver, and an external source at the subjects ear.

The ear molds were designed for open fittings, with a step in the canal and a short bore (see figure 1). The diameters of the bores were 2.5 mm or 3.0 mm, depending on the size of the ear canal.

Ear canal transfer functions H_{ec}, given by

$$H_{ec} = \frac{p_{drum}(f)}{p_e(f)} , \quad (1)$$

with the sound pressure at the ear drum p_{drum} and the sound pressure at the ear canal microphone p_e, were measured with excitation by the speaker array (every 15°) and by the hearing aid receiver. The measurement signal was white noise of 10 seconds duration.

Results

Head related transfer functions (HRTF), which are defined by p_{drum} relative to the sound pressure at the center of the subjects head while the subject is absent, were measured on all ears at the eardrum with the ear molds in the ear canal. They are shown in figure 2 for the source from viewing direction (0°) and for the source from lateral direction (-90° for the left ear, and 90° for the right ear). The characteristic gain at about 3 kHz, which is usually found in HRTFs measured at the ear drum of an completely open ear canal (without an ear mold), is canceled here. Instead, in some HRTFs measured from lateral direction, there is a gain of up to 10 dB at frequencies between 500 Hz and 1 kHz. This can be explained by the vent of the ear mold and the residual ear canal acting as a Helmholtz-resonator. In these cases an external noise leaking through the vent will be amplified.

Figure 3 shows the deviations of the ear canal transfer functions H_{ec} with an external source (frontal direction) relative to the transfer functions with the hearing aid receiver as source. Up to about 1.8 kHz, level differences are smaller than 1 dB. At higher frequencies, deviations depending on the source become larger. The peak at about 1 kHz results from a bad signal to noise ratio in the measurement with the external source. At this frequency p_{drum} (and the HRTF, too) has a notch.

Looking at the mean absolute deviations for all ears and all measured directions of the external source, shown in figure 4, it can be seen, that there are no deviations up to about 1.8 kHz either. For higher frequencies there are mean absolute deviations up to about 10 dB, which differ with different angles of incidence.

Conclusions

The measurements show that the ear canal transfer function (from ear canal microphone to the ear drum)

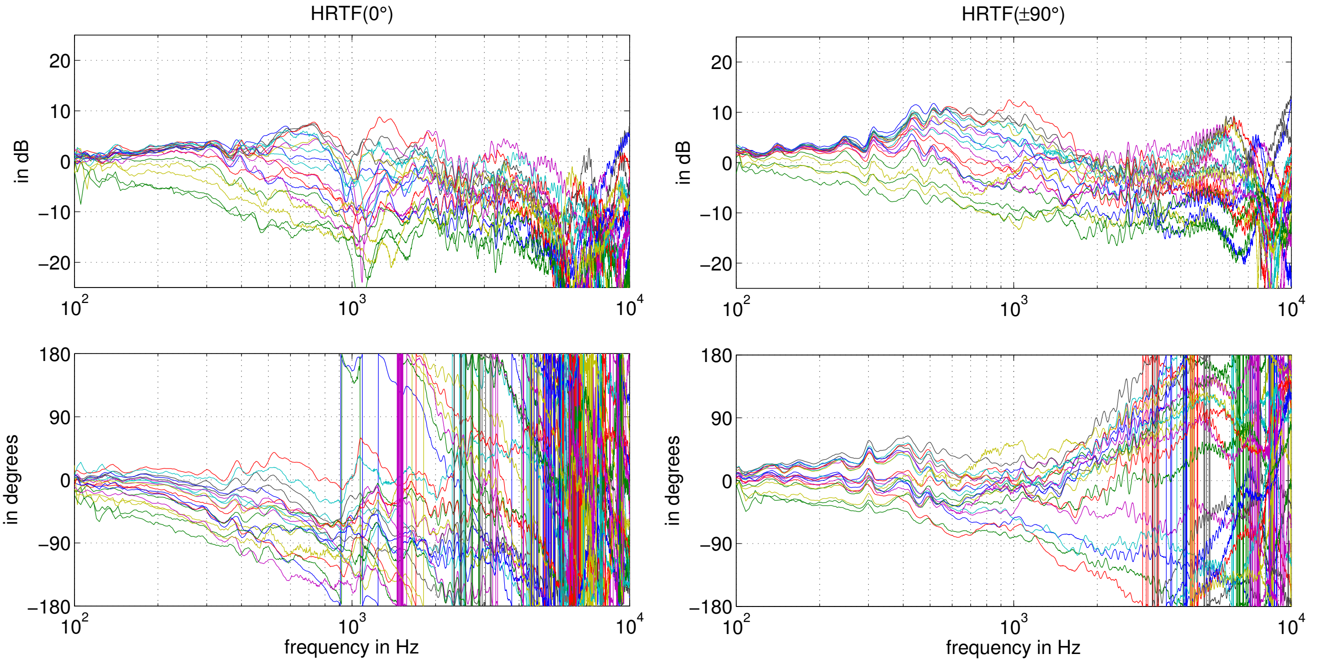

Figure 2: HRTFs with open-fitting ear molds measured at the ear drum, left: with the source from frontal direction (0°), and right: from lateral direction (−90° for the left ear and +90° for the right ear).

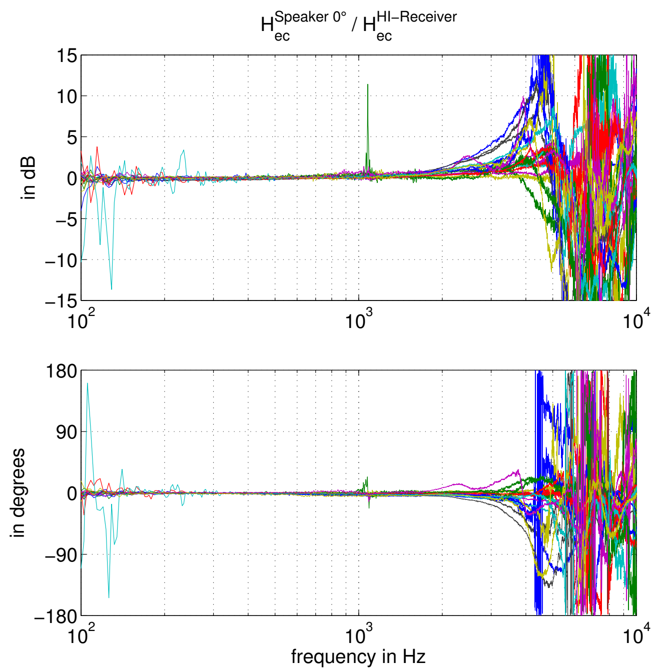

Figure 3: Deviations of the ear canal transfer function measured using an external source at 0° relative to the ear canal transfer function measured using the hearing aid receiver.

remain essentially the same for excitation by a hearing aid receiver and for external sources up to about 1.8 kHz.

At higher frequencies there are deviations in the ear canal transfer functions depending on the source, which also depend on the angle of incidence. If ANC-motivated techniques shall be applied at these frequencies, exact knowledge about the sound propagation in the ear canal for sounds from the hearing aid receiver and from external sources would be required.

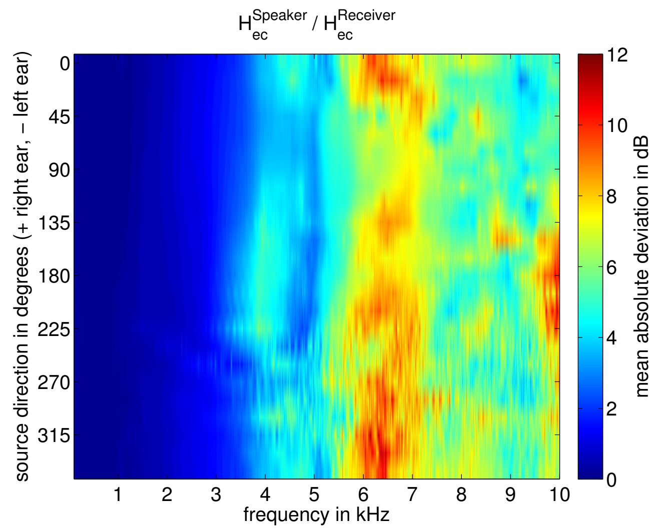

Figure 4: Mean absolute deviations of the ear canal transfer functions for all ears measured using an external source from different angles of incidence relative to the transfer function measured using the hearing aid receiver.

Acknowledgement

This work was supported by the Research Unit FOR 1732 "Individualized Hearing Acoustics", funded by the German Research Foundation (DFG).

References

[1] D. Dalga, S. Doclo: Combined Feedforward-Feedback Noise Reduction Schemes for Open-Fitting Hearing Aids.
In proc. IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA), New Paltz NY, USA, Oct. 2011, pp. 185-188.