Design Tool Auralisation

Christoph Moldrzyk
FSP-PV/PRZ, TU Berlin; e-mail: aural@prz.tu-berlin.de

Introduction

In the early design stage and every following phase of room design done by architects and acousticians, realistic auralisation of room acoustics would be a helpful tool. Both to hand over architects a new design tool and to realise an interdisciplinary communication medium for evaluation of sound and room-acoustical problems. Most important condition for usage of auralisation as a design tool is an authentic reproduction of the acoustics of planned rooms. A first investigation [1] presented a possible approach to record transfer functions of rooms close to human perception: a rotatable dummy head based system. This approach has been further developed and the resulting headphone based auralisation system with head-tracking, designed to reproduce sound in rooms close to reality, has been evaluated.

Dummy head verification

Room transfer functions usable for auralisation are measured by a dummy head with a new concept: the head rotates 150° over the torso from the neck (Figure 1). Why do not rotate the dummy head together with torso?

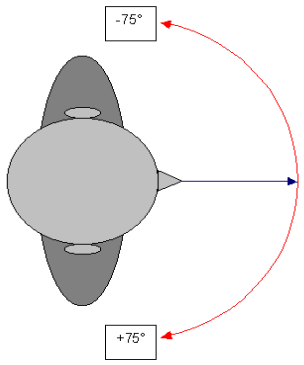

Figure 1: Rotatable dummy head

This is answered by the diagram in Figure 2: shown is only the difference between rotation of *head and torso* to *head over torso* for four angles to the left.

Differences of 15-20 dB in HRTF areas of interest are obviously showing the influence of shoulders and positioning a dummy head close to reality: a sitting listening person (e.g. a concertgoer) is rotating its head, not its shoulders.

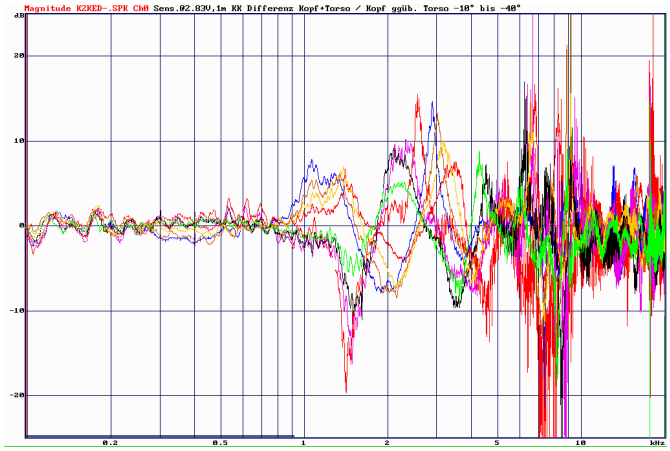

Figure 2: Difference head + torso / head over torso -10° to -40°

The dummy head is a plaster cast, moulded from the author. Dummy head evaluation has been done by:

- comparing measurements of HRTFs (dummy head and human model)
- comparison of size and dimension (stereo photogrammetry)
- psychoacoustical evaluation (listening experiments)

In future it is planned to simulate and compare the HRTFs of dummy head and human model with BE-Methods.

HRTF Comparison

Comparing HRTF measurements of dummy head and human model, a difference is visible (Figure 3). Both are measured with the same microphones in blocked ear canal. Obviously dummy head and human model are not identical.

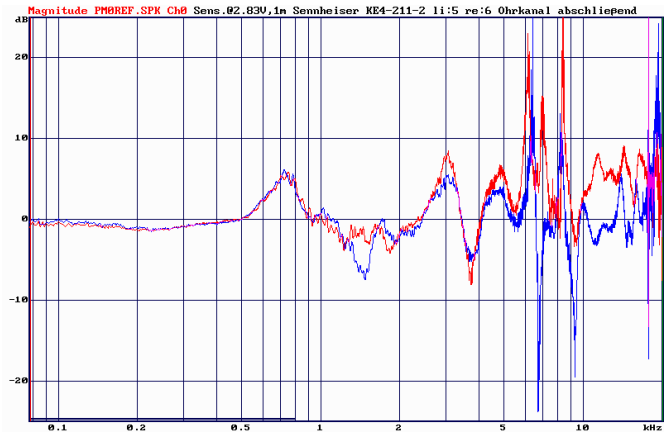

Figure 3: Difference HRTF 0° dummy head / human model

First idear to solve this discrepancy is adding legs with sweatpants to the torso of the dummy head. These are moulded from the legs of the human model. The measured difference is shown in Figure 4.

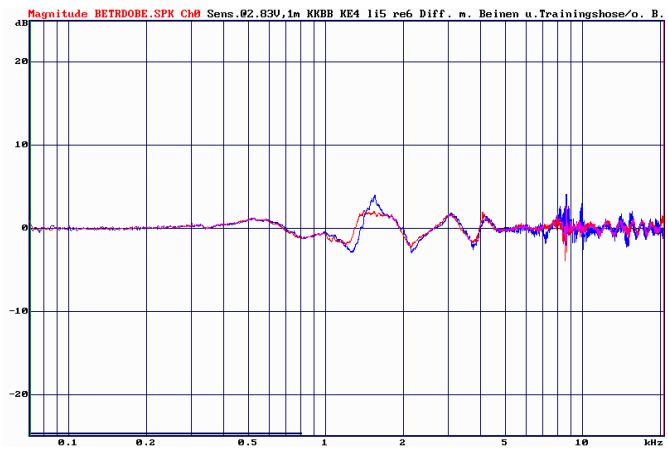

Figure 4: Difference HRTF 0° dummy head with plaster legs and sweatpants / dummy head without legs

The dummy head was measured without clothes. The missing clothes are not causing the amount of difference shown in Figure 3:

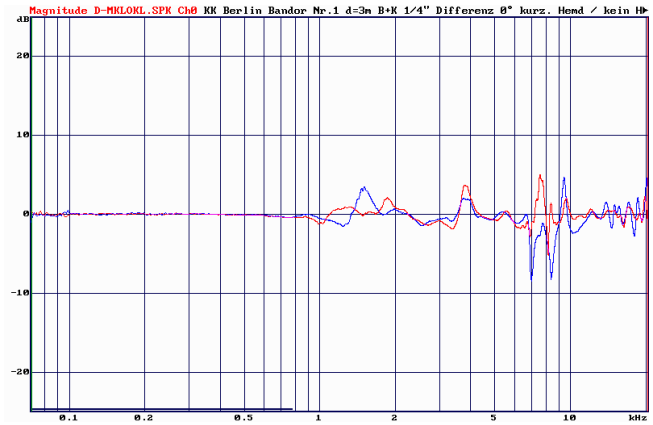

Figure 5: Difference HRTF 0° dummy head with shirt/ without shirt

This indicates differences of dummy head and human model in size and dimension.

Photogrammetric comparison

With the help of photogrammetric measurement it is possible to investigate differences in size of human model and dummy head.

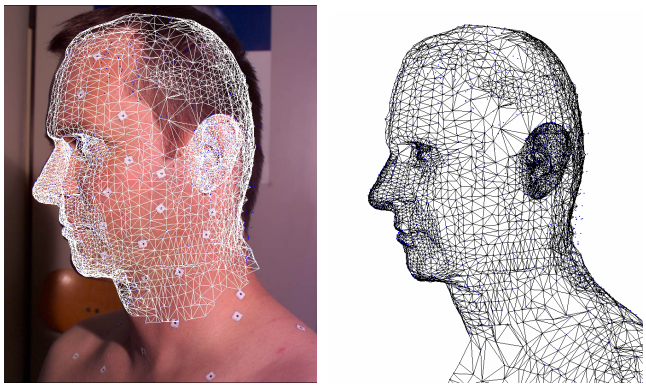

Figure 6: human model and photogrammetric triangle model

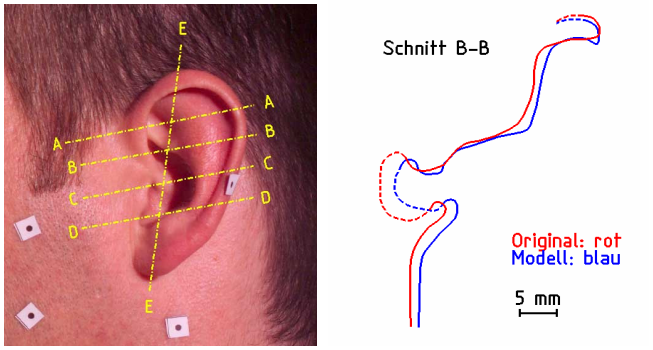

Figure 7: ear cutting lines dummy head / human model

The measurements showed differences between human model and dummy head in size and position of head, shoulders, pinna etc.. Additionally anthropometrical data has been measured according to the CIPIC HRTF Database reference table [2].

Next step would be BEM modelling of HRTFs and comparison of the results with measurements.

Psychoacoustical evaluation

Listening tests have been done to compare reality with auralisation of reality with auralisation of room simulation. The listening room (Audimax TU Berlin) has been simulated with EASE, incorporating measurements of source (5°) and receiver (1/2° horizontal + 5° vertical). Measured and calculated RIR (room impulse responses) have been convoluted with dry sound in real time. Listening subject heard with electrostatic headphones, their head movements have been tracked with a head-tracker. Subjects answered a questionary with 16 semantic differentials and repeated three different stimuli (speech, cello, orchestra).

Figure 8: Measurement at the listening position Audimax TUB

Preliminary results of comparative hearing experiments:

- reality and auralisation of reality are quite close: test subjects weren‘t able to hear any difference in 40% of all stimuli
- only 4% (2 of 50 subjects) heard obvious differences instantaneous (regarding individual HRTFs)
- auralisation of reality and auralisation of simulation are not comparable until now: test subjects heard no difference in only 3,5% of all stimuli though no localisation problems occurred
- optical perception is superimposing acoustical perception; knowing propioceptive effects and dominance of optical localisation, an optical assistance (e. g. HMD) is substantial

Conclusion

With measured RIR it is possible to auralise close to reality. With simulated RIR auralising is far more sophisticated although localisation is close to and front/back conversions are like in reality. Further investigations are intended to improve simulation based auralisation.

References

[1] Moldrzyk, C.: Binaurale Messungen zur Verifikation einer akustischen Entwurfsmethodik für Architekten, Proc. DAGA `03, Aachen, 656

[2] Algazi, V. R., Duda, R. O., Thompson, D. M., Avendano, C.: The CIPIC HRTF Database, Proc. IEEE Workshop on Applications of Signal Processing to Audio and Electroacoustics, NY 2001, 99-102