A Free Database of Head-Related Impulse Response Measurements in the Horizontal Plane with Multiple Distances

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Abstract

A freely available collection of Head-Related Impulse Response (HRIR) measurements is introduced. The impulse responses were acquired in an anechoic chamber using a KEMAR manikin at four different loudspeaker distances – 3 m, 2 m, 1 m and 0.5 m – reaching from the far field to the near field. The loudspeaker was positioned at ear height and the manikin was rotated with a high-precision stepper motor in one degree increments. Besides the raw HRIRs also datasets are available which have been compensated for the use with specific headphone models.

Introduction

In order to localize a sound source, the human auditory system takes advantage of the time lag and level difference between the two ear signals as well as cues added by reflection and diffraction by torso, head and external ears [1]. A head-related impulse response (HRIR), acquired under free-field conditions, is able to describe these features. Several databases of HRIRs are freely available [2, 3, 4], but their angular resolution in the horizontal plane is limited and only [4] contains measurements for more than one source distance (0.8 m and 3 m).

For distances larger than 1 m the distance between the manikin and the source is assumed to have no influence on the binaural cues, only the amplitude decreases for larger distances [5]. If the source is positioned closer to the listener, changes in the binaural cues have to be considered. This study will provide HRIR databases measured in the horizontal plane with a resolution of 1° for sources positioned at a distance of 0.5 m, 1 m, 2 m and 3 m.

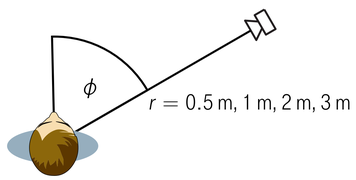

Figure: Coordinate system used in this paper. The azimuth angle ϕ describes the placement of the loudspeaker counter-clockwise around the head. Here $\phi = -60°$.

HRIR Databases

The HRIR databases described here are freely available under a *Creative Commons Attribution-NonCommercial-ShareAlike 3.0* license and can be downloaded at

`http://dev.qu.tu-berlin.de/projects/measurements/wiki`

The datasets are available in different formats suitable for a variety of applications: `.mat` files for use in *GNU octave* and *Matlab*, `.daff` files in the *Open Directional Audio File Format* (OpenDAFF), an emerging open standard for spatial audio data, and `.wav` files for use in the *SoundScape Renderer* (SSR).

References

[1] J. Blauert. *Spatial Hearing.* The MIT Press, 1997.

[2] B. Gardner and M. Keith. HRTF measurements of a KEMAR dummy-head microphone. Technical Report #280, MIT, 1994.

[3] V. R. Algazi, R. O. Duda, D. M. Thompson and C. Avendo. The CIPIC HRTF database. In *WASPAA*. 2011.

[4] H. Kayser et al. Database of multichannel in-ear and behind-the-ear head-related and binaural room impulse responses. *JASP*, 2009.

[5] D. S. Brungart and W. M. Rabinowitz. Auditory localization of nearby sources. Head-related transfer functions. *JASA*, 1999.

[6] B. Bernschütz, C. Pörschmann, S. Spors and S. Weinzierl. Entwurf und Aufbau eines variablen sphärischen Mikrofonarrays für Forschungsanwendungen in Raumakustik und virtual Audio. In *DAGA*. 2010.

Setup and Measurement

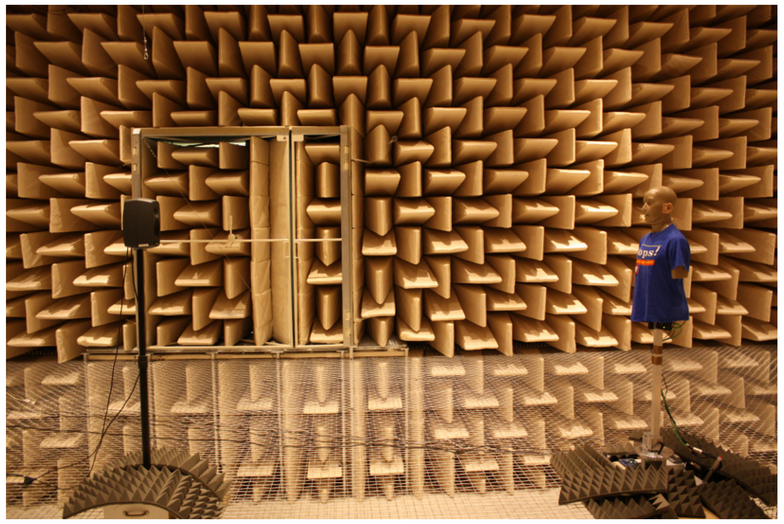

Figure: Setup of manikin and loudspeaker (3 m distance) in the anechoic chamber.

HRIR Measurements

- performed in the anechoic chamber of the Institut für Technische Akustik at Technische Universität Berlin, lower frequency limit is 63 Hz
- Knowles Electronics Manikin for Acoustic Research (KEMAR, type 45BA); large ears (type KB0065 and KB0066)
- manikin was mounted on the turntable of the VariSphear measurement system [6], performing a full rotation (360°) in 1° increments
- two-way loudspeaker Genelec 8030A
- linear sine sweep as measurement signal with low frequency emphasis and a duration of 5.3 s
- ear signals were recorded at 44.1 kHz with G.R.A.S. 40AO pressure microphones, an RME QuadMic pre-amplifier and an RME Multiface II audio interface.

Additional Measurements

- headphone impulse responses for AKG K 601, AKG K 271 MK II, Sennheiser HD25-1
- impulse response of the loudspeaker for all distances at the center of the artificial head with a single pressure microphone (Brüel & Kjær type 4189 using a B&K Nexus conditioning amplifier type 2690-OS1)

Data Processing

The following post-processing was applied to the measured HRIRs:

- truncation of leading and ending zeros to a 2048 samples HRIR length
- correction of interaural time difference (ITD) and interaural level difference (ILD) by adjusting first the position of the loudspeaker and then the amplitude difference
- compensation of the loudspeaker transfer function between 100 Hz and 10 kHz by designing and applying inverse finite impulse response (FIR) filters
- compensation filters for various headphones

Data Analysis

An analysis of the HRIRs revealed that:

- the effect of an amplification at low frequencies due to diffraction by the head [5] is visible for the distances of 1 m and 0.5 m
- the ILD is greater for closer sources, which was also reported in [5]. This can be explained by the fact that the head shadow effect and the decrease in magnitude proportional to $1/r$ are more pronounced for nearby sources. It is most prominent for a location of the source at the side of the right or left ear ($-90°$ or $90°$)

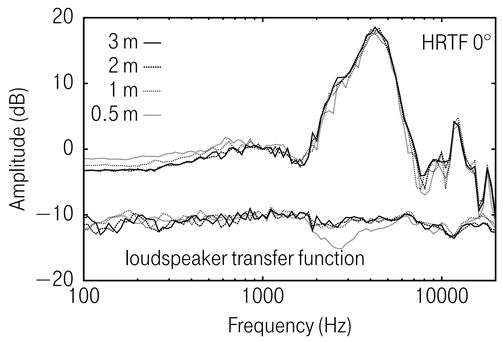

Figure: *Above:* HRTFs for a source position of $\phi = 0°$ including loudspeaker compensation but without headphone compensation. *Below:* loudspeaker transfer functions.

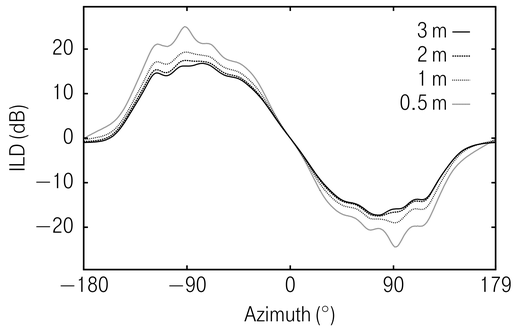

Figure: Interaural level differences (ILDs) of the HRIR datasets for different source distances.

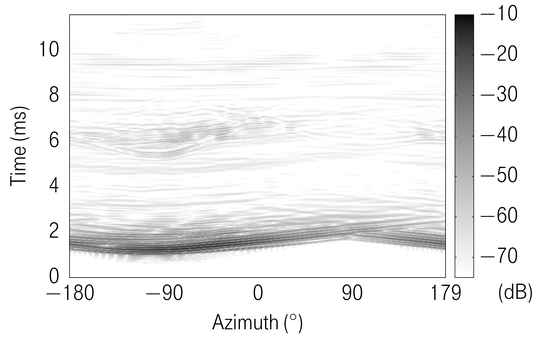

Figure: Amplitude of the measured HRIRs for a distance of 1 m. At $-90°$ a reflection from the manikin to the loudspeaker and back to the manikin is seen at 5 ms.