Proposed paper for AES 21st International Conference on Architectural Acoustics & Sound Reinforcement, June 1-3, 2002, St. Petersburg, Russia.

Sophisticated tube headphones for spatial sound reproduction

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Abstract

Custom tube headphones, fulfilling high requirements of accurate spatial sound perception experiments are presented. The UD-ADU1b headphones demonstrate a maximal ±5 dB deviation in the frequency band 30..9000 Hz, 1/3-octave smoothed. The ear canal blocking attenuates background noise typically 15-20 dB, and allows a precise positioning of the sound source. The non-magnetic tubes are used in neuro- and psychophysiological research.

Precis

High-quality headphones allow in principle a good means for realistic three-dimensional (binaural) sound reproduction because of their good channel separation, i.e., due to the lack of the need of cross-cancellation. However, for precise perceptual studies of 3-D sound the usage of conventional headphones is not optimal. The differences in positioning the headphones alter the sound's pathway in pinnae cavities, creating notable changes in higher frequencies that affect the perception (see Riederer AES 105th Conv., preprint no. 4846). Above all, in many brain imaging methods, such as magnetoencephalography (MEG) and functional magnetic resonance imaging (fMRI) techniques, only non-magnetic devices can be applied on the subject. Furthermore, in some cases the attenuation of the background sound (noise) is necessary; the most devices available attenuate the noise on the expense of their sound quality.

In order to make possible accurate 3-D sound investigations on a 306-channel MEG equipment, special tube headphones were devised (Unides Design Ay.) for the Brain Research Unit at the Low Temperature Laboratory (LTL), HUT. The principal concern was to obtain maximally flat wide-range frequency response (100..10000 Hz) without any active equalization electronics.

The UD-ADU1a tube headphones have two discrete acoustic driver units, which are driven by any normal audio amplifier yielding 100W RMS sound power. The

electrodynamic transducers (passive loudspeaker elements) are custom-fitted to 3.00 m long reinforced PVC tubes (10 mm in outer diameter), to which smaller laboratory rubber tubes of 0.25 m length (6 mm diameter) are fitted. This type of light tube construction allows the most comfortable positioning of the earpieces on the subject; replaceable EAR-tips are attached to the end of the smaller tubes. The earplugs attenuate the background sound typically ca. 15-20 dB, depending on the frequency. They also allow a precise positioning of the sound source on the subject.

The tube headphones with yellow EAR-tips were measured utilizing an artificial ear (Brüel&Kjær Type 4175 with ear canal adapter Type DB2012), in order to apply the correct acoustical ear canal impedance. The MLSSA measurements show a good frequency response of 30..14000 Hz (±10 dB) without any sharp resonance structures. The obligatory HRTF equalization in 3-D sound synthesis removes well these smaller deviations in the response. Twists on the PVC tubes, even as small as 0.2 m in diameter, do not affect the frequency response. The upgrade version of the tube headphones (UD-ADU1b) apply more sophisticated passive electronics in order to minimize more efficiently the disturbing ¼ wave resonances of the long tubes. UD-ADU1b demonstrate a maximal ±5 dB deviation in the frequency band 30..9000 Hz, 1/3-octave smoothed. Comparison measures applying manufacturers tailored measurement software and hardware, including a plastic ear canal replica, confirmed all the above results.

The reproduction position of the UD-ADU1 tube headphones, i.e., sound source at the blocked ear canal, matches perfectly with the HRTF measurement position (see Riederer AES 105th Conv., preprint no. 4846). A natural listening experience of 3-D sound, binaural and surround recordings compared to normal stereophonic recordings will be demonstrated at the AES 21st International Conference.