LABORATORY FOR TESTING OF SOUND PERCEPTION IN VIRTUAL ACOUSTIC WORKING ENVIRONMENT

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Morzynski Leszek, Pleban Dariusz, Szczepanski Grzegorz, Mlynski Rafal
Central Institute for Labour Protection – National Research Institute
Czerniakowska 16
00-701 Warsaw
Poland
Tel: +48 22 623-32-97
E-Mail: lmorzyns@ciop.pl

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ABSTRACT

In the working environment, sound perception affects communication between employees as well as employee safety, because acoustic signals carry information about the dangers present in the environment. However, the perception of sound is influenced both by the characteristics of the working environment itself and the predisposition and disability of the individual. The article presents the construction, properties and equipment of the laboratory for reproduction of acoustical work environment for the study of sound perception. The properties of this laboratory were discussed and the possibilities of using the research equipment to create virtual acoustic environment were presented.

INTRODUCTION

Hearing is one of the most important senses affecting human functioning in the environment.
In the working environment, correct sound perception influences not only communication between workers and course of the work process, but also on the worker's safety, as various sounds and acoustic signals can indicate potential threats in the working environment. However, the sound perception is influenced among others by the characteristics of the working environment itself, including the background noise, the use of hearing protectors and the predispositions and disabilities of the worker. Employees with visual impairment are a particular type of employees, for whom hearing plays a leading role not only in communication but also in spatial orientation [1, 2]. Study of sound perception under various environmental conditions are therefore important for shaping safe working conditions.
Study of sound perception, sound localization or spatial orientation require the development and presentation of appropriate spatial acoustic stimuli. There are various techniques for reproducing spatial sound, from the simplest stereo technique, through the binaural technique based on head related transfer functions (HRTFs), the ambisonic technique, to the sound field synthesis technique [3]. Creation of spatial sound in each of this techniques requires the use of appropriate instrumentation and properly recorded and processed sound samples. In the Central Institute for Labour Protection – National Research Institute a new laboratory was started, which allows to create the virtual acoustic working environment to study sound perception, sound localization and

spatial orientation. Its main element is the acoustic chamber located in the newly established Tech-Safe-Bio laboratories. In this laboratory, spatial sound will be reproduced mostly using ambisonics, however, it is also possible to use a binaural technique. The construction, properties and equipment of the laboratory are presented in the article.

ACOUSTIC CHAMBER

The acoustic chamber is a box-in-box room with appropriate acoustical adaptation (Fig. 1). The dimensions of the chamber without acoustic adaptation are (length x width x height) 14.28 x 5.1 x 5.5 m, and with acoustic adaptation 13,5 x 4,4 x 5,0 m. The volume without acoustic adaptation is 400 m^3 and the acoustic adaptation is 297 m^3. The outer wall of the chamber is a reinforced concrete wall with a thickness of 24 cm while the inner wall is a 18 cm-thick concrete frame structure mounted on vibration isolators. The internal room has a 27 cm multilayer self-supporting ceiling. The floor of the inner room consists of a 10 cm reinforced concrete slab mounted on vibration isolators, on which a floor on joists with vibration isolation joints and mineral wool fulfillment is placed. In the floor along the room walls Helmholtz resonators have been placed. The walls and ceiling of the chamber were covered with two types of multi-layered sound absorbing structures made of Basotect and Caruso ISO Bond foams with wedge-shaped surfaces.

Fig. 1. The acoustic chamber.

Fig. 2 presents the results of measurements of reverberation time of the acoustic chamber in 1/3 octave bands. A total of six reverberation time measurements were performed during which the source of sound was placed in the center of the chamber or in its corner. Measurements were made in the chamber with the basic equipment shown in Fig. 1 (described in the next paragraph). Average reverberation time in 1/3 octave frequency bands for frequencies above 63 Hz is below 0.2 s. This means that the acoustic chamber has properties close to semi-anechoic chamber. In Fig. 3 results of measurements of background noise in acoustic chamber in 1/3 octave bands are presented (four different measurements). Sound pressure level (SPL) of background noise in 1/3 octave frequency bands for frequencies above 80 Hz is below 10 dB. For lower frequencies the SPL of background noise is higher, up to 40 dB. Total average A-weighted SPL of background noise is 17 dB.

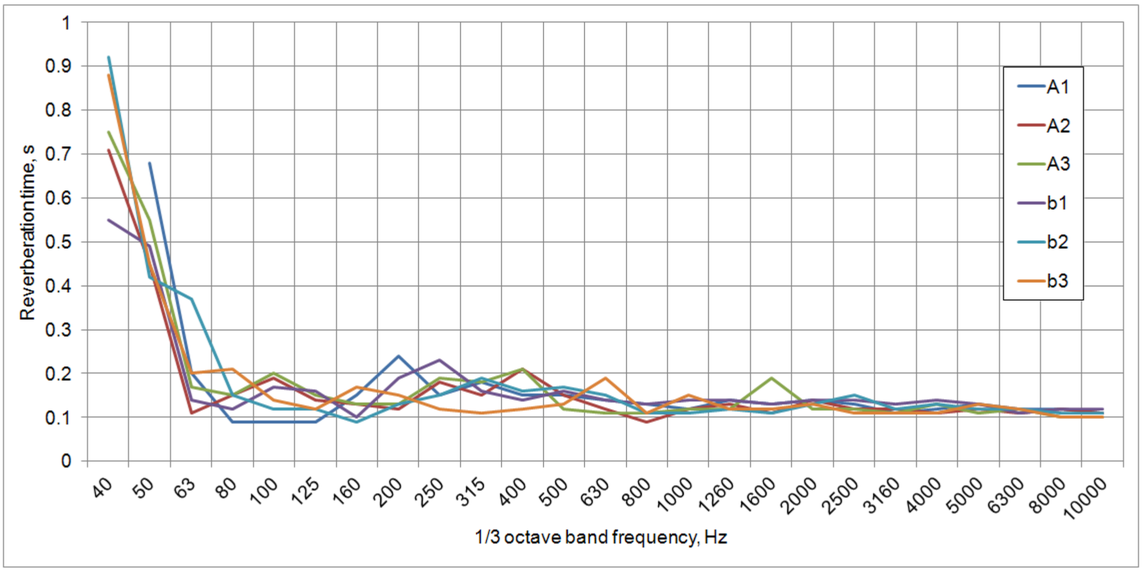

Fig. 2. Results reverberation time measurements in the acoustic chamber (A1 – A3 – sound source placed in the center of the chamber, b1 – b3 – sound source placed in the corner of the chamber).

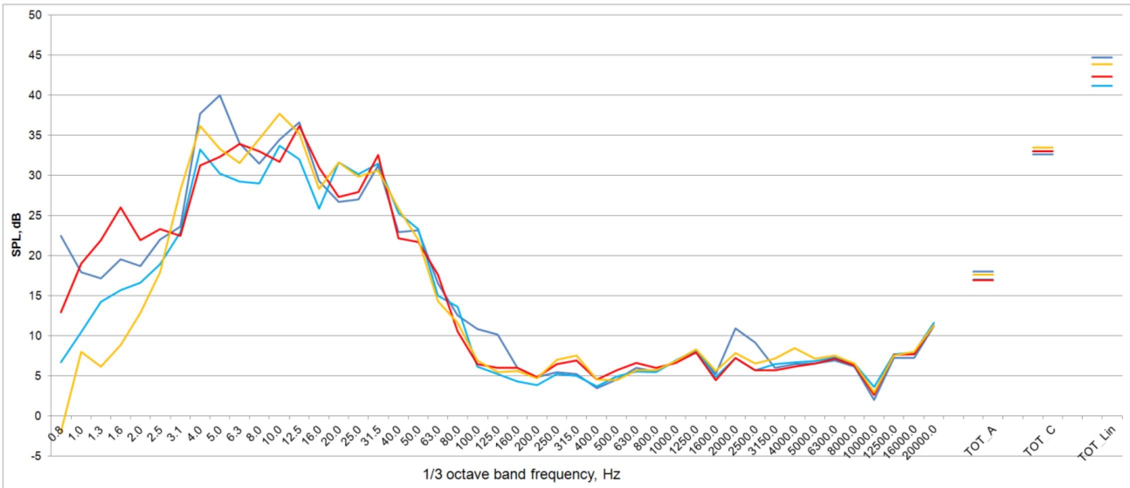

Fig. 3. Results of background noise measurements in the acoustic chamber.

LABORATORY EQUIPMENT

The basic equipment of the acoustic chamber is multi-channel sound reproduction and recording system. Its schematic diagram is shown in Fig. 4. The sound reproduction system has 120 output channels and contains 114 Avantone MixCube speakers and 6 Nexo LS600 / PS8 speaker sets. These speakers are located on an aluminum tube frame mounted to the chamber walls. The frame layout and speaker placement can be freely arranged. The sound recording system consists of 80 Audix TM1 microphones which placement also can be freely arranged. The multichannel sound reproduction and recording system utilizes Dante media networking technology and Yamaha AIC 128-D Dante sound card as a hardware controller. Basic control of the system is from the digital audio workstation (DAW) software, Nuendo 6. Reproduction and recording of signals is also possible from the Matlab program with the direct use of ASIO sound card drivers.

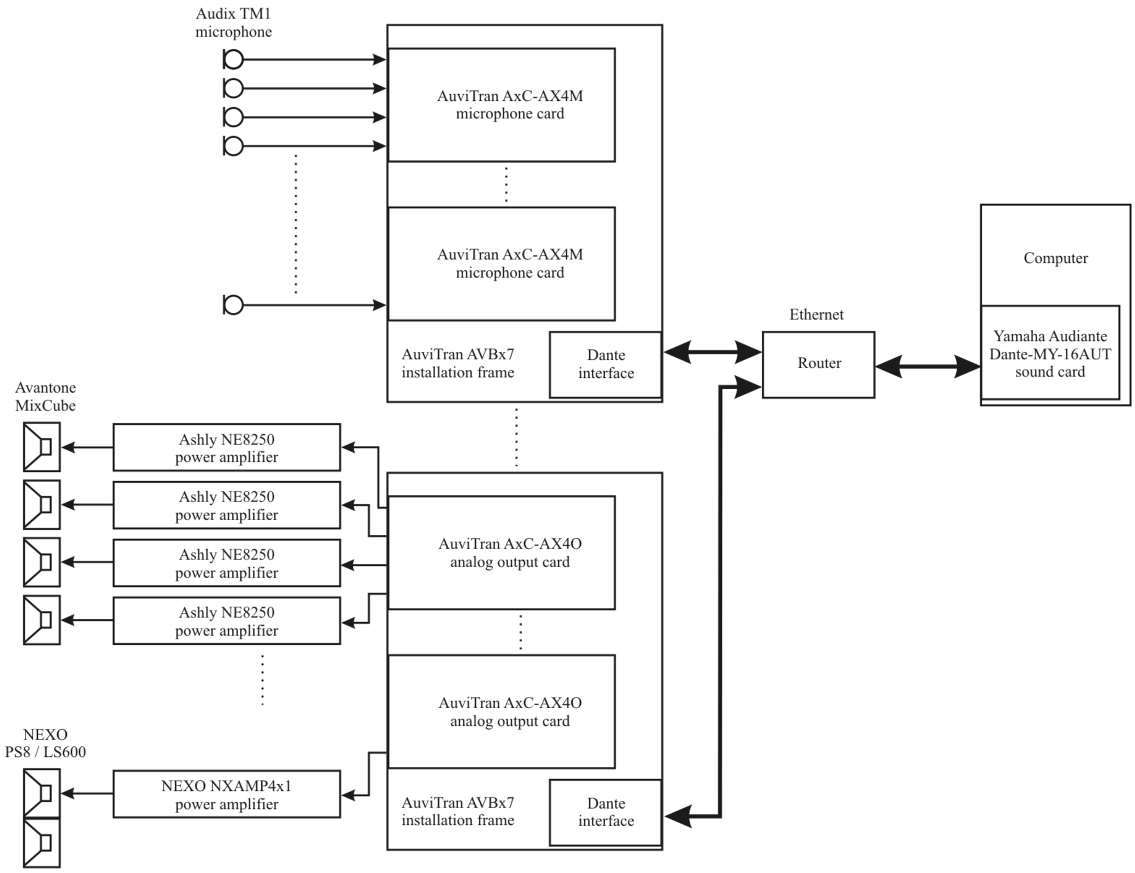

Fig. 4. Schematic diagram of the multichannel sound reproduction and recording system.

As mentioned above, the basic technique for reproducing spatial sound in the laboratory is ambisonics [7, 8, 9]. In the most commonly used first order ambisonics a special type of microphone, ambisonic microphone is used for spatial sound recording. This microphone consists of four closely spaced subcardioid or cardioid (unidirectional) microphone capsules arranged in a tetrahedron. It is used for recording four acoustic signals in so-called ambisonic A-format. The laboratory equipment includes an ambisonic microphone AMBEO VR MIC from Sennheiser and Tascam DR-680 MkII multi-channel digital recorder (Fig 5.) used for ambisonic recordings in A-format. Sound recorded in ambisonic A-format is converted to ambisonic B-format and then to the n-channel audio output with the use of Sennheiser AMBEO A-B converter, Harpex-B and Harpex-X plugins to the DAW software. An example of speakers arrangement for ambisonic recording reproduction in the laboratory is shown in Figure 6.

Fig. 5. Ambisonic microphone Sennheiser AMBEO VR MIC and Tascam DR-680 MkII multi-channel digital recorder.

Fig. 6. Speaker arrangement for ambisonic sound reproduction.

Other laboratory equipment that enables analysis and recording of acoustic signals for use in a virtual acoustic working environment includes: Brüel & Kjær LAN-XI 3052 data acquisition cassette with 4191 microphone and PULSE software, and two Acoustic Camera with Ring72 AC Pro and Paddle2x24 AC Pro microphone arrays and Noise Image software. For binaural sound recording G.R.A.S. Kemar head and torso simulator as well as 45CB Acoustic Test Fixture, which are laboratory equipment, can be used. For binaural signals reproduction STAX electrostatic headphones can be utilized.

SUMMARY

The article presents the construction and equipment of a laboratory enabling the creation of a virtual acoustic working environment. The present work focuses on the collection of sound samples in the working environment as well as the proper reproduction of recorded sounds in the laboratory. The developed environment will allow the study of sound perception, sound location and spatial orientation. In the future it will be possible to use the laboratory to teach the spatial orientation of people with visual disabilities.

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REFERENCES

1. Blauert J.: Spatial Hearing: The Psychophysics of Human Sound Localization, MIT Press, Cambridge, 1996
2. Furmann A., Skrodzka E., Nowotny P., The effect of sound reproduction method on performance in sound source localization by visually impaired and normally sighted subiects, Acta Physica Polonica A, Vol. 123, No. 6, 2013, pp. 988 – 944.
3. Ahrens J., Analytic Methods of Sound Field Synthesis, Springer, Berlin, 2012.
4. Hojan E., Jakubowski M., Talukader A., Wereda H., et al., A new method of teaching spatial orientation to the blind, Acta Physica Polonica A, Vol. 121, No. 1-A, 2012, pp.A5-A8.
5. Skrodzka E., Maciągowski M., Furmann A., The concept of the auditory training for blind and visually impaired children and teenagers, Acta Physica Polonica A, Vol. 125, No. 4-A, 2014.

6. Bogusz-Witczak E., Skrodzka E., Furmann A., Hojan E., Przybek K., Results of auditory training for blind and visually handicaped children and adolescents, Acta Physica Polonica A, Vol. 127, No. 1, 2015, pp. 117 – 119.
7. Gerzon M., Periphony: With-height sound reproduction, Journal of the Audio Engineering Society, vol. 21, no. 1, 1973, pp. 2 – 10.
8. Kronlachner M., Spatial transformations for the Alteration of Ambisonic Recordings, master thesis, University of Music and Performing Arts, Graz University of Technology, 2014.
9. Plessas P., Rigid sphere microphone arrays for spatial recording and holography, master thesis, Graz University of Technology, University of Music and Performing Arts, 2009.