ARCHIVES OF ACOUSTICS
33, 1, 19–25 (2008)

AUTOMATIC MEASURING SYSTEM FOR HEAD-RELATED TRANSFER FUNCTION MEASUREMENT

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(*received June 15, 2007; accepted November 30, 2007*)

In this paper the Head Related Transfer Function (HRTF) Automatic Measurement Equipment is presented. The system allows to measure HRTF with high spatial resolution within a considerably short time. The system employs many switched sound sources and a rotary chair. HRTF describes a transfer function of the human head and pinna and is unique for each human. Individual measurement of HRTF is necessary for applications where precise simulation of sound source localization is essential. An accurate determination of HRTF requires the position of sound source to be changed in the space surrounding test participants. It necessitates hundreds of measurements with high spatial resolution. The procedure becomes very time consuming and tiring for the participants.

Keywords: HRTF, sound source localization.

1. Introduction

HRTF is a representation of the influence of acoustical arrangement composed of pinna, head and torso on the deformation of acoustic signals spectrum at the moment of reaching the ear of the listener [1]. The deformation of the acoustic signal spectrum is also influenced by the shape and the material structure of tissues, which the head is built of. Thanks to changes in the spectrum, the listener is able to locate a sound source in the space surrounding him. Since there are many sound source positions in the space, it is necessary to know many HRTFs to be able to truly recreate these positions [2, 3].

The system presented in this paper allows to quickly measure HRTFs. Using many switchable sound sources and a rotary chair, it is possible to measure HRTFs in a very short time in many points in space that surrounds test participants. The described device is a component of a support system for people with serious vision problems, however further tests should still be done with their participation.

2. Measuring system outline

The HRTF measuring device is constructed for a special group of test participants. It is assumed, that the measurement will be made for people with severe vision problems [4]. Therefore, the device is designed to reach many demands such as the highest automation of measurements, which assures a short measurement time (ca 10 minutes), and offers great ease of manipulation. Any participant of the test should feel comfortable during the measurement process, and should be given sufficient information on each part of the measurement. To reach these demands, the device is equipped with a bidirectional communication system allowing the participant to report the problem at any time. In addition to voice communication, visual control of the room is provided. It is possible to monitor the test room using a camera mounted on an arc with speakers.

To provide a short measurement time, HRTFs are measured for both ears simultaneously. The way sound sources are configured significantly shortens this time too. The speakers are mounted on vertically positioned arc (see Fig. 1). It allows to measure the range of vertical angles from $-45°$ to $+90°$ in one chair position. In certain points in the space of the room, the measurement is made by switching measurement signals to subsequent speakers by an electronic switch.

The number of measurement points for elevation angles is adjusted by changing the number and position of the speakers. On the other hand, the number of measurement points for horizontal angles depends on the size of the rotation step of the chair. The rotation of the chair is controlled by a stepper motor, which assures high horizontal resolution. Default vertical resolution is $9°$ in regular sound source positions. Assuming the same horizontal resolution, the number of measurement points is 640. The measurement in 16 points for one horizontal angle and simultaneous measurements for both ears allows to make the whole measurement in less than 10 minutes. Obviously, the number of measurement points can be modified. Changing the resolution in a vertical plane means changing the position of the speakers. In a horizontal plane, changing the resolution means changing the rotation step of the chair.

HRTF measurement can be done in the range of frequencies from 200 Hz to 8 kHz. The lowest frequency depends on the test room parameters. The device works in an anechoic chamber, therefore the cut-off frequency of the chamber limits the operational range of the device. The high cut-off frequency of the device is on the one hand confined by the set of the speakers, and on the other – by the set of the microphones. Miniature microphones used in hearing aids, but with an untypical flat frequency response, are used in the device. Another factor limiting the high cut-off frequency are the dimensions of microphone fixing elements. For 5-mm tubes the wave phenomena are significant for frequencies above 10 kHz.

The system is operated via a portable IBM PC computer to control measurements and data acquisition [5]. The device communicates with the computer through a USB interface. At the same time, signals operating the device, measurements signals and camera pictures are transmitted via the interface. A special feature of the device is its compact construction and modularity which makes it very easy to assemble or disassemble and convenient to transport.

Fig. 1. Overview of the HRTF measurement equipment.

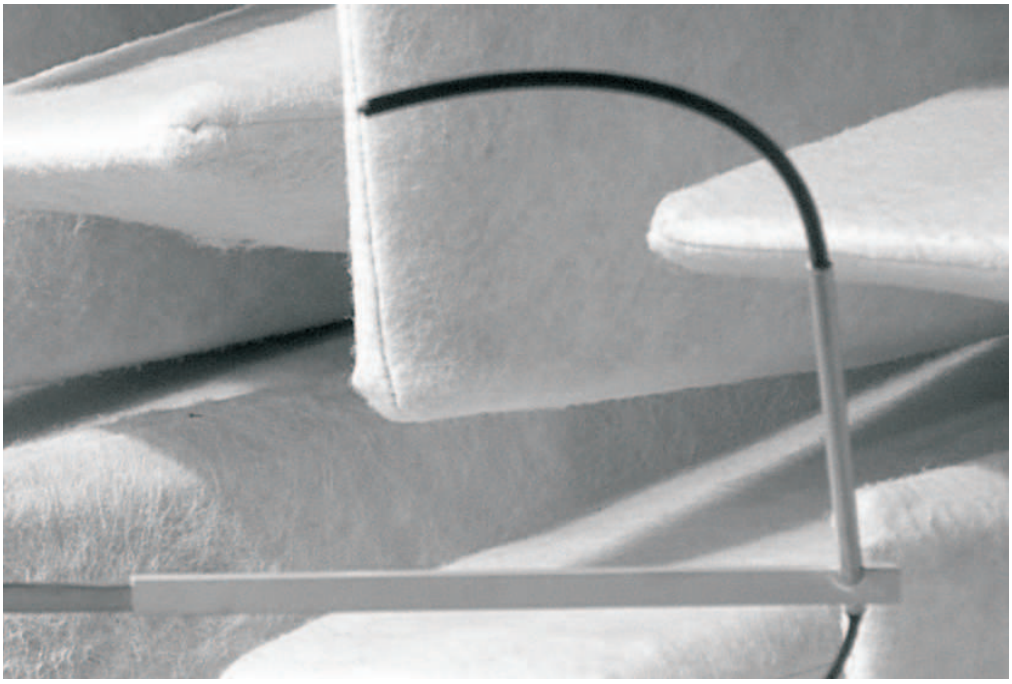

Fig. 2. Measurement microphone.

3. Measurement algorithm

The measurement of a single HRTF is accomplished using a transfer method, which is popular in digital measurements systems. A wide spectrum measurement signal is used for stimulation. The system uses the following signals: chirp, MLS, white noise, pink noise. The length of a generated signal can be changed within the range from 128 up to 8192 samples. Sampling frequency is 48 kHz, but it is possible to decrease it. The stimulating signal is repeated several times in order to average the answer of the system in the time domain. This operation allows improving the S/N ratio of received responses. There is no need to apply longer measurement signals, because, according to other researches, HRTFs may be presented even with such resolution as 100 Hz. On the other hand, responses determined in the system will be used for convolution with real signals, and therefore they cannot be too long. Moreover, long measurement signals make the assessment time longer.

The whole measurement procedure is comprised of two parts: the measurement of reference responses and the measurement of regular HRTFs. The measurement of reference responses is made for all measurement spots determined by the system operator. During this procedure, microphones, speakers and the whole system work exactly like during any regular measurement. The only difference is that there are no test participants. The HRTF measurement results obtained in the second part are related to reference responses obtained before.

Using a reference response for each measurement point in the space allows limiting many inconvenient effects, which decline measurement accuracy [6]. Especially the influence of frequency responses and directivity responses of speakers and microphones is eliminated. The influence of a test room and the reflection from the device elements on measurement results is partly reduced.

The final result of the measurement process are HRIRs (Head Related Impulse Response, that is HRTF's reverse Fourier transform) produced to allow their direct use in convolution with real signals.

4. Measurement procedure

The measurement procedure comprises several phases. The first is the system activation and configuration. It involves determining the horizontal and vertical resolutions of measurements. The next step is the selection and fixing of active test speakers position. At this stage the kind of measurement signal and the number of averages should be chosen as well as the calibration of sound level should be carried out.

In the second phase, participant of the test should be properly positioned in the chair, so that the 0° speaker is placed on the ear canal entrance level and the microphones are located at ear canals entrance. The setup of the speakers' arc in relation to the microphones can be monitored using the camera view.

After the test participant measurement is completed, the reference responses are measured. Once the preparation is finished, regular HRTF measurements are carried out according to earlier parameter setups.

In the last phase of the procedure, measurement results are saved in plain text files, in the form of HRIR. Such storing allows access to test results from any other application at the same time, and is clear to the user.

5. System control software

In order to apply the measurement procedure, dedicated software was designed. The modularity of this software, which consists of two basic elements, is its special feature. Figure 3 presents the main window used to control measurements. Via this interface, the operator can influence the measurement course and conditions as well as all configuration parameters. Additionally, there is also a test participant communication part.

A separate element of the software is an OCX control, which exchanges data between the device and the user interface. Calling certain functions of the control, it is possible to steer such parameters as the armchair rotation, the speakers movement or switching. Applying this solution allows to use the device for purposes not provided by the user interface of the system.

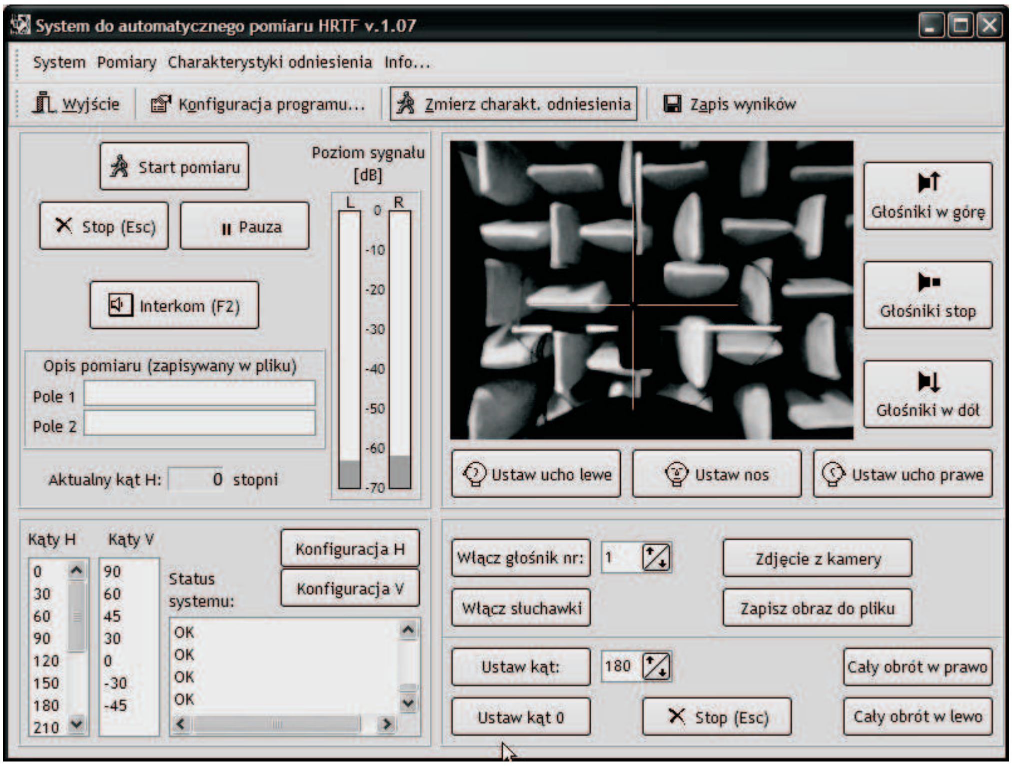

Fig. 3. The main window of the HRTF measurement control software.

6. Conlusions

The HRTF measurement system presented in the paper allows very fast measurements of HRTFs with a high spatial and frequency resolution. The system's operational algorithms guarantee the repeatability of measurements and minimize the influence of many disadvantageous factors on the results of measurements. Compact structure and modularity of construction allows easy transport of the device.

Acknowledgments

The HRTF measuring system was designed and built in cooperation with Łódź University of Technology. The work is part of the "Integrated system supporting person with severe vision problems with user's sound interface" project led under the directorship of Prof. Paweł Strumiłło.

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