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PRACTICAL ASPECTS OF USING HRTF MEASURING DEVICE

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Measurement of Head Related Transfer Function is complicated due to the object of the test, namely the transfer function of acoustical arrangement composed of pinna, head and torso. The test involving the participation of a person requires providing appropriate conditions for conducting measurement. Maintaining constant geometrical configuration of the sound source and the microphone placed in the ear's channel is particularly important. Fulfilling this condition as well as determining the exact position of the sound source in relation to the measurement microphone may require application of a special measurement device. The paper presents the results of measuring HRTF function using special device. The problems encountered during the measuring process are discussed and the possible solutions are suggested. Finally, the results of the tests for a real human subject are presented in the paper.

Key words: sound source localization, HRTF.

1. Introduction

The measurement of HRTFs is a complex process. One of the factors complicating the measuring process is the necessity of maintaining high precision in positioning of the sound sources in relation to microphones [1]. It is important in the case of the tests conducted with high spatial resolution [2]. Particularly if the tests are conducted for many participants in short time, a precise setup of the listener's head requires a special equipment [3]. On one hand, it is necessary to assure constant measuring conditions and adequate precision of measurement. On the other, the comfort of tests participants and providing condition allowing a quick measurement have to be taken under consideration.

2. Parameters of the device

Details of the device has been described in the paper [4]. The described device is a component of a support system for people with serious vision problems and the further tests are to be done with their participation.

The HRTF measuring device has 16 sound sources. The reason for using such number of speakers is the need to conduct tests for many various spots in the listener's surrounding in the shortest time possible. The different positions are found in the following way: the participant in the test turns around his vertical axis while taking a step in defined direction. The distances between the steps define the spatial resolution of measurement in horizontal dimension. The vertical dimension of spatial resolution is determined by the arrangement of speakers placed on the arc including range of vertical angles between $-45°$ and $+90°$.

For the precision of the measurement it is important to use a point sound source. The source must produce test signals in the entire operational frequency range of the device. Two-way car speakers were applied. According to producer data the speakers should operate within a small box. Figure 1 presents an example of amplitude frequency response of the used speakers. The speakers' operational range of frequency is between 200 Hz and 20 kHz. It should be noted that the frequency responses are not equalized and differ slightly for each speaker less than 4 dB. The applied measurement of reference response in the device for each tested spot neutralizes the influence of measuring set on the results of the tests.

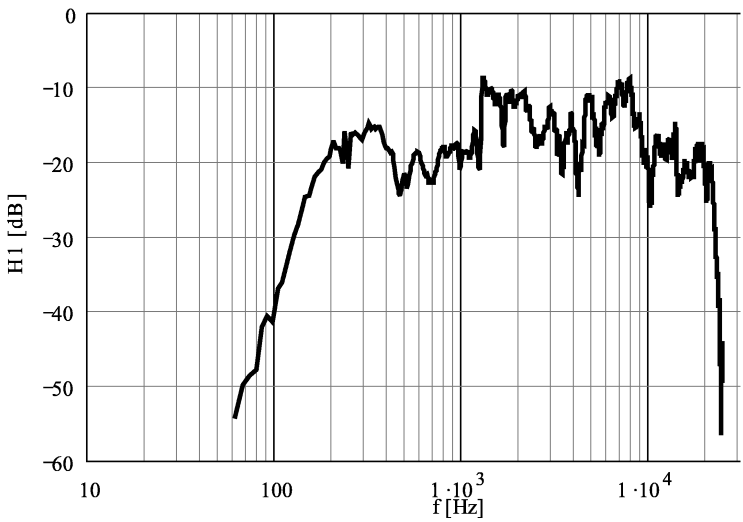

Fig. 1. An example of frequency response of the speaker used in the HRTF measuring device.

The measurement microphones used in the device are the same as those used in hearing aids. It should be underlined that the particular type of microphones has equal frequency response in its entire operational range of ca. 60 Hz and 8 kHz (Fig. 2). It means that these microphones are not commonly used in the hearing problems treatment. The choice of microphones was determined by the importance of the quality of the device and therefore the similarity of frequency responses of each microphone was achieved. The other advantage of this particular type of microphones is their small size. That is indeed a significant feature since it allows reducing the size of the outer cover. This feature minimizing cover impact on the acoustic field around the head of the test participant.

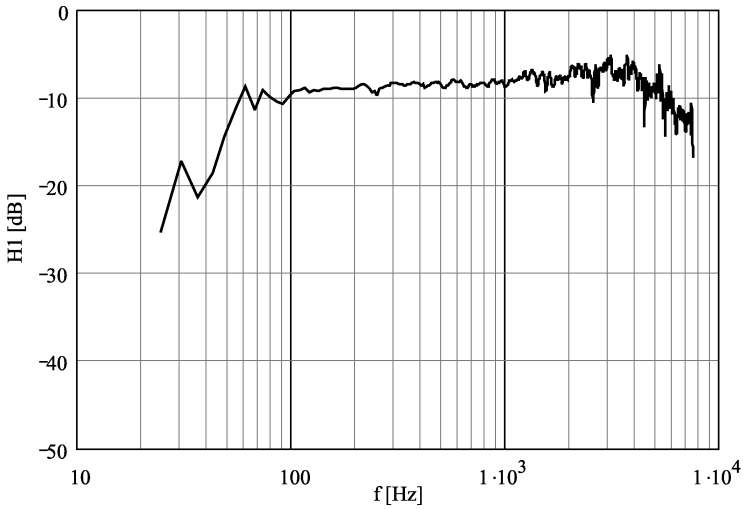

Fig. 2. An example of the measurement microphones frequency response.

The operational frequency range of the HRTF measuring device is limited by the lower cut-off frequency of the anechoic chamber in which the tests are conducted. The other factor influencing lower frequency is the operational frequency range of speakers. The lower cut-off frequency within the operational range of the speakers is higher than the value of the cut-off frequency of the anechoic chamber thus the operational frequency range for the entire device starts at around 200 Hz.

The upper cut-off frequency limit of the device is determined by the frequency range of the microphones. Hence the upper cut-off frequency is about 8 kHz. The other factory carrying impact on operational frequency range of the device is the influence of microphones' covers on the acoustic field around the head of the test participant. The microphones are placed in ca. 5-mm diameter tubes. The wave phenomena for this type of construction elements have a significant impact for 10 kHz frequency and above. But that is transversal dimension of applied elements; the length of the microphones cover is more significant dimension in this case and can influence acoustic field within the operational range of the device.

3. Problems encountered during measuring process

One of the methods to eliminate the impact of microphones' cover elements on the acoustic field around the head of the test participant is using microphones placed directly in the matter closing ears' channels [3]. In this case the usage of cover elements could be avoided and the solution is more advantageous for the precision of the results. On the other hand, the use of plain microphone without a rigid support construction attached to the measurement device gives way to the uncontrolled head motions. The impact of this fact on the tests' results is described below. It should be noted that the use of the microphones without rigid support increases the amount of time needed for exact positioning of the participant's head and also makes the measurement of the reference response more difficult.

One of the major challenges faced while conducting the tests was positioning of the listeners. In the first tryout the microphones were fixed in a way similar to medical stethoscope. Microphones were coupled with flexible wires; these were attached to ears in such a way that the microphones were suspended and their transducers were on the level of ears' channels entrances. The head of the human subject was placed on a holder fixed to the extension of the armchair's back. The distance between the head and the head holder was adjusted using cushions of different sizes. By increasing or reducing the amount of cushions the head of the test participant was placed at varied distances from the holder. The position of the head was controlled trough electronic visual system. On the screen the researcher could see the lines matching the position of ears' channels entrances and adjust the position of the head accordingly.

This method was verified negatively. The participants during the tests do move their heads slightly. Using a band to fasten the head in the holder did not bring any significant improvement. Those minimal head motions have an impact on the geometry of the measurement arrangement. In the case of high-resolution measurement performance the stability of geometrical configuration: the sounds source – the microphone, is crucial for the accuracy of the measurement.

The other method of attaching measurement microphones was then proposed and tested (Fig. 3). The microphones were fixed on a nonflexible construction. The construction had the possibility of adjusting the position of the microphones, though. The microphones were placed on the level of ears' channels entrances like before. Applying the fixed construction resulted in the fact that the test participant felt the microphones support structure limitation. In this case it was easier for the test participant to control head motions: when they appeared, it was a simpler task to put the head back in right position. The other advantage was that the distance between the microphones and the head holder was preset. The researcher avoided long process of positioning the head in relation to the holder. The only thing to be done was locating the listener in a proper elevation according to the sound sources.

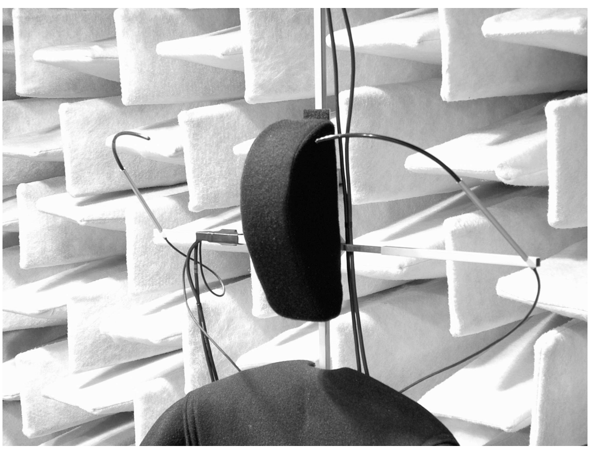

Fig. 3. The scheme of setting the measurement microphones.

The most important of all the advantages of this particular way of setting the microphones is the possibility of the precise microphones positioning while measuring the reference response and while conducting the tests with human participant, as well. It is very significant for the accuracy of measurements, particularly when the impact of the measuring set and that of the research room should be minimized.

Although conducting the measurement of reference response for each assessment spot excludes the impact of the measurement set, some acoustic phenomena cannot be reduced this way. During the tests it was observed that for the vertical 90° angle and for the angles close to this value, in the reference impulse response the sound reflection from the seat of the armchair was observed. (Fig. 4, $t \approx 7$ ms). During the test involving the participant, the reflection does not occur, because the person is seated in the armchair and therefore covering the seat surface. The phenomena of reflection while measuring the reference response, after the sound reaches the seat of the armchair, could be eliminated by using additional sound diffusion device.

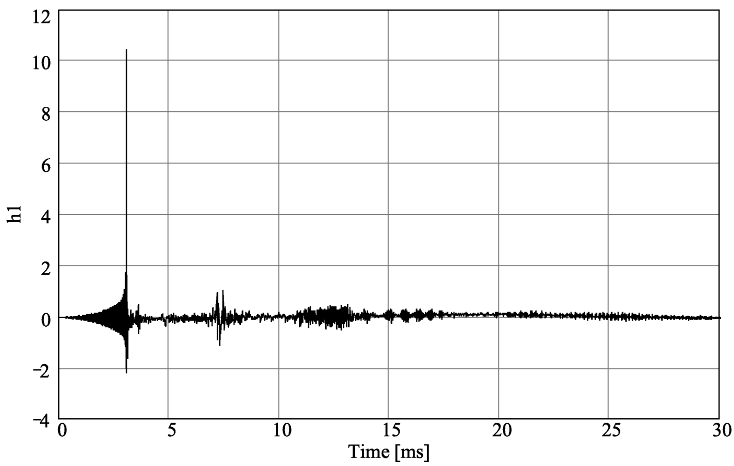

Fig. 4. The impulse response for vertical 90° angle.

Summing up, in the case of sound reflection from elements covered by the test participant, the use of the reference response is not sufficient. Similar phenomena were observed for different angles but never to such extent as in the case of 90° angle.

The impact of the research room is neutralized as much as possible by measuring the reference response. While measuring the reference responses the components with frequencies around 80 Hz were singled out (Fig. 5). It could be said that it was the effect of the wave interference inside the room. Although the tests are conducted in anechoic chamber, it is a place designed basically to make measurements involving machines, there is a concrete platform in the middle of the chamber intended for placing machines. This can contribute to forming interference phenomenon. Repositioning the device inside the chamber reduced the presence of the interference occurrence. Nevertheless, the phenomenon was observed only for frequencies outside the operational range of the device.

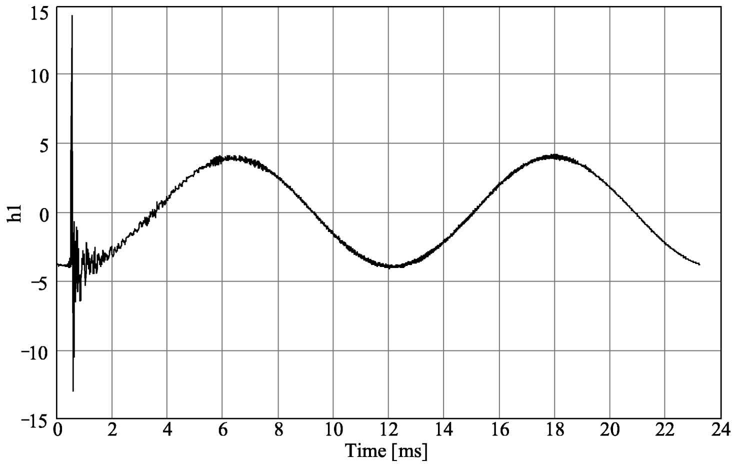

Fig. 5. The impulse response containing a small frequency component.

4. Conclusions

The measurements involving HRTFs measuring device have been presented in the paper. The encountered problems were discussed together with the eventual solutions to them. On the basis of conducted measurements and subjective tests it could be assumed that the device is measuring the HRTFs accurately enough to recreate the position of the sound source in the space surrounding the listener. The scope for future tests is to verify if the proposed adjustments eliminate the impact of the research room by conducting tests in the reverberation room sufficiently. To eliminate the influence of physical movements of the participant it is recommended that the tests should be conducted using a dummy head.

Acknowledgments

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