BETTER BINAURAL RECORDINGS USING THE REAL HUMAN HEAD

Panu Maijala
Laboratory of Acoustics and Audio Signal Processing
Helsinki University of Technology
P.O.Box 3000, 02015 HUT, FINLAND
Tel: +358 9 451 2479 Fax: +358 9 460 224
Email: Panu.Maijala@iki.fi

1. INTRODUCTION

Most binaural recordings today are done with an artificial or dummy head replicating the human head not only in average dimensions and details but also in approximate hardness and softness of skin and bone. Some of the recording heads also model the shoulders and a few have hair on the head, because all of these details have an effect on the sound.
The binaural technology [1] originates in the philosophy that our perception of sound is controlled by the sound pressure signals at our two eardrums. Authentic auditory experience is reproduced if the real life sound pressures are exactly reproduced at the listeners' eardrums. At least at higher frequencies, the filtering characteristics of a mannikin - even the best one - differ from those of a human.
Localization performance with artificial heads is known to be quite poor and recordings using real head are found to yield better results [5]. When evaluating the sound quality in mobile work machines real head is the only solution when moving. Those machines are seldom automated so highly that one could just put a dummy head inside the cabinet and let it go. The optimum situation is when the operator can be the recording head himself and the recording doesn't affect in any way to the action of the machine.
Our problem was to evaluate the sound quality in the cabinet of a mobile work machine. We studied several tractors and loaders by recording the sound of the machine with a dummy head and real heads. The sound samples recorded by real head are found to be more truthful than samples recorded by dummy head. We will figure this out by listening tests.

2. THE REAL HEAD RECORDING SYSTEM

Our real head recording system is portable and it consists of a little battery powered preamplifier (Fig. 1) and a DAT recorder. The preamplifier was designed using a single supply operational amplifier SSM-2135S. As microphones we use miniature condenser pressure microphone capsules (Sennheiser KE-4-211-2) within E-A-R earplugs (Fig. 2). The sound was picked up at the entrance of the blocked ear canal where the microphone stays well in its position by the aid of the handle which goes behind the ear (Fig. 3 and 4). The microphone capsule used in the real head recordings was verified to be good enough (100 Hz - 20 kHz ±1dB) by normal free field measurements.

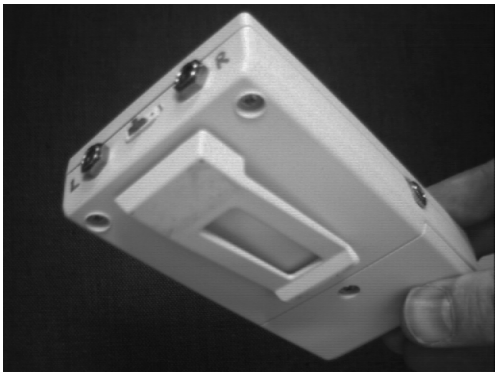

Fig. 1 Preamplifier

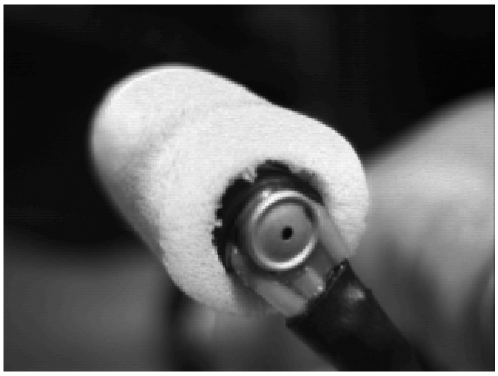

Fig. 2 Capsule in E-A-R

2.1 . Theory of binaural recording

The transmission of the sound from the entrance of the ear canal to the ear drum is independent from the direction of the sound. Some designs have placed the microphones at the same location as the eardrums, with special equalization to correct for the double traversal of the ear canal (first in recording and again in playback). The sound can be picked up at the entrance too [1]. The proof is derived for the blocked ear canal too which is more practical than near the ear drum [2] [3]. The microphone can be even a few millimeters outside the ear canal entrance [4].

Fig. 3 Handle goes behind ear

Fig. 4 Capsule in a blocked ear

The influence of the differences between subjects to the equalization filters is minimized when the transmission functions are measured from the entrance of the ear canal [1].
The microphone capsule could be moulded to earplug. This eliminates a lot of adjustment because the location of the capsule could be repeated accurately.

2.2. Calibration

To carry out proper calibration we designed an adapter (Fig. 5) for the microphone capsules and the well known Brüel&Kjær calibrator. The adapter muffles disturbing noise about 40 dB below the calibration tone. This is very useful when the calibration must be carried out in a noisy environment.

Figure 5 The calibration setup

2.3. Equalization

Figure 6 is an average of 16 different headphone (Sennheiser HD580) transmission magnitude spectra on a real head. Figure 7 is the same with our mannikin. A considerable variation across subjects exists for all headphones, especially at high frequencies. The headphones should be equalized carefully for each subject.

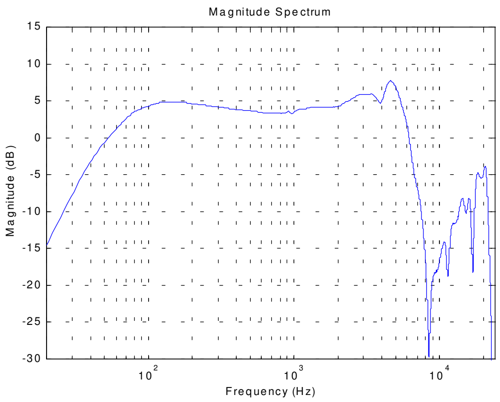

Fig. 6 Headphone transfer characteristics of a human head …

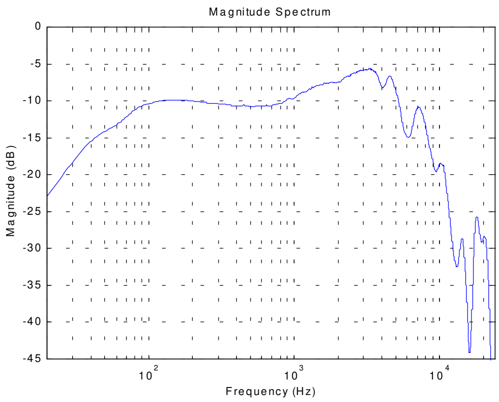

Fig. 7 … and a mannikin

3. LISTENING TESTS

When the recordings are compared informally, the sound samples recorded by real head are found to be more authentic by most listeners. One way to figure out how well the recording head does preserve the spatial information is to estimate the ability of the subjects to localize sound incidents in listening tests. We recorded the sound of a car passing by with a high quality dummy head (Cortex Manikin MK2) and a real head. The task was to report the direction the car was driving to in relation to the recording head.
There were 22 subjects with controlled normal hearing aged 20-30 years. They were not trained nor the recording real head was selected by any particular way. No personal equalizations were made.

3.1. Results

In the error table below the FB (front-back) error was the most general as expected. Some subjects had no errors in real head recordings and some persons had no errors in dummy head recordings.

Total percentage of errors	28 %	Standard dev. of FB errors	1.7
Standard deviation of all errors	2.8	Max. FB error percentage (single subject)	75 %
Maximum error percentage (single subject)	53 %	Min. FB error percentage (single subject)	25 %
Minimum error percentage (single subject)	19 %	Dummy head errors (all material)	14 %
Front-back errors (all material)	25 %	Real head errors (all material)	14 %
Front-back errors from FB-samples	50 %		

In this experiment we couldn't show any difference in localization between real or dummy head recordings. We will need some further research to clarify why real head recordings sound better.

4. ACKNOWLEDGMENT

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5. SUMMARY

In this paper we have described the equipment we use in evaluating the sound quality in mobile work machines. Dummy head recording systems have many benefits but if the best spatial quality is required the solution is individualized real head recordings and careful headphone equalizations.

7. REFERENCES

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