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Relationship between contact force and electrical impedance of bone-conducted sound transducer on human head

人体頭部における骨導音トランスデューサの押付圧と電気インピーダンスの関係

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1. Introduction

From a point of view of sound propagation, auditory sense can be divided mainly into two; Air-conducted sounds and Bone-conducted sounds. Air-conducted sounds travel from the outer ear to the inner ear through air, and most of the hearing is in this form. On the other hand, bone-conducted sounds travel from surface of a human to inner ear through skin and bone. Bone-conducted sounds are especially used for clinical applications, and nowadays used as headphones without occlusion of the environmental sound[1-2].

The contact state of the bone-conducted sound transducer affects the sound[3]. However, it is impossible to estimate contact state without extra instruments. Previous measurements[4] use the artificial mastoid, which emulates mechanical impedance of the mastoid process. However, as its purpose is calibration of bone-conducted transducer for clinical analysis, this method cannot measure contact state of transducers on human head.

On this problem, we have been proposing a method of estimating contact state using the electrical impedance of bone-conducted sound transducer[5-6]. The previous studies showed effect of contact force on electrical impedance with simulated human head model and implied a feasibility of this contact state estimation method. In this study, the electrical impedances were measured with human head and compared to that of simulated human head. The results of this study connect previous studies, which measured with simulated human head, to realistic use of the estimation method.

2. Experiment conditions

Experimental setup is shown in Fig. 1. An impedance analyzer (E5061B, Agilent) was connected to the bone-conducted sound transducer (AS400, AfterShockz) for measuring the electrical impedance. The transducer was placed on approximately 5 mm forward of the ear canal. The contact forces F were tested for 0, 0.1, 0.3, 0.5, 1, 3, and 5 (N), covering a comfortable contact force range[7]. The contact forces of the transducer were set by placing weights on the transducer. Electrical impedance was measured for 300 points in logarithmic scale with a range of 1 Hz to 60 kHz. The impedance was measured 10 times for each condition. Eight subjects (ages: 22-27, normal hearing) have participated the experiment, and for each subject the experiment was conducted for the right ear.

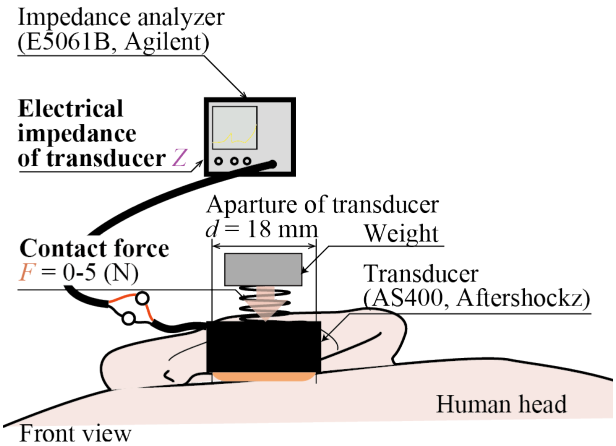

Fig. 1 Experimental setup for measuring electrical impedance at different contact force.

3. Results and discussions

Experimental results for each subject are shown in Fig. 2(a) – (h). From these results, the peaks of the electrical impedance around 100 Hz were observed for all of the subjects. Larger F induces higher impedance and frequency of the 1st peak of the impedance. It was similar to what observed in previous study with human head model. The second peak is considered to be caused by the mechanical property of the transducer itself, as shown in Fig. 3. The variation of the electrical impedance was significant at lower contact force, below 0.1 N. The reason for this would be explained with difference of the matching of human skin and the transducer.

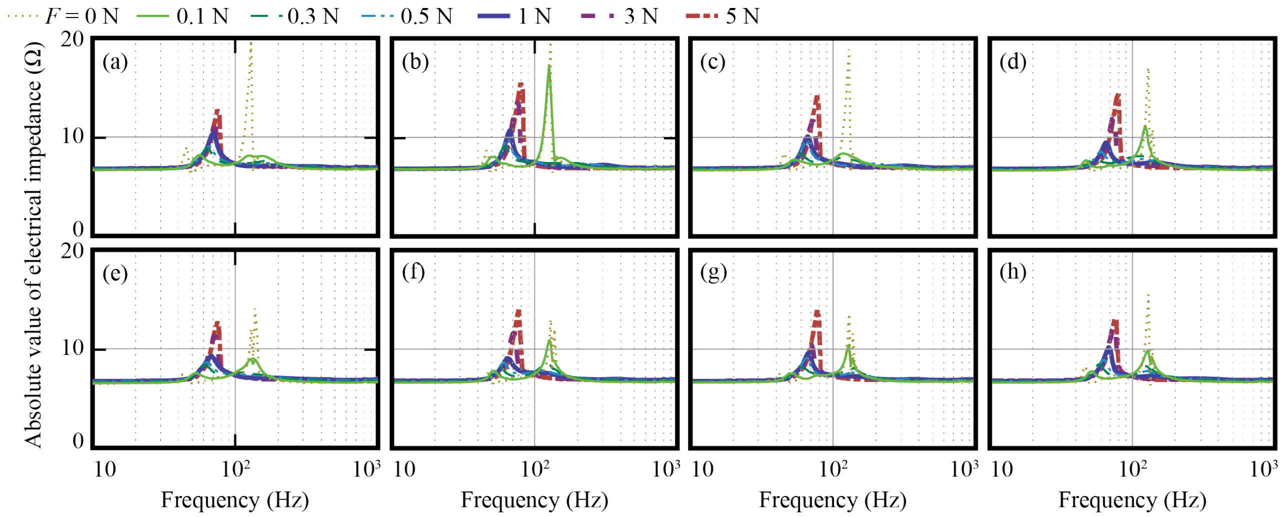

Fig. 2 Experimental results for each subject. (a) results of subject 1, (b) results of subject 2, (c) results of subject 3, (d) results of subject 4, (e) results of subject 5, (f) results of subject 6, (g) results of subject 7, (h) results of subject 8.

At this range of contact force, some parts of the transducer did not contact with the skin for some of the subjects. At higher contact force, the deformation of the skin makes stable matching with the transducer, and results in similar shape of the electrical impedance characteristics.

The change of the electrical impedance had similar shape for all subjects in term of the peak value and frequency, similar to that of measured in the previous study with simulated human model[6]. One of the reasons for this change could be the nonlinearity of the human skin. Further discussion with physical point of view would be required.

4. Conclusions

In this study, experimental results of a relation between the contact force and the electrical impedance of bone-conducted sound transducer with human head were shown. The experiment was conducted with 8 subjects and the electrical impedance were measured for conditions of contact forces F = 0, 0.1, 0.3, 0.5, 1, 3, and 5 (N). The results showed that electrical impedances of human heads have characteristics which have been shown in the previous studies with simulated human mode, and have variation for each subject. Similar peaks were observed for all subjects, and the peak frequencies and values were changed according to the contact force.

Further investigation on common component of the electrical impedance would be required. Estimation of contact force with human head result is required to show feasibility of previously proposed method.

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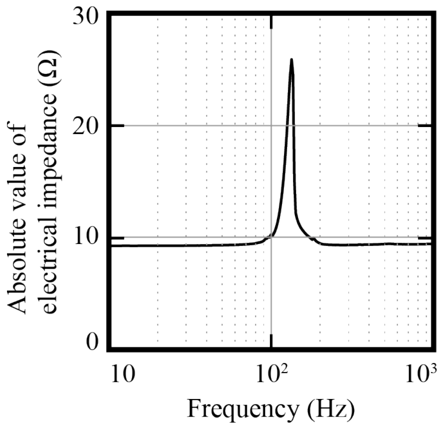

Fig. 3 Frequency response of .the transducer without contact with human.

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