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APPLICATION OF NEW BONE CONDUCTION PICKUPS AND EARPHONES OF EARPLUG TYPE FOR SPEECH COMMUNICATION UNDER HIGH AMBIENT NOISE

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ABSTRACT

An acceleration-type vibration pickup is now widely used for the speech transmission under high ambient noise. But, the position of attachment and the speech intelligibility in high ambient noise over 100dB are open problems. In order to improve these problems, we developed the following two kinds of vibration pickups: (a) A noise-canceling-type vibration pickup inserted in external auditory canal can cancel the surrounding noise (45dB at 2.5kHz). (b) A vibration pickup attached to lip part can pick up intelligible speech (95% at 115dB). Since ordinary headphones and earphones are not suitable for listening under high ambient noise, we proposed the new earphones of earplug type. It can be used under high ambient noise with normal hearing level (95.6% at 90dB).

1 - INTRODUCTION

In high ambient noise environments such as airports, streets, factories and construction sites, speech transmission becomes impossible because of the low signal-to-noise ratio. To realize the speech transmission, a considerable number of studies [1] have been made on application of a bone conduction pickup. But, the spectra and acceleration levels of speech obtained with the pickup change by the position of attachment on the head and face. In addition, as the noise level increases, the pickup responds to the surrounding noise. From the viewpoints, to explore a further possibility of bone conduction pickups, we developed the following two kinds of vibration pickups: (a) A noise-canceling-type vibration pickup. (b) A vibration pickup attached to lip part. There is another problem to improve: ordinary headphones and earphones are not suitable for listening under high ambient noise because of air leakage. We proposed the new type earphones made of magnetic diaphragm adhered to earplug [2].

In this paper, the effectiveness of the vibration pickups and the earphones are examined. Furthermore, as to those speech transmission systems, it is experimentally considered whether the prediction of articulation scores by articulation index is applicable or not.

2 - NOISE-CANCELING-TYPE VIBRATION PICKUP

A vibration pickup inserted in external auditory canal has been put to practical use. But, it is difficult to take measures for high ambient noise over 100dB and hum noise; accordingly a new bone conduction pickup, which can cancel the surrounding noise and hum noise, is proposed. Structure of the pickup is shown in Fig. 1.

Design and produce of the pickup. Noise-canceling-type vibration pickup is composed of two monomorph elements and two pieces of steel wire. One side of the monomorph element is fixed to the case on the grounds that the sensitivity can be raised by utilizing the bar-shaped element with fixed and free ends. Two steel wires are soldered to the brass plates. When the pickup is inserted in external auditory canal, the wires touch the canal wall and can pick up the vibration of bone-conducted speech sounds.

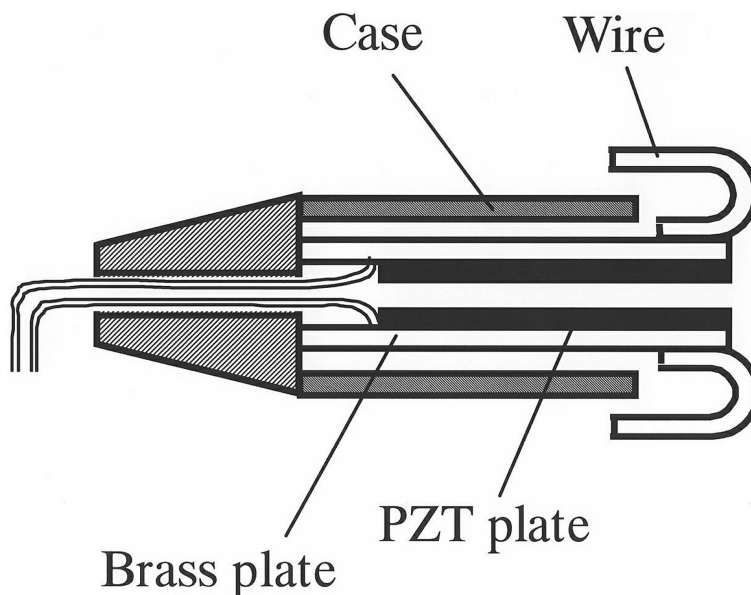


Figure 1: Structure of noise-canceling-type vibration pickup.

Effects of noise canceling. If the sensitivities of two elements are equal, this pickup can cancel the surrounding noise and hum noise by adding one output to the other inverted output. At that time, bone-conducted speech is not canceled. Because the vibration modes of external auditory canal wall are different between the upper and the lower parts. The noise canceling effects were measured as to pure tone of 94dB.

The attenuation effects by the pickup based on the noise response of a monomorph element are shown in Table 1. It is found that the attenuation effects of 45dB or less are obtained. The reason why the effects vary by frequencies is that phase differences are caused by the positions of the two elements.

Frequency [Hz]	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
Attenuation [dB]	16	21	28	12	19	38	35	42	38	45	28	22

Table 1: Noise canceling effects of the pickup.

3 - THE VIBRATION PICKUP ATTACHED TO LIP PART

In respect of signal-to-noise ratio, it is thought that lip part is more advantageous than the usual attaching positions of the pickup [1], because lip part is close to the speech organs. When a small vibration pickup (RION PV-11A) is attached to lip part, the attaching conditions of the pickup, speech response and noise response are examined.

Attaching conditions of the pickup. As to attaching conditions, contact areas and mass of pickup system are examined from the viewpoints of the sensitivities to both bone-conducted speech sounds and air-conducted noise. From the results, we decided that the contact areas were 2cm² and the mass was 1.7g.

Speech response. The place of the experiment was an anechoic room (4x5x3m). In this room, three students read out articulation test cards of Japanese two syllables. The speech levels were 70dB(C) and 80dB(C) at a distance of 1m from the lip. Then the bone-conducted speech sounds existed at the lip part were recorded on digital audiotape through the pickup.

The spectra of the recorded speech sounds were obtained by utilizing 1/3 octave band filter and level recorder. They are shown in Fig. 2.

Noise response. The sensitivity to air-conducted noise of the pickup attached to lip part was measured in a reverberation room (68m³) by reproducing 1/3 octave band noise with two loudspeakers. Sound pressure levels of 1/3 octave band noise were 70dB(C) and 80dB(C).

The acceleration levels to air-conducted noise of the pickup system are shown in Fig. 2. From the comparison of the acceleration level to bone-conducted speech sounds and that to air-conducted noise,

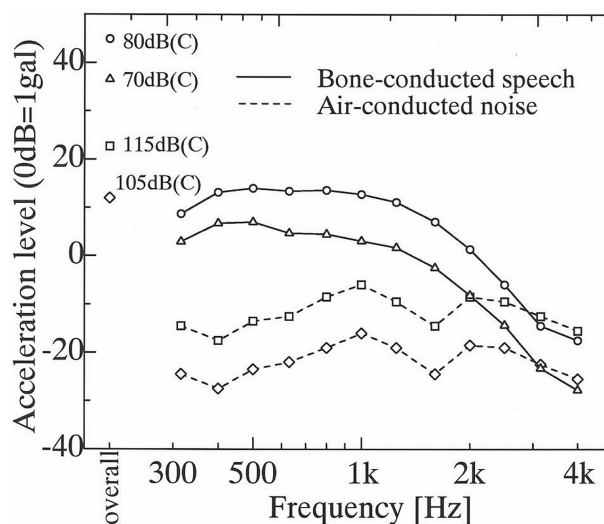


Figure 2: Spectra of bone-conducted speech and air-conducted noise picked up at the lip part.

in the case of speech level is 80dB(C), it is possible to take signal-to-noise ratio of 20dB when the noise source contains all frequencies and its overall sound pressure level is 115dB(C). By the way, articulation scores of the speech sounds, obtained with the vibration pickup attached to lip part, can be calculated from Fig. 2.

4 - EVALUATION OF NEW BONE CONDUCTION PICKUPS

To confirm effectiveness of new bone conduction pickups, they are evaluated by articulation tests.

Conditions of the experiment. The reverberation room was used as a high ambient noise field. In this room, one of the authors read out articulation test cards of Japanese two syllables, and the outputs of the vibration pickups were recorded on digital audiotape. These test sources were heard by subjects with the earphones of earplug type in quiet field. The conditions of the experiment are shown in Table 2.

Results and discussions. Scores of syllable articulation obtained with each vibration pickup in high ambient white noise are shown in Table 3. The intelligibility of the vibration pickup attached to lip part is much higher than that of the noise-canceling-type pickup and of a vibration pickup (NHC G-450), inserted in external auditory canal, for portable phones. The noise-canceling-type pickup gives 5.6% better intelligibility than the vibration pickup for portable phones. From this result, however, we are not able to say that speech intelligibility is improved largely by the noise canceling effects. But, the subjects commented that the noise-canceling-type pickup gives better signal-to-noise ratio than the pickup for portable phones.

Prediction of articulation scores by Articulation index. Articulation index (AI) can be calculated by utilizing physical characteristics of speech transmission system. In the case of speech transmission is done under high ambient noise, AI values can be calculated by Kryter's 20-band method [3] applied to Japanese. We examined relations between syllable articulation scores of test results and AI values as to bone-conducted speech. The relations are shown in Fig. 3. It can be said that articulation scores of bone-conducted speech can be predicted by articulation index. With regard to the vibration pickup attached to lip part, the predicted scores are almost in accord on the scores of test results.

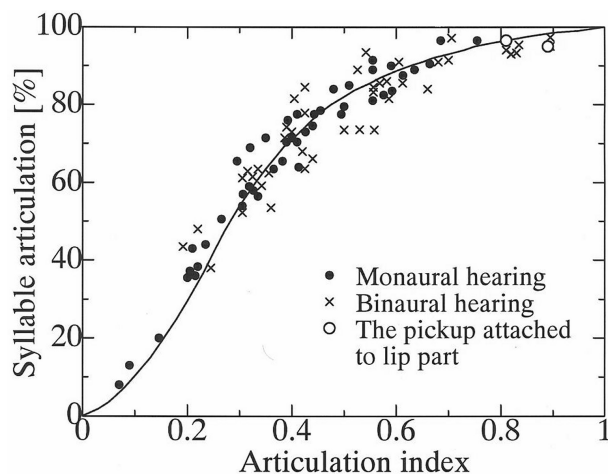


Figure 3: Relations between syllable articulation scores and AI.

Class	Noise source	Noise levels [dB(C)]	Speech levels at 1m [dB(C)]	Hearing level	Transmission band width	Subjects
The pickup attached to lip part	White noise (reproduced with two loudspeakers)	105	70	Adjusted by the subjects to comfortable hearing level	300~3400 Hz	4 students (4 times as to same condition)
		115	80			
Noise-canceling-type pickup		100	75		300~4800 Hz	
A vibration pickup for portable phones						

Table 2: The conditions of articulation test (the case of speaking place is under high ambient noise).

Class	Noise levels [dB(C)]	Syllable articulation [%]
The pickup attached to lip part	105	96.5
	115	95
Noise-canceling-type pickup	100	70.3
A vibration pickup for portable phones		64.7

Table 3: Scores of syllable articulation.

5 - EARPHONES OF EARPLUG TYPE

The earphones of earplug type [2] can be inserted in the external auditory canal as well as usual earplug. The earphone can drive the small cavity, which enclosed by the earplug and listener's eardrum, directly. The earplug selected has the attenuation effects of 20dB or more in the frequency range above 1kHz. To compare the new earphones with ordinary headphones, articulation test is carried out under high ambient noise.

Conditions of the experiment. Recording place of test sources was the anechoic room. As a noise field, white noise was reproduced with two loudspeakers in the reverberation room. In this room, subjects

who are the same to previous chapter heard the test sources with the earphones of earplug type and close type headphones (SONY MDR-CD770). Other conditions of the experiment are shown in Table 4. **Results and discussions.** Scores of syllable articulation are shown in Table 4. The intelligibility obtained with the earphones of earplug type is 30% higher than that obtained with the close type headphones. These results make it clear that the new earphones are suitable for listening under high ambient noise. Furthermore, it may safely be said that the earphones can be used for listening of portable players in the vehicles under high ambient noise such as airplanes and trains.

Class	Speech level at 1m [dB(C)]	Noise level [dB(C)]	Hearing level $L_{Ceq,4m10s}^*$ [dB]	Syllable articulation [%]
The earphones of earplug type	75	90	80	95.6
Close type headphones				65.5

Table 4: The conditions and results of articulation test (the case of hearing place is under high ambient noise) *: 4 minutes and 10 seconds are the time for hearing of an articulation test card of Japanese two syllables.

6 - CONCLUSIONS

To improve the shortcomings of ordinary vibration pickup for speech transmission, headphones and earphones, two kinds of new bone conduction pickups and the earphones of earplug type were proposed. From the results, several conclusions can be given in following.

- Speech intelligibility of the vibration pickup attached to lip part in high ambient noise is excellent (105dB-96.5%, 115dB-95%) compared with the other pickups. The reason for this is that lip part is close to the speech organs.
- The noise-canceling-type vibration pickup gives better signal-to-noise ratio than the vibration pickup for portable phones. In addition, the noise-canceling-type pickup gives 5.6% better intelligibility than the pickup for portable phones under 100dB.
- The earphones of earplug type can be used enough for speech communication under high ambient noise with normal hearing level. This means that the earphones protect one's ears from hearing and high ambient noise levels for the sound insulation effects of earplugs.

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REFERENCES

1. **T. Yanagisawa and K. Furihata**, Application of a Bone Conduction Pickup to Oral Communication in Very Noisy Environment, In *Inter-noise75*, pp. 643-646, 1975
2. **S. Matsubara, K. Furihata and T. Yanagisawa**, Electroacoustic Transducers of Earplug Type for Active Noise Control in External Auditory Canal, In *Active99*, pp. 1257-1266, 1999
3. **K. D. Kryter**, Methods for the Calculation and Use of the Articulation Index, *Journal of Acoustical Society of America*, Vol. 34 (11), pp. 1689-1697, 1962