Title	骨導提示音による気導提示音の抑圧法の検討
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Study on the suppression method

of the air-conducted sound by the bone-conducted sound.

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The relationship between human and sound is close and it is difficult to separate. It is said that its history dates to before recorded history. There are essential sounds such as music and conversation in our daily lives. On the other hand, there are sounds that interfere with the necessary conversation or become a hindrance. These unwanted sounds are called noise. There are various environmental noises in our daily lives such as the sound of shopping streets, cars and trains running, construction sounds, and dog barking sound. Listening to these noises at high sound pressure levels for a long period of time increases the risk of noise-induced hearing loss. There are three types of hearing loss, conductive hearing loss, sensorineural hearing loss, and mixed hearing loss. The noise-induced hearing loss is a type of sensorineural hearing loss. The sensorineural hearing loss is caused by a malfunction of the inner ear or higher neural system, and it is difficult to improve with a hearing aid. In terms of hearing protection and reducing the risk of the noise-induced hearing loss, it is important to suppress noises in daily life and protect our ears.

In these days, the hearing protection devices are used to suppress noise. These devices include earplugs, which are inserted into the ear canal, and earmuffs, which cover the ears. Hearing protection devices are evaluated and tested according to JIS standards, allowing for high levels of noise suppression. Active-noise control (ANC) technology uses a microphone to capture the target noise, and then presents an inverted phase and equivalent amplitude signal through a speaker to suppress the noise. However, this technology and these devices are assumed to leave the ear canal (EC) close, which can suppress not only noise but also important sounds. Therefore, there is a need for a method of suppressing external noise with our EC open.

In this study, the bone-conduction (BC) devices are focused on because that allow for the perception of sound with EC open. To realize a noise suppression method that does not block EC, the purpose of this research is to suppress stationary noise presented through air-conduction (AC) by presenting BC sound. In this study, three experiments were conducted to investigate whether it is possible to suppress a stationary noise by the BC device.

Several studies have been conducted to investigate the use of BC sound for noise suppression. Ito conducted hearing experiments based on the hypothesis that there is linearity in the transmission pathways of AC and BC sounds and the principle of ANC. They examined whether it is possible to suppress environmental noise by providing the inverse phase component of the noise with amplitude adjustment through BC. As a result, it was found that the internal sound image of environmental noise moved, and that noise suppression was possible through BC. Sakai considered the differences in the transmission characteristics between AC and BC pathways, which causes a phase delay between them, and examined whether pure tones could be suppressed by adjusting the amplitude and phase of BC tone in the experiment using an adjustment method. As a result, it was revealed that pure tone could be suppressed by BC tone.

The results of Ito showed qualitative suppression effects, but they were only able to show the internal sound image position changed. The results of Sakai achieved sufficient amounts of suppression (more than 10 dB), but there were problems such as the influence of subjective factors due to the use of the adjustment method, and the assumption that the noise was only periodic noise (pure tone). Additionally, neither study was limited to suppress in only one ear and the effect of binaural hearing was not considered.

In this research, three experiments were conducted. In the first experiment, the suppression conditions of amplitude and phase of BC tones were examined for AC tones at six frequencies. The differences in transmission paths between air and bone-conducted sounds were considered. The amplitude and phase conditions of BC tones were determined by the method of limits. In the second experiment, the amplitude and phase conditions of BC tones were used to determine if it is possible to suppress a complex tone. In the third experiment, the same amplitude and phase conditions of BC tones were used to determine if it is possible to suppress stationary noises. Based on the amplitude and phase conditions of BC tones obtained in the first experiment, the filter for each participant was designed, and BC experimental stimuli were created to suppress stationary noise presented through AC.

The results of the experiment revealed three things. First, it is possible to sufficiently suppress pure tones presented through AC by BC tones. Second, it is possible to suppress complex tone presented through AC by BC tone, but the amount of suppression was lower than that of pure tones. Third, it is possible to suppress stationary noise using BC sound through accurate filter design, but the amount of suppression was lower than that of complex tone.