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Evaluation of Pure Tone Cognition in Electric Vehicle in Consideration of Background Noise Inside and Outside Critical Band

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In this paper, we propose a method for masking high-frequency noise such as motor and gear noise, which are unpleasant noises in the interior of EV, by using background noise. However, unlike the white noise used in the masking theory, EV interior background noise has a frequency gradient. Therefore, the masking theory with flat frequency response cannot be applied as is, and out-of-critical-band effects may occur. Accordingly, an experiment was conducted to understand the effect of out-of-band noise by using a masker with a modified white noise out-of-band parameter, which is closer to the EV interior background noise.

First, the sound pressure level outside the critical bandwidth was increased and a pure tone recognition experiment was conducted in the presence of a sound pressure level difference. Even outside of the critical band, experiments were conducted by increasing some sound pressure levels near and far from the critical band to determine which frequencies were affected. The results showed that masking curves outside the critical band affected masking perception and that the frequency band affected was not only the masking curves near the critical band.

Next, a pure tone recognition experiment was conducted using a rightward descending masker like the EV interior background noise. The increase in the low-frequency side was set at +10 dB and +20 dB, while the decrease in the high-frequency side was set at -10 dB and -20 dB. The experimental results showed that pure tone recognition decreased as the sound pressure level outside the critical bandwidth increased, and that the wider the frequency range of the increase, the more difficult the recognition became.

Next, we determined the degree of concern for pure tone when a smoother frequency gradient was used. The results showed that the sound sources with higher sound pressure levels at lower frequencies had lower degree of concern for pure tone. It was also found that the degree of concern for different frequency pure tones at the same gradient did not change much.

Finally, pure tone recognition was evaluated when presented with a masker that more closely resembled the sound of an EV interior. Maskers were used to simulate steady running state at 30 km/h, 20 km/h, and 10 km/h. As shown in Fig. 1, for all muskees, the sound pressure level required to recognize the muskie increased with increasing vehicle speed. As shown in Fig. 2, the protrusion quantity at 1000 Hz and 8000 Hz tended to increase at 10 km/h, where the frequency gradient was the largest.

These results indicate that when a frequency gradient exists, such as in the case of EV interior background noise, maskers outside the critical band also affect recognition. Therefore, it is suggested that even in the quieter EV interior background noise, it may be possible to inhibit the perception of high-frequency sound.

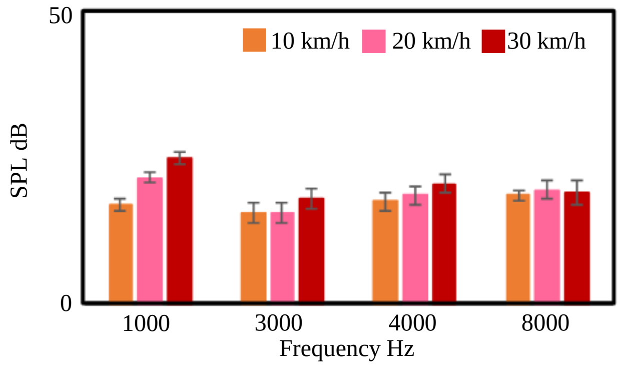

Fig. 1 Pure tone recognition threshold of pseudo sound in electric vehicle

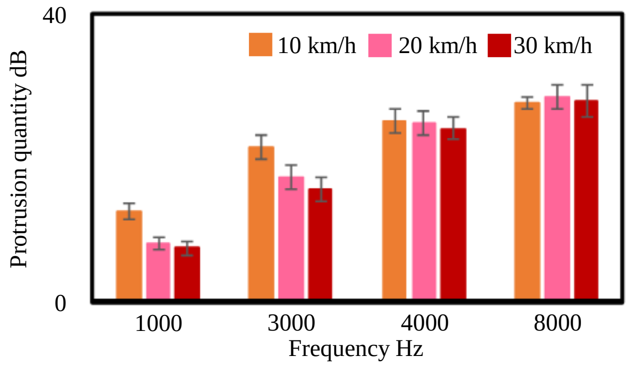

Fig. 2 Protrusion quantity of pseudo sound in electric vehicle