

# Objective Evaluation Method for Interior Sound Quality in Electric Vehicles (First Report)

## -Sound Quality Evaluation Method for In-Cabin Electric Powertrain Noise-

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This study proposes an objective index for quantitatively evaluating the sound quality of electric powertrain noise (e-PT noise) in electric vehicle (EV) interiors. Interior noise in EVs mainly consists of e-PT noise, road noise, and wind noise. Among these components, e-PT noise is characterized by tonal discrete frequency components generated by motors and gear systems, which can cause perceptual annoyance even at relatively low sound pressure levels. Conventional noise metrics, such as the A-weighted sound pressure level, are not sufficient to represent the annoyance associated with such tonal noise.

To address this issue, a subjective evaluation experiment was conducted with noise and vibration (NV) experts. Based on empirical ride evaluations carried out on European public roads in the past, nine representative driving conditions, including acceleration, deceleration, and cruising, were set. For each driving condition, 14 different presentation sounds with distinct timbres in EV interior were prepared. Fourteen NV experts with more than seven years of experience in automobile vibration and noise development evaluated the sounds using Scheffé's paired comparison method. Based on the evaluation results, a new sound quality index, EPNI (e-Powertrain Noise Index), was derived using the psychoacoustic metric: specific tonality  $T(z)$ , as defined in equation (1).

$$EPNI = \max_z (\text{Specific tonality } T(z)) \quad \cdot \cdot \cdot \quad (1)$$

$$\text{Critical band } z = 5, 5.5, 6, 6.5, \dots, 22$$

The proposed index was applied to the interior sounds of three EVs shown in Fig. 1. As illustrated in Fig. 2, the index corresponded well with the subjective evaluation results of the experts. In contrast, such a tendency was not observed when the sounds were compared using the A-weighted sound pressure level shown in Fig. 3. These results indicate that EPNI is a useful index for quantitatively representing the annoyance of e-PT noise.

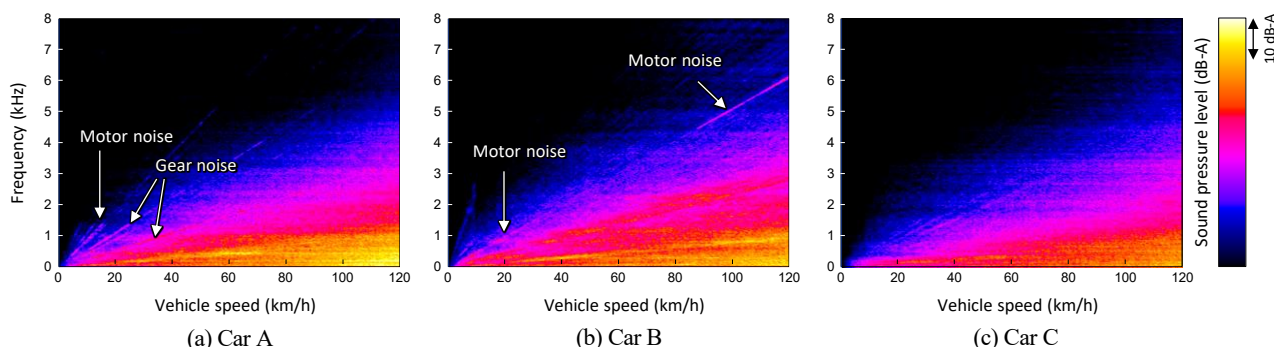


Fig. 1 Comparison of vehicle interior noise of different EVs under 2 m/s<sup>2</sup> acceleration (at left microphone of artificial head)

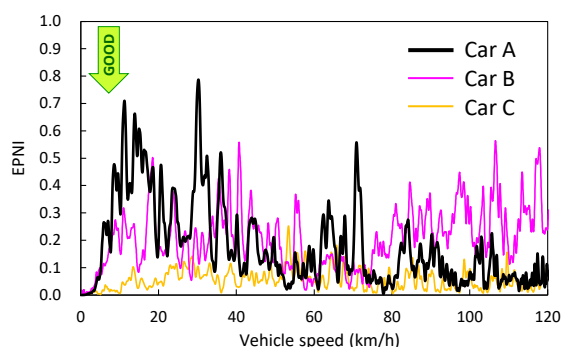


Fig. 2 Comparison of EPNI in vehicle interior of different EVs

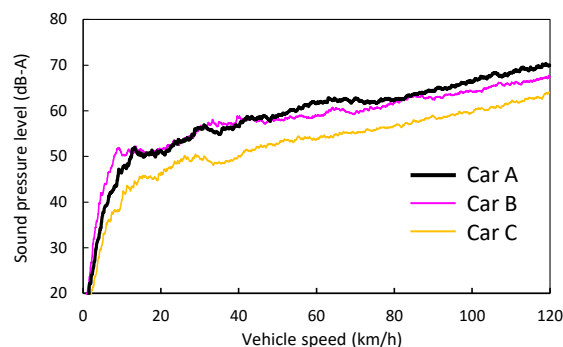


Fig. 3 Comparison of SPL in vehicle interior of different EVs