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Prediction of Aerodynamic Noise from Cooling Fans in Automotive ECUs using Acoustic Analogy

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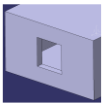
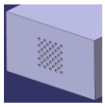
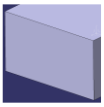
In the development of in-vehicle infotainment Electronic Control Units (ECUs), air-cooling solutions are required to address thermal and acoustic challenges due to increasing vehicle intelligence and electrification. To improve noise control strategies, this study introduces Computational Fluid Dynamics (CFD) combined with an acoustic analogy approach to predict aerodynamic noise generated by ECU cooling fans. The effectiveness of the proposed method is verified by comparing simulation results with experimental noise measurements for different fan usage cases shown in Table 1. Fig. 1 indicates sound pressure levels at one of the receivers located around the housing unit. The prediction results reproduced the overall trend of the measured frequency response and the tones caused by blade passing of the fan rotor. It was also found that this prediction method can clarify the factors influencing the acoustic field around the test samples. Based on the verification of prediction errors over a wide frequency range, the predicted values are generally lower than the measured values for most of the test samples as shown in Fig. 2. The prediction error in sound pressure level relative to the measured values is within 8 dB. Furthermore, it is confirmed that the aerodynamic noise generated by the housing unit and that produced by the air-cooling unit can be distinguished in the prediction results.

Table 1 Details of the test samples, the blade passing frequency and the computed volume flow rate.

Item	**Housing unit**			**Air-cooling unit**			
Sample detail	With square opening (opening ratio 1.0)	With perforated panel (0.27)	Without opening (0.0)	Finless (flow area ratio 1.0)	Fin type 1 (0.77)	Fin type 2 (0.88)	Fin type 3 (0.93)
							
Blade passing frequency (Hz)	262	267	240	1803	1844	1841	1817
Volume flow rate (m^3/min)	Q_h	$0.49Q_h$	0	Q_a	$0.90Q_a$	$0.91Q_a$	$0.95Q_a$

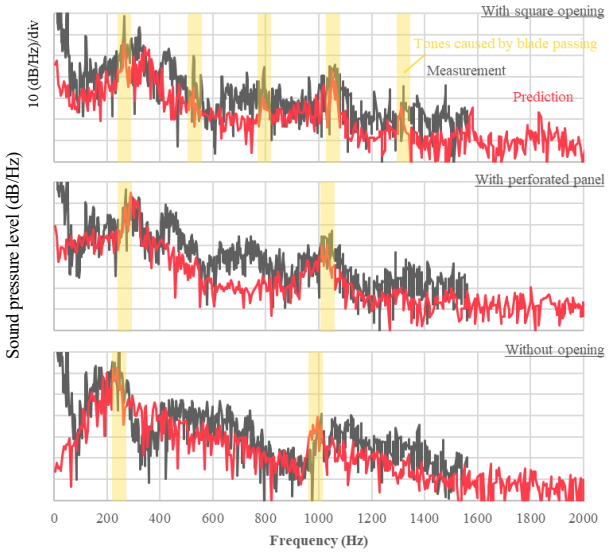


Fig. 1 Sound pressure levels at one of the receivers located around the housing unit.

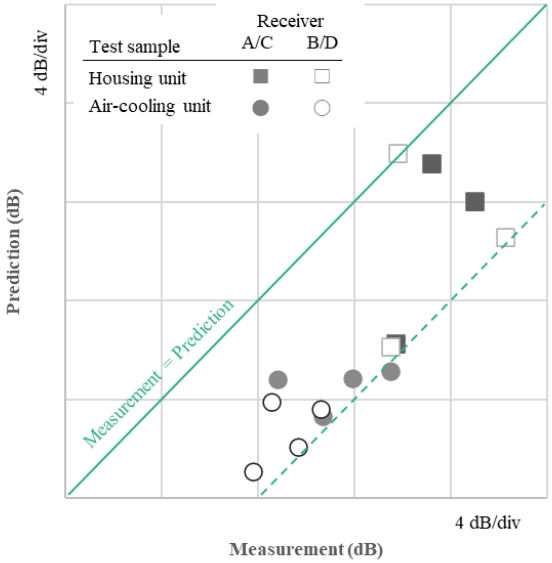


Fig. 2 Comparison of the overall values calculated from the measured and predicted data over the 200–2000 Hz frequency range.