Noise attenuation of the engine compartment of a vehicle

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Abstract: Road traffic noise amounts to roughly half of the overall ambient noise. Usual noise control techniques have not been enough to decrease the noise annoyance by road traffic along the last decades. In order to relate the noise levels generated by the vehicle at near field with the usual levels radiated to the far field, it is necessary to characterise the noise reduction produced by the engine hood. Here, preliminary results on such characterisation are presented. Insertion loss and transmission loss have been measured in several locations around the vehicle. Besides the microphone inside the engine compartment, another microphone is needed outside the vehicle. The responses between a loudspeaker and both microphones were measured using the maximum length sequence method. Preliminary results show that noise reduction provided by the engine hood depends on the microphone location, varying from 16 dB to 27 dB at vertical and lateral positions.

Keywords: engine noise; vehicle noise; engine compartment; transmission loss; insertion loss.

Reference to this paper should be made as follows: Ibarra, D. (2017) 'Noise attenuation of the engine compartment of a vehicle', *Int. J. Vehicle Noise and Vibration*, Vol. 13, No. 1, pp.66–72.

Biographical notes: David Ibarra received his BS in Electrical and Communications Engineering from the Instituto Politecnico Nacional, Mexico City, in 2006, his MS in Acoustics Engineering from the Universidad Politecnica de Madrid, Spain, in 2010, and PhD in Acoustics Engineering from the Universidad Politecnica de Madrid, Spain, in 2013. Currently, he is a Research Professor of the School of Engineering and Sciences at Tecnologico de Monterrey. His teaching and research areas include environmental acoustics, road traffic noise, noise control and vibrations, signal processing, room acoustics, electroacoustic systems, archaeoacoustics and acoustic therapies.

This paper is a revised and expanded version of a paper entitled 'Noise reduction of the engine hood of a vehicle' presented at 13th European Automotive Congress, Valencia, Spain, 14–16 June 2011.

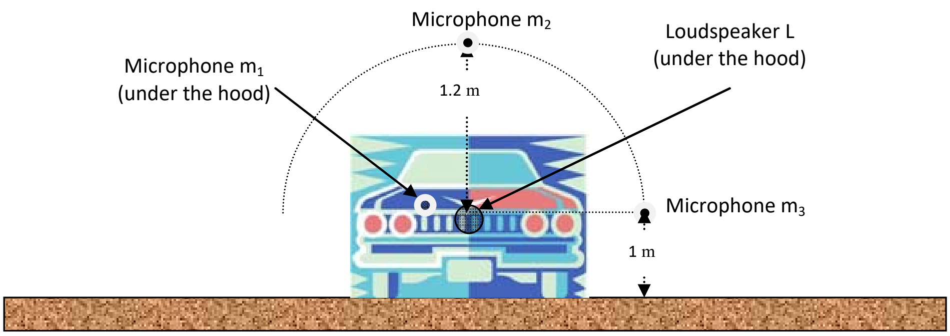
1 Introduction

Noise radiated by individual vehicles can be influenced by driving behaviour. For instance, engine noise produced by aggressive drivers is, in average, 5–6 dB, in urban circuits, and 8–9 dB, in suburban roads, higher than the global engine noise. The rolling noise generated by these drivers is, in average, 3–5 dB above the global rolling noise (Ibarra et al., 2010). In order to discriminate these aggressive drivers from the main traffic stream, an onboard electro-acoustic system was proposed, consisting of two microphones, one for the engine noise, located inside the engine compartment, and another for the rolling noise, near to one of the rear wheels, together with a noise measurement system. For the sake of comparison with the usual limit noise levels, the noise measurements carried out by these near field microphones might be extrapolated to the far field (Anfosso-Ledee, 2004; Cho and Mun, 2008). Previously, the engine noise picked up by microphone under the compartment must be propagated to another outside. In other words, the attenuation of the noise through the engine compartment must be calculated. This is the aim of this paper. Section 2 describes two methods to measure the noise attenuation through a panel. Section 3 shows the results, and Section 4 presents the main conclusions.

2 Methods

Let us consider a loudspeaker, L, inside the engine compartment of the vehicle (Figure 1). Three microphones m_1, m_2 and m_3, are located under the compartment, outside in the vertical axis over the compartment, and beside the car, respectively. Microphones m_2 and m_3 are over a circumference of radius 1.2 m, centred at the position of the loudspeaker. The height of microphone m_3 is 1 m. Let r_1, r_2 and r_3 be the time response between the loudspeaker L and the microphones m_1, m_2 and m_3, respectively, measured with the engine compartment closed. By Fourier transforming these time responses, the frequency responses H_1, H_2 and H_3 are obtained.

Figure 1 Setup for the measurement of *TL* and *IL* (see online version for colours)



Transmission loss (*TL*) through the engine compartment at the positions of microphones m_2 and m_3 are defined as (Beranek and Ver, 1992):

$$TL_2(f) = 20\log\left(\frac{|H_2(f)|}{|H_1(f)|}\right) \tag{1a}$$

and

$$TL_3(f) = 20\log\left(\frac{|H_3(f)|}{|H_1(f)|}\right) \tag{1b}$$

where |.| denotes spectral magnitude. Alternatively, if the frequency responses at microphones m_2 and m_3 are measured with the engine compartment open and closed, insertion loss (*IL*) can be defined as (Beranek and Ver, 1992):

$$IL_2(f) = 20\log\left(\frac{|H_2(f)|open}{|H_2(f)|closed}\right) \tag{2a}$$

and

$$IL_3(f) = 20\log\left(\frac{|H_3(f)|open}{|H_3(f)|closed}\right) \tag{2b}$$

Whilst *TL* represents the protection against the engine noise provided by the compartment, *IL* characterises the attenuation produced by inserting the compartment between the inner loudspeaker and the outer microphones.

3 Measurement results

Both *TL* and *IL* of the engine compartment of a Renault Kangoo vehicle were measured at the installations of the centre for applied acoustics and non destructive testing (CAEND, CSIC), using a spherical box with a loudspeaker Macrom RG 2.30 and three microphones SHURE MX183. Figure 2 shows the frequency response of the loudspeaker and microphone.

The loudspeaker and the microphones where located in the positions shown in Figure 1 and the time responses were measured by using the maximum length sequences (MLS) method (Cobo et al., 2007). Figures 3 and 4 illustrate the locations of the loudspeaker and microphones. To filter out reflections and diffractions at surfaces and objects near the measurement site, time responses were appropriately windowed. The windowed time responses were then transformed to the frequency domain to obtain the corresponding frequency responses. The application of equations (1)–(2) provides finally the *TL* and *IL* functions.

Figure 5 shows the engine compartment *TL* and *IL*, at the locations of microphones m_2 and m_3, as a function of frequency. Table 1 summarises the overall *TL* and *IL*, in the frequency band (20 Hz, 5 kHz).

Figure 2 Free field frequency responses of the spherical loudspeaker (above) and microphone (below) (see online version for colours)

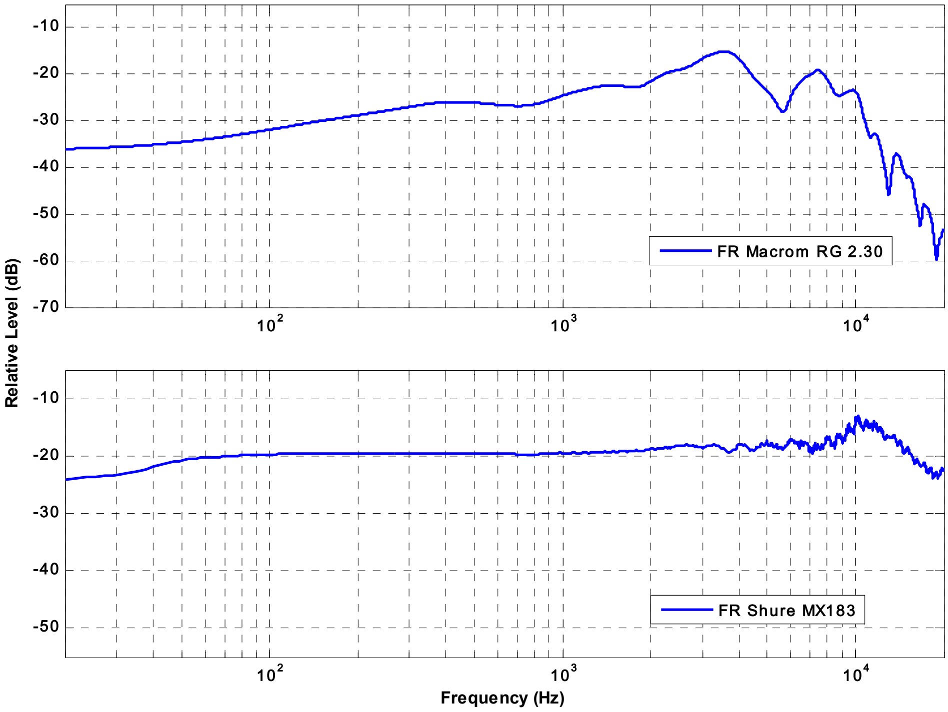
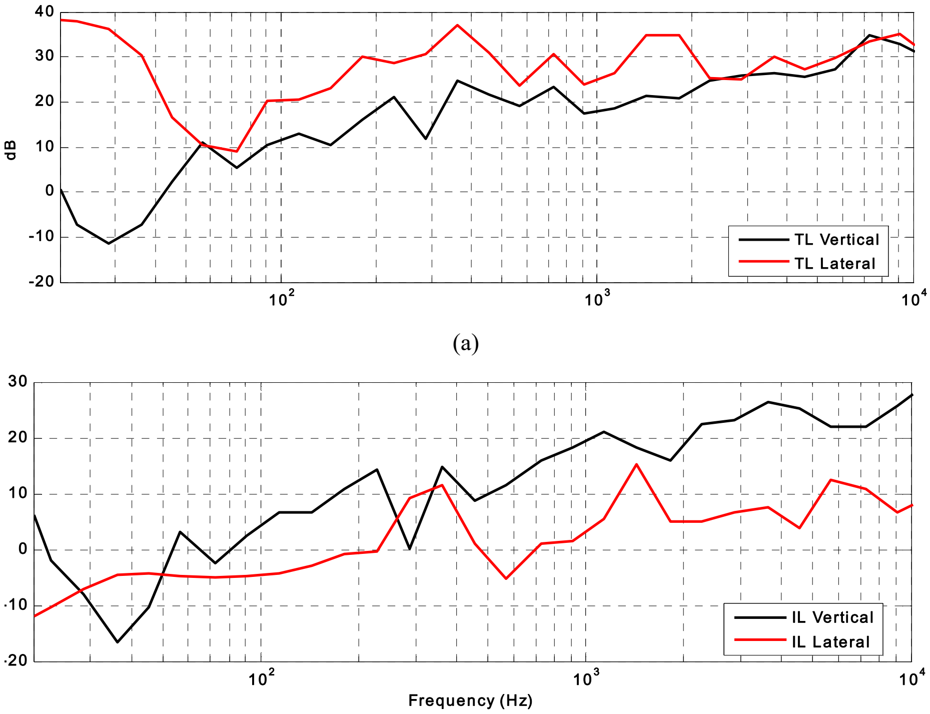


Figure 3 (a) Locations of the loudspeaker and microphone m_1 inside the engine compartment (b) Position of the outside, vertical microphone m_2 (see online version for colours)

(a) (b)

Figure 4 Position of the outside, lateral microphone m_3 (see online version for colours)

Figure 5 (a) *TL* and (b) *IL* of the engine compartment at the positions of the vertical and lateral outer microphones (see online version for colours)



(a)

(b)

As it can be seen:

- There are frequencies at which both *TL* and *IL* are negative. For the case of *TL* (below 43 Hz for the vertical position), this suggest that resonances inside the engine compartment occur at these frequencies. On the other hand, negative *IL* values can arise in noise leaks under the engine compartment.
- Both functions, *TL* and *IL*, differ significantly even for the same microphone position. *IL* values are significantly lesser than *TL* values.
- Both functions show also great differences with the microphone location. This supports the need of a more complete measurement of *TL* along the circumference in Figure 1 (directivity function). However, while TL_3 (lateral position) is greater than TL_2 (vertical position), the opposite happens with *IL*.

Table 1 Overall TL and IL of the engine compartment at the vertical and lateral positions

	TL (dB)	*IL (dB)*
Vertical position (m_2)	16.7	12.9
Lateral position (m_3)	27.0	3.7

4 Conclusions

This work has reported preliminary results on the measurement of noise reduction through the engine compartment of a vehicle. Two metrics were used two characterise the noise reduction: *TL* and *IL*. Both are calculated from the log-spectra of the transfer functions between a loudspeaker inside the engine compartment and microphones inside and outside the engine compartment. Measurements of both TL and IL were carried out at two points (vertical and lateral) of a circumference in a plane perpendicular to the engine compartment. Experimental results show that TL characterises better than IL the noise reduction in this application. In addition, they highlight the need for a more complete angle characterisation of the TL of vehicle engine compartment.

Acknowledgements

The author would like to thank Pedro Cobo for his help in the experiment design of this project at CSIC.

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