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Method to Determine the Speed of Vehicles by Means of Noise Levels Variation

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Abstract

Statistical Pass-By Index is a parameter defined on ISO 11819-1: 1997, that pretends to measure the influence of road surfaces on traffic noise. One of the base parameters of this index is speed of vehicles on the road. The present paper shows a method to determine the speed of vehicles on the road using the shape of noise levels variations, and shows the improvement that this method can give one the selection of most correct pass-by levels.

Keywords: Statistical pass-by index, Acoustical speedometer, ISO 11819-1.

1 Introduction

The characterization of the Statistical Pass-By Index [1] implies the implementation of several *in situ* measurements of the maximum sound level, L_{Max}, for the pass-by of vehicles and the control of their speed.
Since it is necessary that the L_{Max} of the noise measured is representative of the pass-by of the vehicle, should be selected only the events that meet this objective and should be excluded the events that have the influence of other factors, including noise from other sources.

Given the large number of measurements needed (at least 100 cars and 80 trucks [1]) it appears that may not be an easy task selecting only the events representing the noise of pass-by of each vehicle, especially when the volume of traffic is high and/or when drivers decide to use the horn.

The present method wants to establish an objective way to select the right events, based on the theoretical relationship between the variation of sound levels at the pass-by of one vehicle and their speed, in order to avoid the negative impact of subjective decisions to consider or not some event, because, for example, there are other vehicle on the proximity or someone make use of horn.

2 Theoretical foundations

Assuming that the vehicles can be simulated by a single omnidirectional point source, the sound intensity level, L_I, at a given distance d of the vehicle is given by (ISO 9613-2, 1996 [2]):

$$L_1 = L_W - A_{div} - A = L_W - 11 - 20\log(d) - A \tag{1}$$

Where L_w is the sound power level of the vehicle (this parameter depends on the type of vehicle, its speed and interaction tire/pavement), $A_{div} = -11 - 20\log(d)$ the Geometrical Divergence and A a generic attenuation.

Assuming that the pass-by of a vehicle at constant speed in a straight path, as illustrated in Figure 1, implies only the variation of Geometrical Divergence, you can write sound intensity level, L_I, as a function of time t, speed v and perpendicular distance to the road $d_\perp$, using the following equation:

$$L_1 = L_W - 11 - 20\log\left(\sqrt{d_\perp^2 + (vt)^2}\right) - A \tag{2}$$

Normalizing the expression (2) for the maximum value that occurs for $t = 0$, we can write:

$$L_1 - L_{Max} = -20\log\left(\sqrt{d_\perp^2 + (vt)^2}\right) + 20\log(d_\perp) = -20\log\left(\sqrt{1 + \left(\frac{v}{d_\perp}t\right)^2}\right) \tag{3}$$

For $d_\perp$=7,5 m, is shown in Figure 2 the theoretical variations of sound levels for the following speeds: 50 km/h, 90 km/h and 120 km/h, and the linearization of expression (3) for the same speeds.

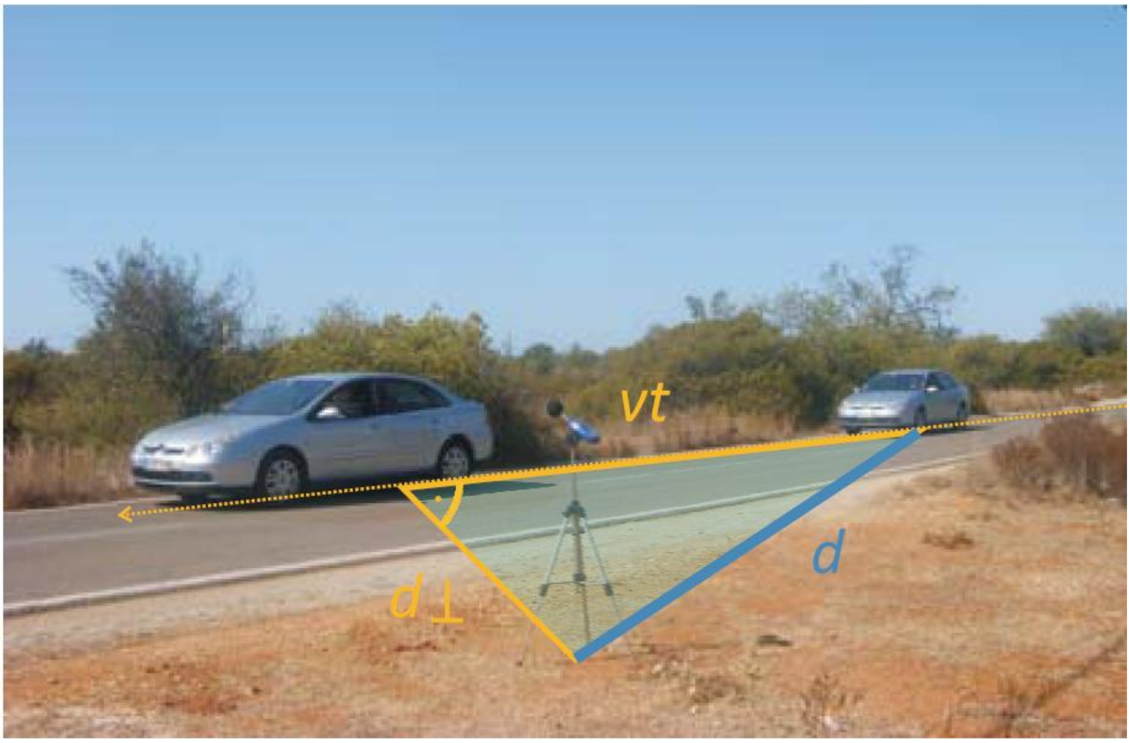

Figure 1 – Trigonometric relations between the pass-by of a vehicle and a point at a given distance $d_{\perp}$ of the road.

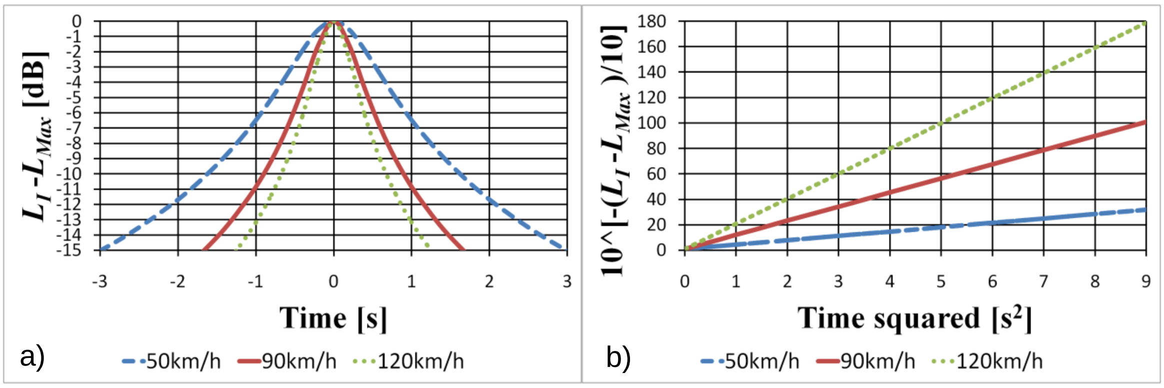

Figure 2 – a) Theoretical variation of normalized noise levels for vehicle pass-by at 3 different speeds and b) linearization.

Can be proved that speed v has the following relationship with the slope m on the graph b) of Figure 2:

$$v = d_{\perp}\sqrt{m} \text{ [m/s]} \tag{4}$$

So, is expected the following slopes for measurements at $d_{\perp}$=7,5 m:

$$m_{50km/h} = 3{,}4\,,\ m_{90km/h} = 11{,}1\,,\ m_{120km/h} = 19{,}8 \tag{5}$$

3 Experimentation

3.1 Equipment

To perform the experiment was used:

1. Two car with cruise control: Brand: Citroen, Model: Xsara and C5.
2. Two Class 1 sound level meter: Brand: 01dB and RION, Model: Blue Solo and NA 27, which allows recording the sound levels at 20 ms steps.

3.2 Results

Measurements were made at 3 different speeds: 50 km/h, 90 km/h and 120 km/h.
There are, in Figure 3, examples of experimental results for each of these 3 speeds.

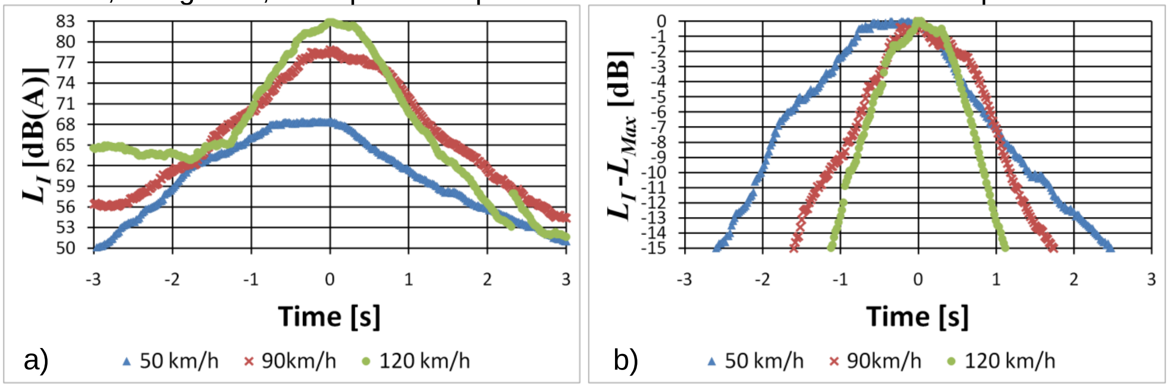

Figure 3 – Example of experimental results: a) variation of noise levels and b) variation of the normalized noise levels.

The results led to the prediction of the following average values:

- 50 km/h at the speedometer of vehicle → predict 47 km/h ± 17%.
- 90 km/h at the speedometer of vehicle → predict 79 km/h ± 11%.
- 120 km/h at the speedometer of vehicle → predict 108 km/h ± 8%.

It thus appears that the uncertainties of measurements of speed by this method are greater than ± 3% established in ISO 11819-1 [1], so that, as would be expected, this method is not suitable for accurate determination of speed of vehicles, but has apparently enough resolution to allow distinction of uncharacteristic pass-by.

Be noted that was not checked the uncertainty of speedometer of the vehicle, so it is not conclusive the deviation of the average values predict, when compared with the value of speedometer.

3.2.1 Details

Analyzing the graphs of Figure 3, we can see that in the immediate vicinity of 0 seconds (because the vehicle is not a point) and when the noise levels are lower (due to the influence of residual noise and others attenuations), there are greater differences between experimental values and theoretical expression.

Accordingly, it is necessary to select the most appropriate areas of ascend and descent levels. For the present results obtained it was considered sufficient and necessary to limit the analysis to the values which are between 15 dB and 2 dB below the maximum value.

To note that, at the speed of 120 km/h, a 15 dB variation occurs just in 1 second, so it is necessary that the sound level meter has an integration time less than 1 second.

3.3 Results with horn

There are, in Fgure 4, examples of two experimental results, when the driver used the horn, before and exactly when passing trought noise level meter.

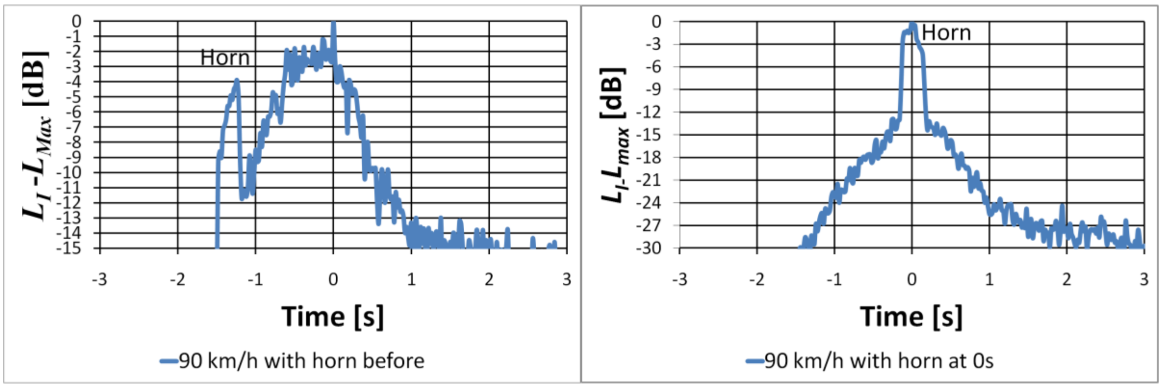

Figure 4 – Example of experimental results normalized: a) with horn before b) with horn at 0s.

Like we can see, the results of Figure 4a) can be used, if we select the right maximum, but results of Figure 4b can not be used.

4 Conclusions

While it appears to be necessary further developments, in order to fully demonstrate the feasibility and applicability of the method, we think that the results are encouraging to do in fact more measurements, including others situations of atypical vehicle pass-by, to provide the best limits of representativity, which can be used to improve the accuracy and applicability of ISO 11819-1.

References

[1] ISO, International Standard 11819-1: Acoustics - Measurement of the influence of road surfaces on traffic noise. Part 1. Statistical Pass-By method. 1997.

[2] ISO, International Standard 9613-2: Acoustics. Attenuation of sound during propagation outdoors. Part 2: General method of calculation. 1996.