Relating the near field noise of passenger cars with the driving behavior

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Road traffic noise amounts to roughly half of the overall ambient noise. Usual emission (vehicle emission limits) and immission (barriers, sound-reducing windows) noise control techniques have not been enough to decrease significantly the annoyance by road traffic over the last three decades. The positive effect of these control techniques has been counteracted by the increase of traffic density. Moreover, the traffic noise annoyance is highly correlated with the maximum noise levels usually produced by aggressive drivers. However, current traffic noise measurement systems are based upon an overall assessment, so that they are unable to discriminate between quiet and noisy drivers. Therefore, a near field noise measuring system is proposed in this paper that is able to measure the contribution of each vehicle to the road traffic noise, allowing the detection of noisy drivers. The system is based on two onboard microphones, one for the engine noise and other for the rolling noise. Experimental results are provided that demonstrate the performance of the proposed system on five drivers, along suburban and urban courses of a large city, with petrol and diesel vehicles. The analysis of concurrent acoustical and driving condition data reveals that the system is capable of discriminating clearly those vehicles generating the maximum noise levels.

Primary subject classification: 13.2.1; Secondary subject classification: 52.3

1 INTRODUCTION

It has been estimated that 20% of the EU population (80 million people) suffer for noise levels that are considered to be unacceptable, and another 45% (170 million people) are likely to live in areas where noise can cause serious annoyance[1]. Percentages are similar, or even worse, in other densely populated countries[2]. Roughly half of the noise in urban areas is considered to arise from road traffic[1].

Road traffic noise may be reduced by either emission (at the source) or immission (at the receiver) control techniques. Whereas noise emission control techniques generally affect the entire area in which they are applied, noise immission control techniques are local and effective only in the place where they are applied. In many countries, immission control measures (noise barriers, sound-reducing windows, etc) are applied where L_{Aeq} exceeds 65 dBA, thus benefiting only a moderate number of people. One of the first noise emission control measure was the regulation of the maximum permissible sound level for different vehicle types[3]. However, although noise emission limits in the EU have decreased in 8-11 dB in the last 30 years, community surveys indicate that noise annoyance has been rather stable over time[3]. Taking the traffic growth into account, this means that the improvements in noise emission of individual vehicles have been approximately counteracted by the increase of traffic density.

An additional reason that has been suggested to explain the rather reduced impact of the regulated noise limits in the global community noise is the lack of realism and representativeness of driving conditions in the measurement method on which vehicle type approval is based[2]. Whilst real vehicle noise emission is affected by driving behavior[4], the type approval measurement is carried out in unrealistic conditions.

In many countries, the reduction of the regulated noise emission limits for road vehicles has been accompanied by recent legislation establishing

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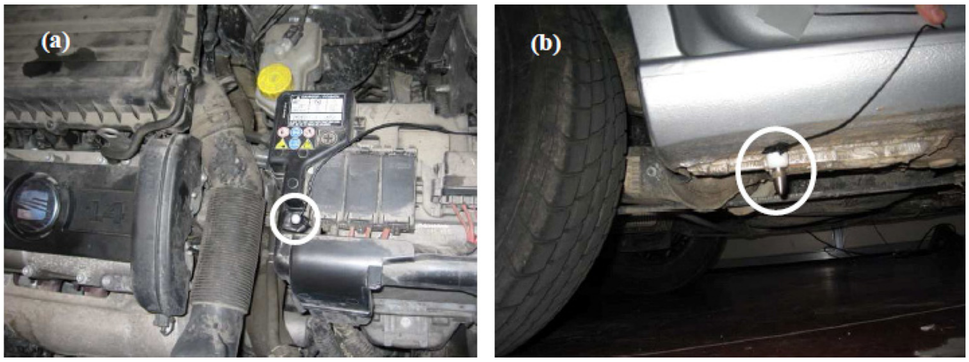

Fig. 1—Locations of the microphones for (a) the engine noise and (b) the rolling noise.

environmental noise limits which cannot be exceeded. In Spain, for instance, the Noise Law 37/2003, a transposition of the EU Directive 2002/49/CE, sets 65 dBA as the day level L_d limit in residential areas (55 dBA as the night level L_n limit). However, this noise limit level is surpassed every day in many of the measurement stations of the environmental monitory network of a densely populated Spanish city as Madrid[5].

The European Union set up the goal of attaining an ambiental A-weighted noise level reduction in the member countries of 10 dB for the year 2020[1]. Concerning the road traffic noise, Kropp reported that it is possible to reduce road traffic noise emission in 5 dB with the technology currently available, provided that the three involved parties (vehicle manufacturers, tire manufacturers and road managers) coordinate each other to decrease all the vehicle noise sources.[6] For instance, a total road traffic noise reduction of 5 dB should require a decrease of 6 dB of tire/road noise combined with a diminution of 4 dB of engine noise at 30 km/h, or 2 dB at 110 km/h.[6] This calculation did not take into account the driving style. But a same vehicle can be driven in either noisy or quiet ways by two different drivers. As pointed out by Plunt[7], driving behavior would also have substantial impact on noise radiation by vehicles. Reduction of noise radiation involves the moderate use of acceleration avoiding high average rpm at lower gear shifts. As an example, eco-driving with large low speed torque at 2000 rpm can potentially decrease the engine noise 8-10 dB with respect to a small low speed torque[7].

The opposite of eco-drivers, aggressive drivers, are responsible of the radiation of Maximum Noise Levels (MNL) to the environment. Furthermore, MNL is highly correlated with noise annoyance[8]. According to Rylander[9], decreasing MNL in 10 dB would reduce the very annoyed population in 15%.

Thus, the general goal of a reduction in the A-weighted level of 10 dB for the year 2020 could be obtained if the 5 dB potentially afforded by the current technology is combined with some administrative control on noisiest drivers. However, nowadays, noisy drivers are hidden in the whole traffic stream, and there are no technical devices which are being used to distinguish them. The primary goal of this paper is to elucidate if these drivers can be detected via a noise measurement system on board the vehicle. This system

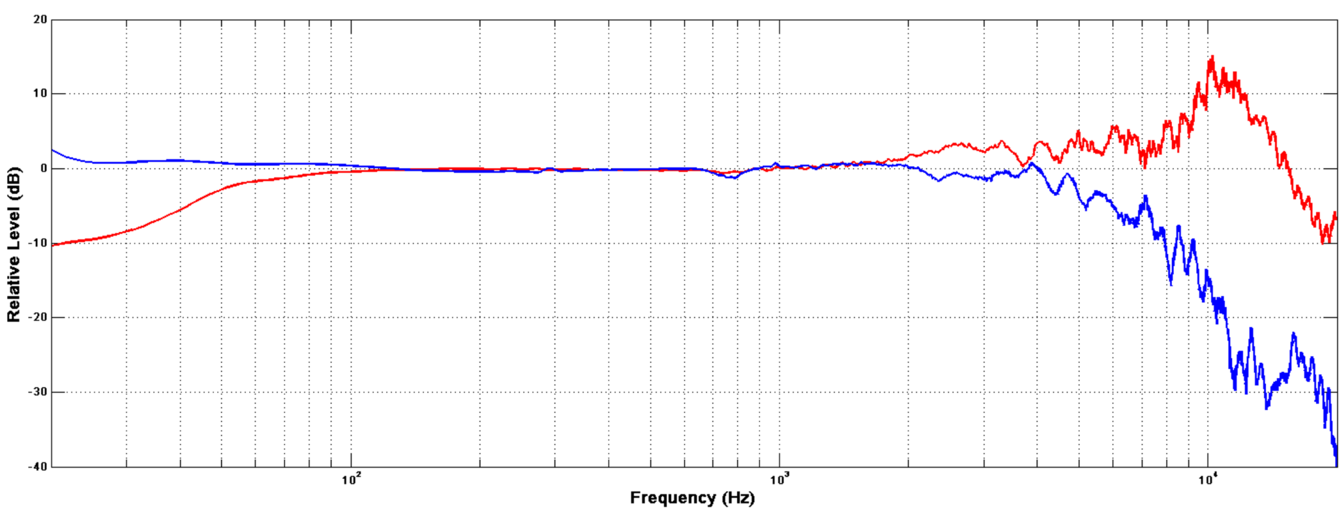

Fig. 2—Frequency responses of the Shure MX183 microphone (red) and the nose cone (blue).

should include acoustic sensors (microphones) to measure the contribution of the two main noise sources in vehicles, namely, the power unit noise and the tire/road noise[10–12]. For this purpose, one of the microphones is located near the engine while the other is positioned close to one of the wheels[13]. Simultaneously, information about the driving performance can be picked up from the CAN BUS interface of the vehicle, so that the analysis of coincident acoustical/driving behavior data would allow establishing the correlation, if any, between the noise emitted by individual vehicles and the driving style.

It should be noted that such noise monitoring system would provide engine and rolling noise levels at the near field of the vehicle, which should not be confused with the far field levels usually taken into account in noise legislation. Also, the measurement of the near field rolling noise proposed here does not follow the Close-Proximity (CPX) method set up in ISO/CD 11819/2 standard, since this method measures the influence of road surfaces on traffic noise while our goal is to measure the contribution of each vehicle to the road traffic noise.

The paper is organized as follows. First, the selected vehicles, drivers, and driving courses, as well as the acoustical sensors are described in Sec. 2. Section 3 illustrates the capabilities of the proposed system by means of an experiment carried out in urban and suburban courses, with different car types and drivers.

2 MATERIALS AND METHODS

2.1 Selection of the Vehicles, Courses and Drivers

Passenger cars are usually classified into different segments depending on their size, refinement, and therefore price. Analyzing the Spanish fleet, two vehicles in the segment B (Hatchback), very popular in the circulation in large cities, were chosen. These vehicles are compact, low capacity and typically up to 73 kW (100 hp) power with low fuel consumption. Analyzing car records in Spain for 2009, this segment corresponds to 30% of the fleet.

Since the market proportions of diesel and petrol engines in Spain are 60% and 40%, respectively, it seems reasonable to analyze both types in the study. Taking also into account the vehicle record statistics published by ANFAC (Spanish Association of Vehicle Manufacturers), the chosen vehicles were:

- Vehicle #1: Seat Ibiza Petrol.
- Vehicle #2: Seat Ibiza Diesel.

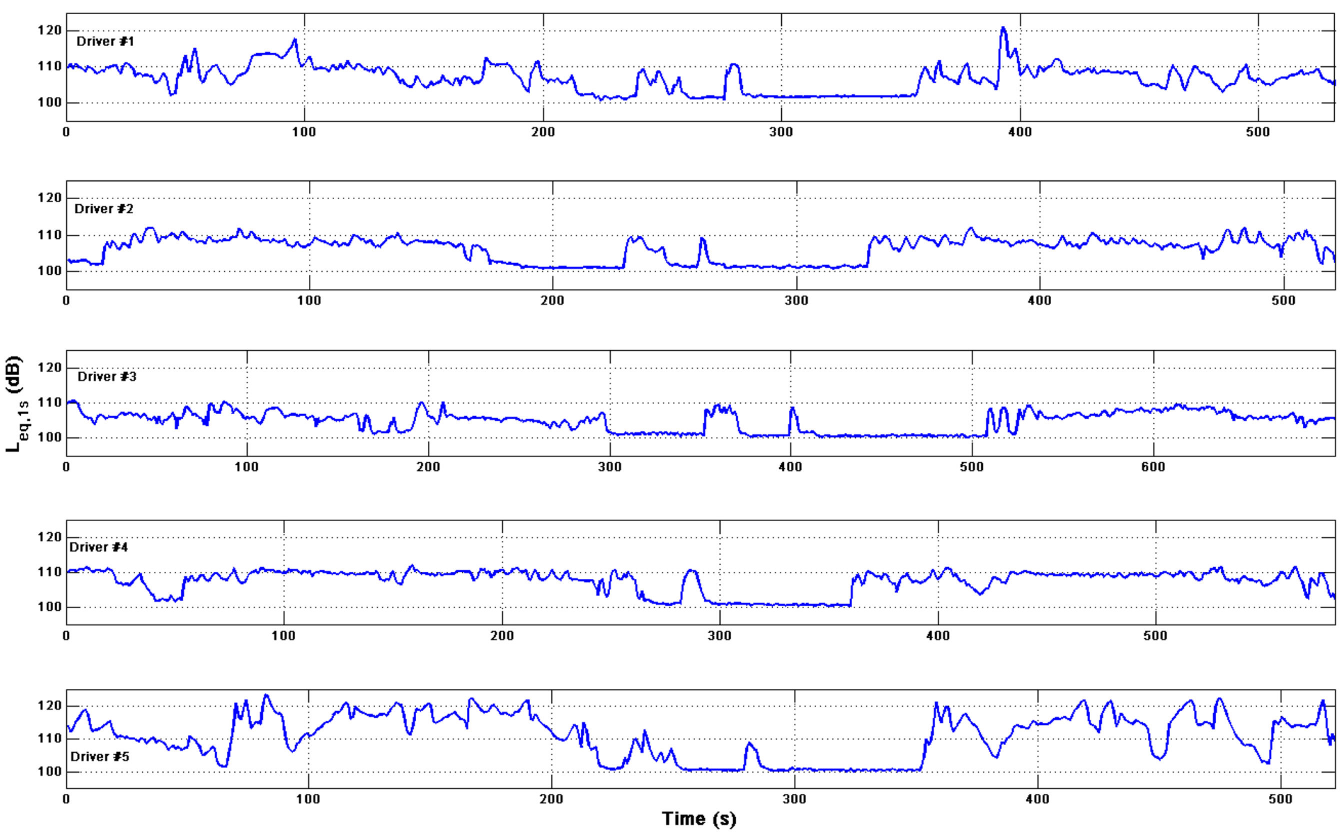

Fig. 3—Time evolution of the engine noise $L_{eq,1s}$ for the five drivers of the diesel vehicle along the suburban course.

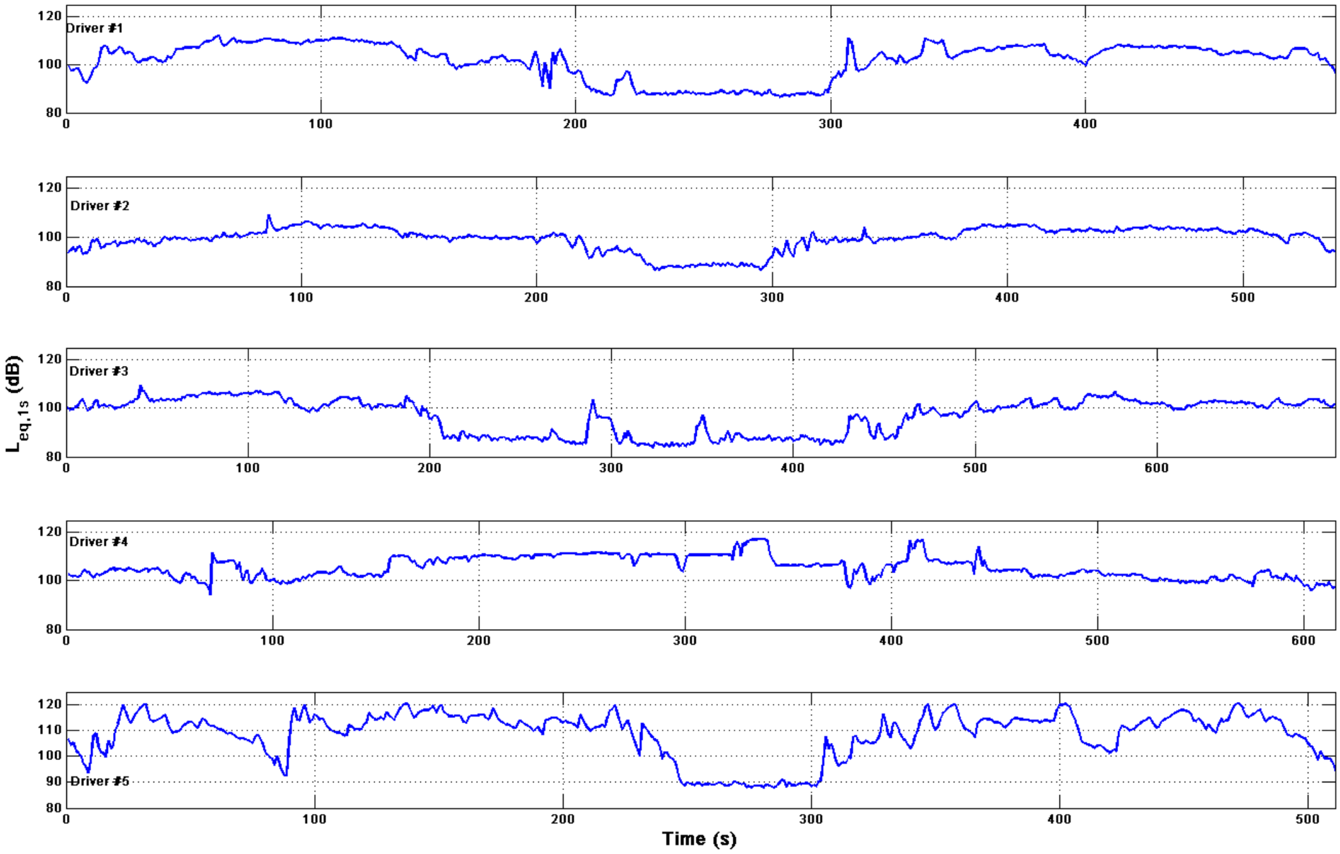

Fig. 4—Time evolution of the engine noise $L_{eq,1s}$ for the five drivers of the petrol vehicle along the suburban course.

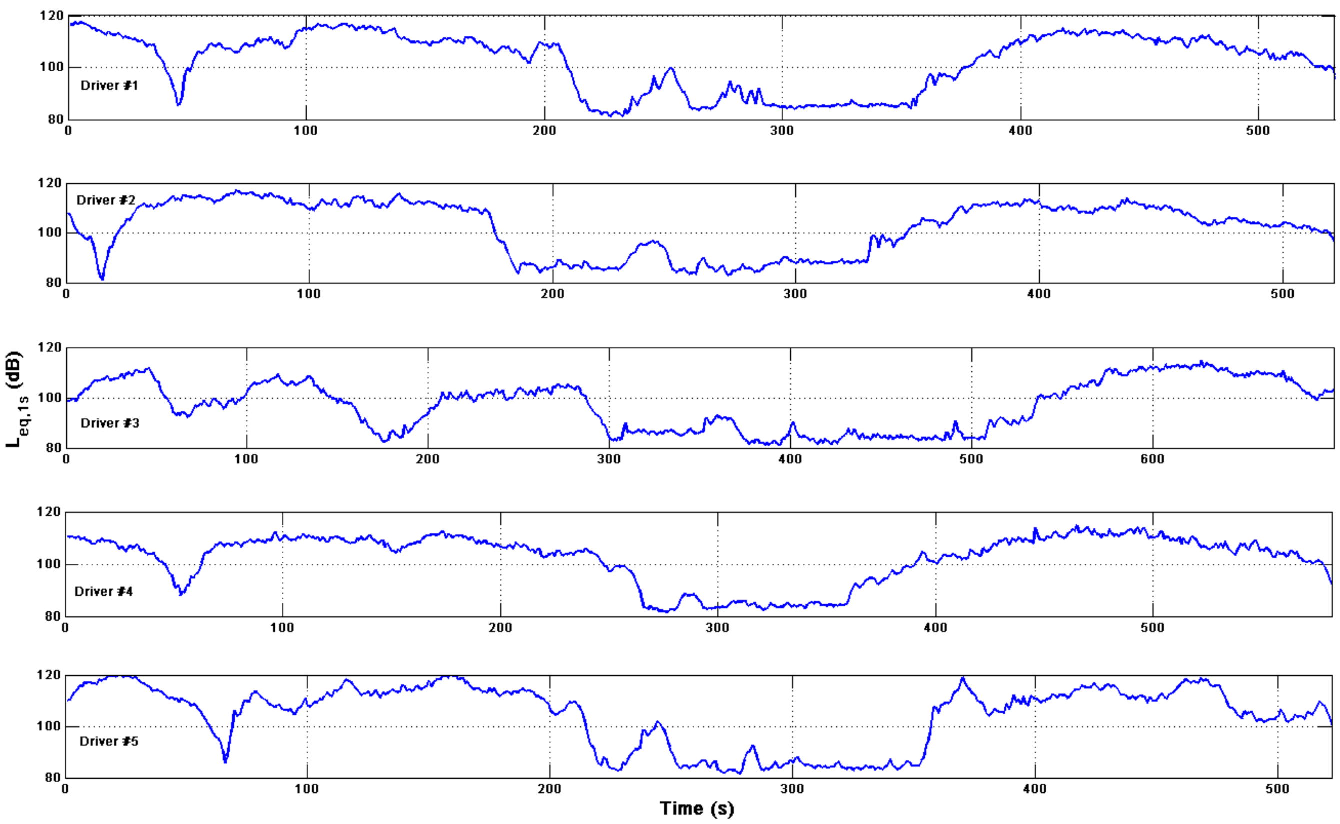

Fig. 5—Time evolution of the rolling noise $L_{eq,1s}$ for the five drivers of the diesel vehicle along the suburban course.

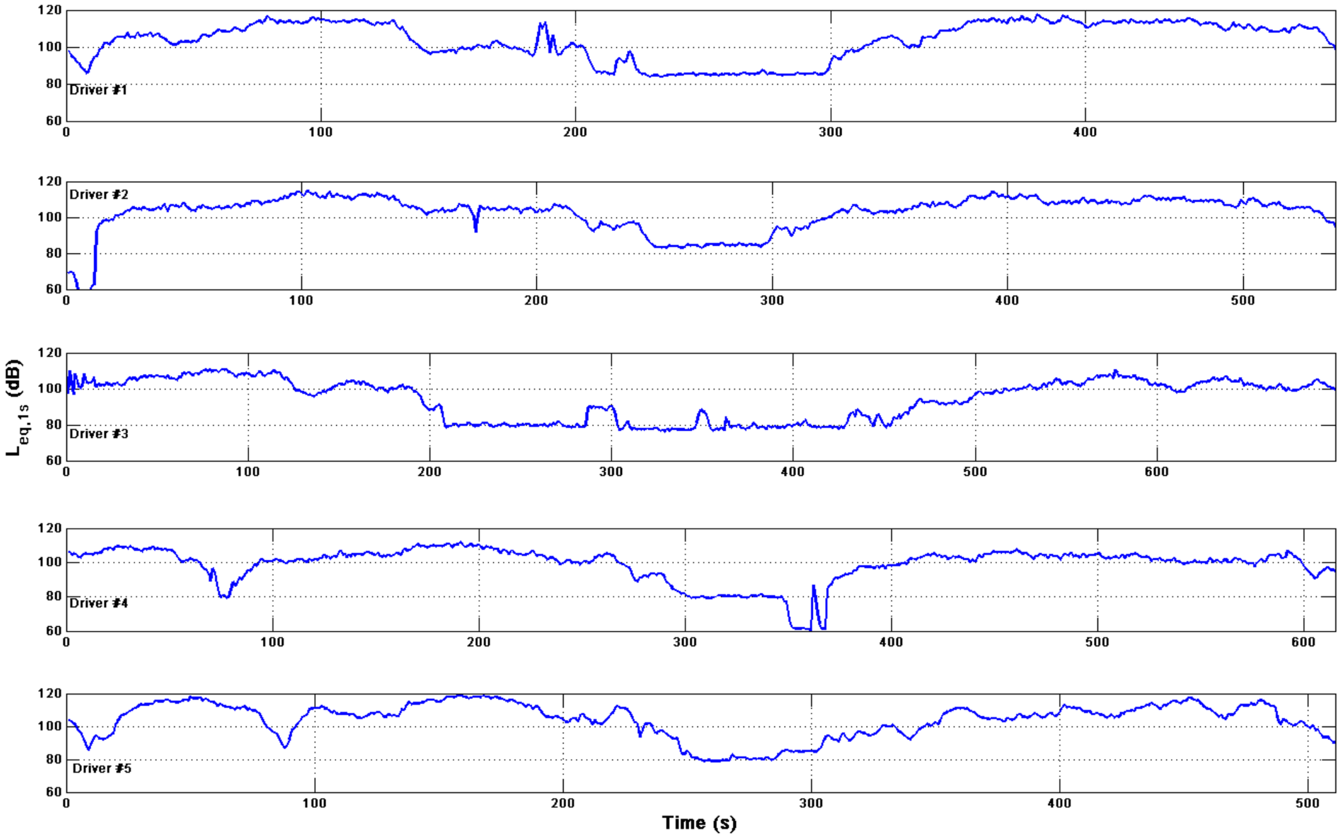

Fig. 6—Time evolution of the rolling noise $L_{eq,1s}$ for the five drivers of the petrol vehicle along the suburban course.

According to the EU Report *Research for the Sustainable Mobility*[14], over 75% of the EU population lives in urban areas. Thus, urban transport has a large burden in the overall mobility. For example, a fifth of the distances travelled in the EU are urban and suburban courses of length lower than 15 km (9.4 mi). Also, the main itinerary of drivers from home to the working place is between 8 and 12 km (5 and 7.5 mi).

Therefore, two driving courses were chosen in the Carabanchel district, at the south of Madrid. The

Table 1—Driving parameters along the suburban course with the diesel vehicle.

Driving parameter		Driver #1	#2	#3	#4	#5
Vehicle speed (km/h)	Average (km/h)	92.0	87.9	63.3	76.6	100.7
	Maximum (km/h)	126.2	124.2	108.5	98.9	158.5
	Standard deviation (km/h)	25.6	22.3	25.8	17.5	25.2
Engine speed (rpm)	Average	1980	1910	1880	1830	3450
	Maximum	3150	2950	2980	2910	5010
	Standard deviation	510	450	430	380	730
Course	Distance (m)	8587	8648	8547	8678	8558
	Time (min)	5.6	5.9	8.1	6.8	5.1
Time at gear shift (%)	1st	0.0%	0.0%	0.0%	0.0%	0.0%
	2nd	5.5%	2.8%	13.4%	2.3%	13.4%
	3rd	28.8%	2.8%	45.1%	9.8%	66.9%
	4th	36.5%	14%	19.5%	16.2%	11.1%
	5th	19.3%	71.5%	13.8%	67.3%	0.0%
	Gear changing	9.9%	8.9%	8.2%	4.4%	8.6%

Table 2—Driving parameters along the suburban course with the petrol vehicle.

Driving parameter		Driver #1	#2	#3	#4	#5
Vehicle speed (km/h)	Average (km/h)	95.0	79.2	82.5	80.1	94.8
	Maximum (km/h)	125.4	101.9	107.3	102.8	157.4
	Standard deviation (km/h)	23.1	15.4	17.5	15.6	34.5
Engine speed (rpm)	Average (rpm)	2650	2490	2590	2585	4040
	Maximum (rpm)	6280	5990	5890	5930	5850
	Standard deviation (rpm)	652	520	650	488	1163
Course	Distance (m)	9347	9380	9350	9344	9635
	Time (min)	5.9	7.1	6.8	7	6.1
Time at gear shift (%)	1st	0.0%	0.0%	0.0%	0.0%	0.0%
	2nd	0.0%	0.0%	3.6%	2.0%	15.1%
	3rd	20.4%	3.0%	12.6%	4.3%	44.4%
	4th	17.0%	12.2%	21.5%	24.3%	22.5%
	5th	55.2%	77.0%	52.8%	62.2%	7.8%
	Gear changing	7.4%	7.8%	9.5%	7.2%	10.2%

suburban course runs along the M40 circumvallation highway, which supports a traffic density of 120 000 to 140 000 vehicles per day. It has a length of 8600 m (5.4 mi), with three lanes in each direction, and a maximum speed limit of 100 km/h (62 mi/h). The L_d in this area, according to the above referred strategic noise map of Madrid, is >75 dBA.

The urban circuit includes streets with speed limited to 50 km/h (31 mi/h) (in some sections the limit is 30 km/h (18.6 mi/h)), supporting a traffic density from

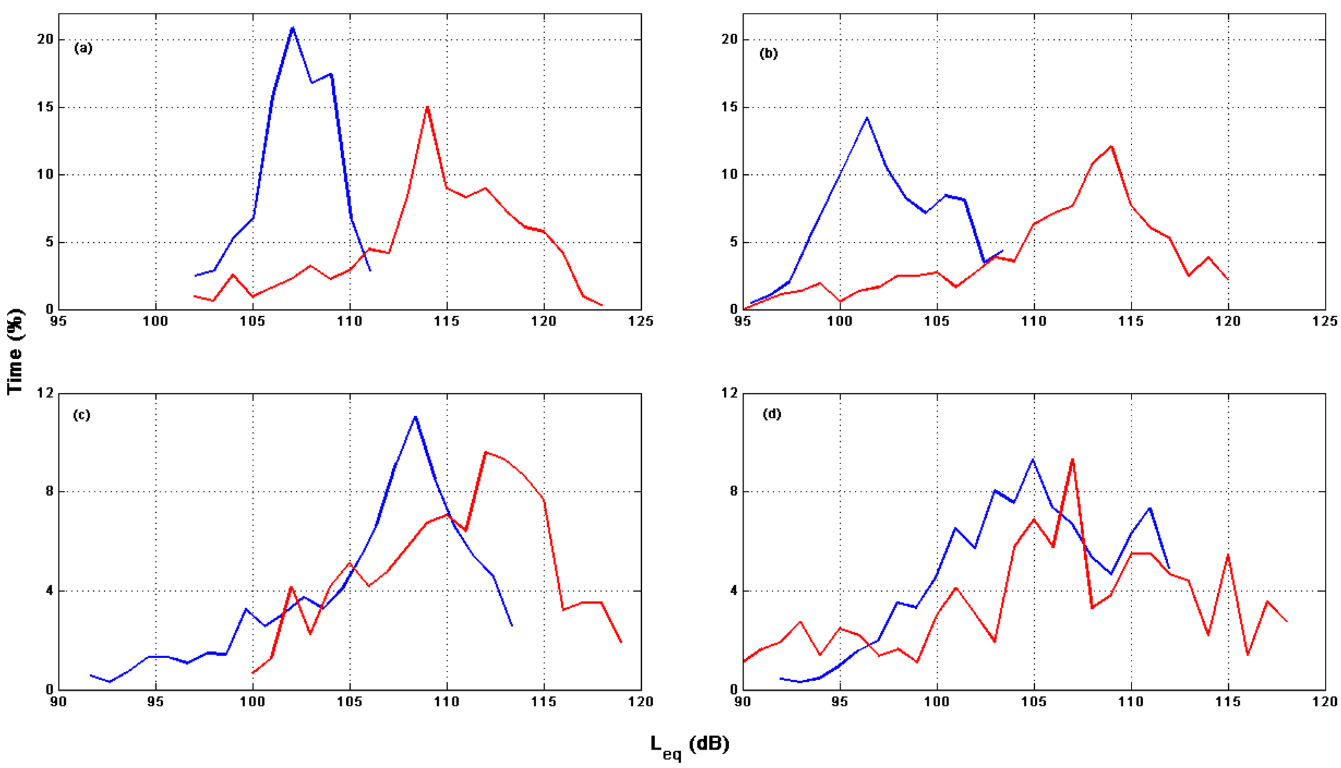

Fig. 7—Histograms of the averaged drivers #1-4 (blue) and driver #5 (red) for (a) engine diesel, (b) engine petrol, (c) rolling diesel, and (d) rolling petrol $L_{eq,1s}$ along the suburban course.

Table 3—Equivalent engine and rolling noise levels (dB) of the complete suburban course.

	Diesel				Petrol			
Driver	Engine noise		Rolling noise		Engine noise		Rolling noise	
#1	109	$\langle L_{eq} \rangle_{1-4}$	111	$\langle L_{eq} \rangle_{1-4}$	107	$\langle L_{eq} \rangle_{1-4}$	111	$\langle L_{eq} \rangle_{1-4}$
#2	108	108	111	109	102	105	108	108
#3	106		106		103		104	
#4	109		108		107		104	
#5	117		113		114		111	

20 000 to 40 000 vehicles per day, with a L_d of 70–75 dBA. 50% of the circuit runs through streets of a single lane in the direction of traffic, while the other 50% roughly correspond to streets with two lanes in each direction. It is approximately 8500 m (5.3 mi) large and is equipped with 25 traffic lights.

Five drivers have been selected for the tests on both vehicles, taking into account the statistics provided for the DGT (Spanish traffic managing administration) of Spain. Since the men/women ratio of Spanish drivers is 60/40%, three were men and two women. Two drivers (one man and one woman) had a driving license for less than five years. The other three had a driving license fir more than 5 years, one of them being a professional driver.

2.2 Acoustical Parameters: Microphones for Engine and Rolling Noise

Two microphones were used to measure the near field engine and tire noise of the vehicles. Since the main engine noise source during pass-by experiments is the air intake orifice[15], a Shure MX183 microphone was mounted inside the engine hood, close to this orifice, Fig. 1(a). The other microphone, also a Shure MX183, was mounted below the car chassis, near the wheel further from the exhaust duct, Fig. 1(b). To reduce the aerodynamically induced noise, this microphone was coated with an anti-turbulence nose cone. Both microphones were glued to the vehicle with a mastic adhesive.

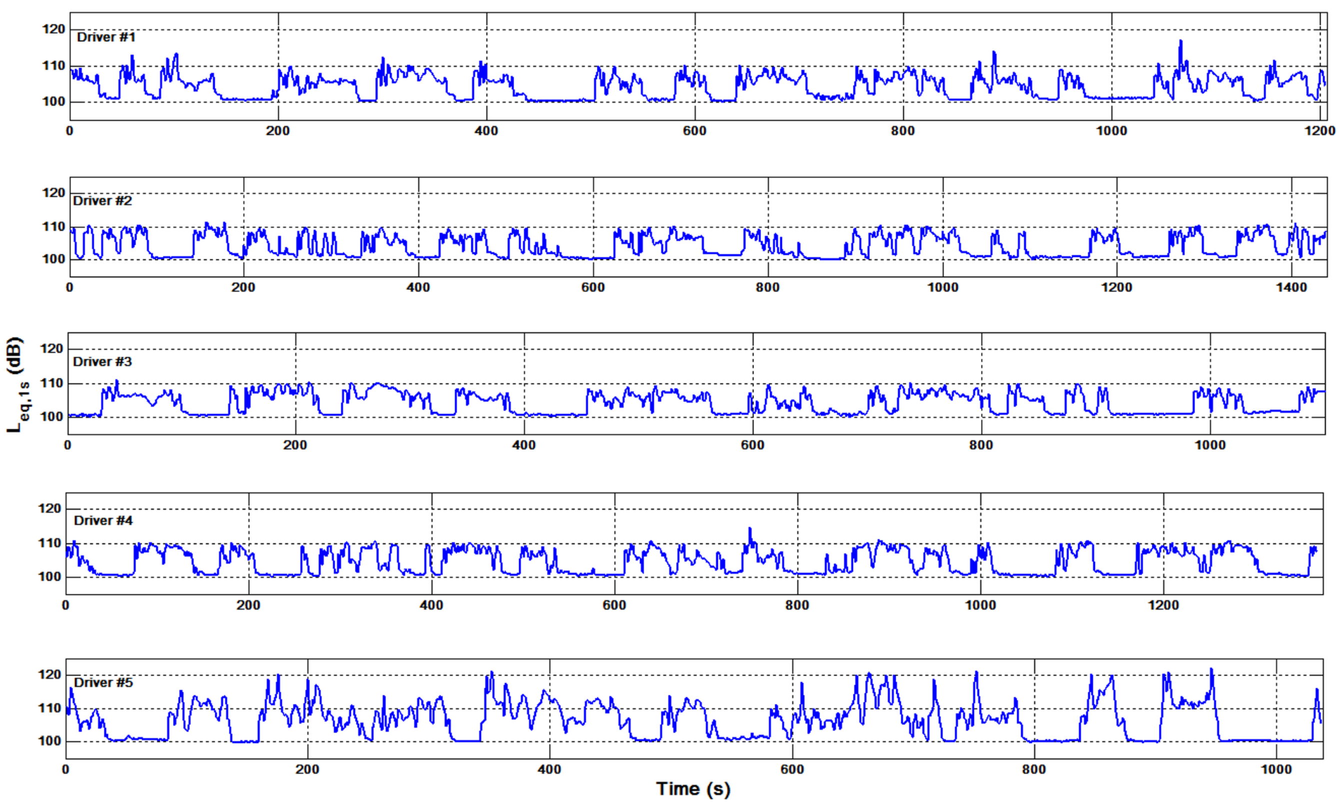

Fig. 8—Time evolution of the engine noise $L_{eq,1s}$ for the five drivers of the diesel vehicle along the urban course.

The Shure MX183 microphones have a nominal sensitivity of −27.5 dB re 1V/Pa (at 1 kHz) and support a maximum SPL of 117 dB, at 1 kHz for a 1 kΩ load. In prevision of louder noise levels, mainly in the engine noise microphone, the preamplifier was manipulated according its user guide to increase its dynamic range, at the cost of decreasing its nominal sensitivity. Tests carried out in a reverberant room demonstrated that the modified microphone+preamplifier supported roughly 129 dB.

The nose cone modifies the frequency response curve of the outer microphone. Figure 2 shows the frequency response curves of both the microphone and the nose cone. As it can be seen, the noise cone introduces a low-pass filtering effect at a cut-off frequency of roughly 4 kHz. This should not introduce a significant effect in the measurement of the tire/pavement noise since its spectrum decays rapidly above 1 kHz[16,17].

Engine and rolling noises were measured with the vehicles running in the conditions described in the Sec. 2.1. Previously, both microphones were adjusted with the B&K 4231 sound calibrator. Driving condition parameters were measured through the vehicle CAN BUS system, which includes a TMCAN-A0I4-Eth-ODB2 module. This system is interfaced to the acquisition system through an ELM317 probe, allowing to pick up information of three signals, namely, the engine speed (rpm), the engine load (%), and the accelerator position (%).

2.3 Test Procedure

Once the vehicle has been instrumented, each driver is asked to run both courses, urban and interurban, following the current traffic conditions. Additionally, driver #5 (the professional one) was requested to drive more aggressively, trying to reduce the time spent in both courses. The tests were conducted at different times, both during morning and evening, and on different days of the week. Acoustical and driving condition measurements are synchronously triggered at some starting point of both circuits. Once the circuits are completed, the vehicle returns to the laboratory for changing the driver and transfer the data to the workgroup server for further post-processing and analysis.

Besides the microphones, for acoustical data, and the CAN BUS system, for driving condition data, a Vbox Lite II GPS was used to record information on the vehicle position (latitude, longitude and height),

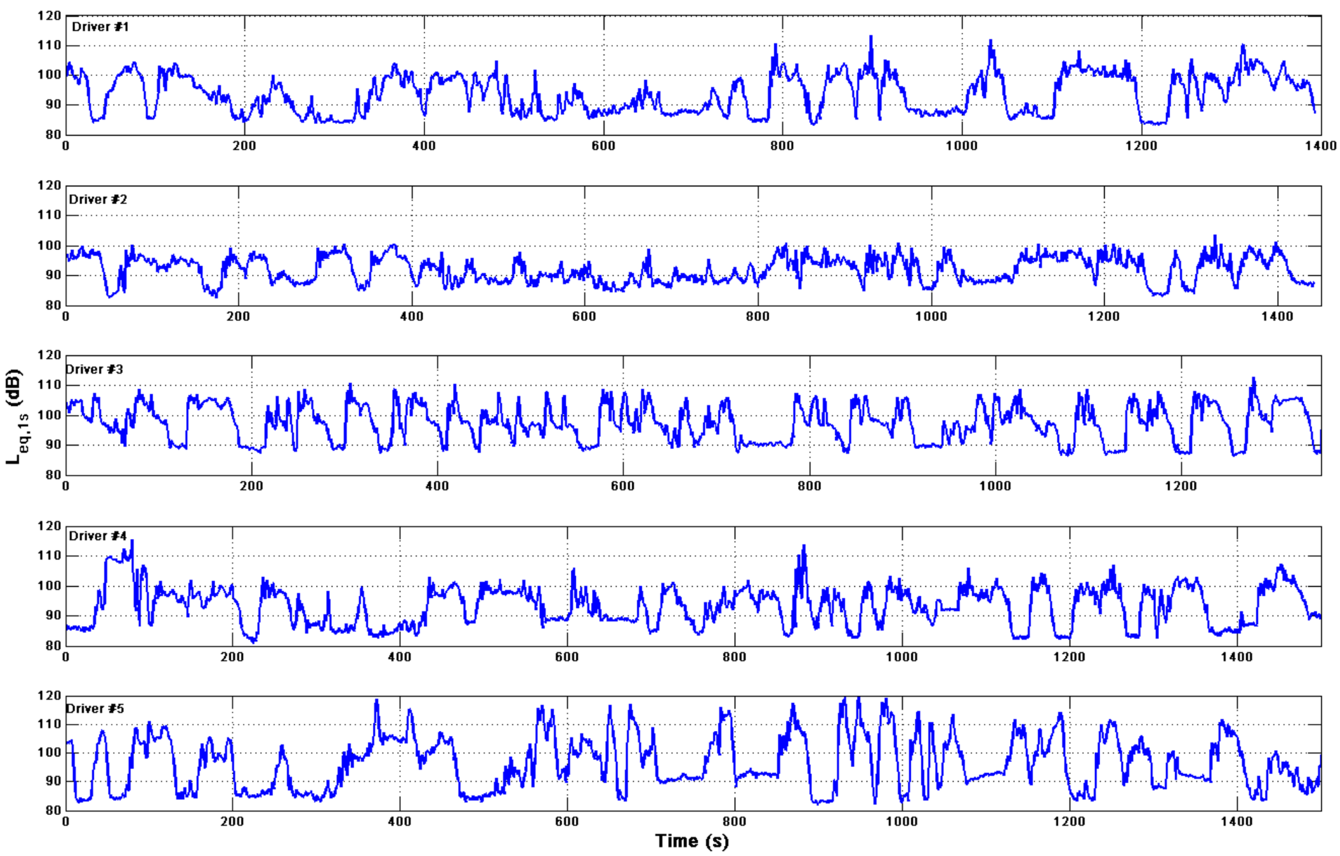

Fig. 9—Time evolution of the engine noise $L_{eq,1s}$ for the five drivers of the petrol vehicle along the urban course.

vehicle speed and acceleration (both longitudinal and lateral), and travelled distance and time.

3 EXPERIMENTAL RESULTS

Concurrent acoustical and driving behavior data were measured for the vehicles, paths and drivers described in Sec. 2.

3.1 High Speed Suburban Course

The two vehicles (diesel and petrol) described above were driven by the five drivers along the suburban course. Tables 1 and 2 summarize the parameters characterizing the driving style of the five drivers. Note that diesel vehicle uses lower average rpm than petrol vehicle, as corresponds to an engine with larger low speed torque. As expected, this course is done mainly in 4^{th} and 5^{th} gears and medium engine speed for petrol vehicle, except for driver #5 which is characterized by a much more aggressive use of acceleration (more frequent use of 3^{rd} gear, high rpm regime). Despite that, he spent roughly the same time than the others drivers to run the course, for the petrol vehicle case, and slightly less time, for the diesel vehicle.

Figures 3 and 4 show the time evolution of the $L_{eq,1s}$ of the engine noise for the diesel and petrol vehicles along the suburban course. This circuit contains a direction changing, which is done through a roundabout including a traffic light. This is observed in an obvious sound level decrease roughly at the centre of the time histories. As expected from the use a high engine regime (3^{rd} gear, high rpm), an evident noise increase of the engine noise is seen in driver #5, in comparison with the other four drivers, for both the diesel and petrol vehicles. Notice also that engine noise is higher for the diesel than for the petrol vehicle, mainly at the minima (neutral gear, in the traffic lights of direction changing).

Figures 5 and 6 show the time history of the $L_{eq,1s}$ of the rolling noise for the diesel and petrol vehicles along the suburban course. As expected, this noise is more correlated with the speed of each vehicle. However, whilst the rolling noise of driver #5 is significantly higher than other drivers for the diesel vehicle (its average speed is also appreciably higher, see Table 1), differences are less noticeable in the case of petrol vehicle (compare average speeds in Table 2).

For the sake of comparison, Fig. 7 shows the level histogram of time history of driver #5, in comparison

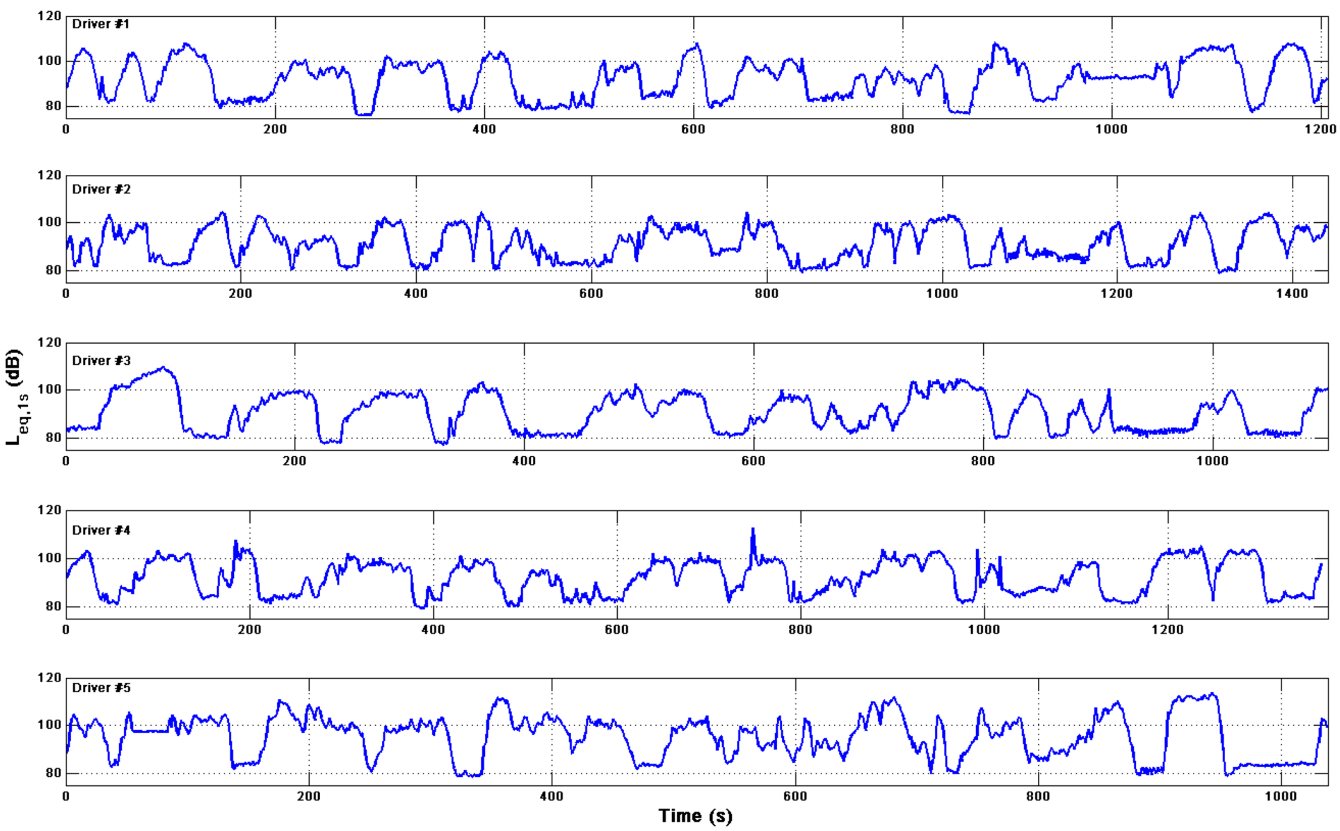

Fig. 10—Time evolution of the rolling noise $L_{eq,1s}$ for the five drivers of the diesel vehicle along the urban course.

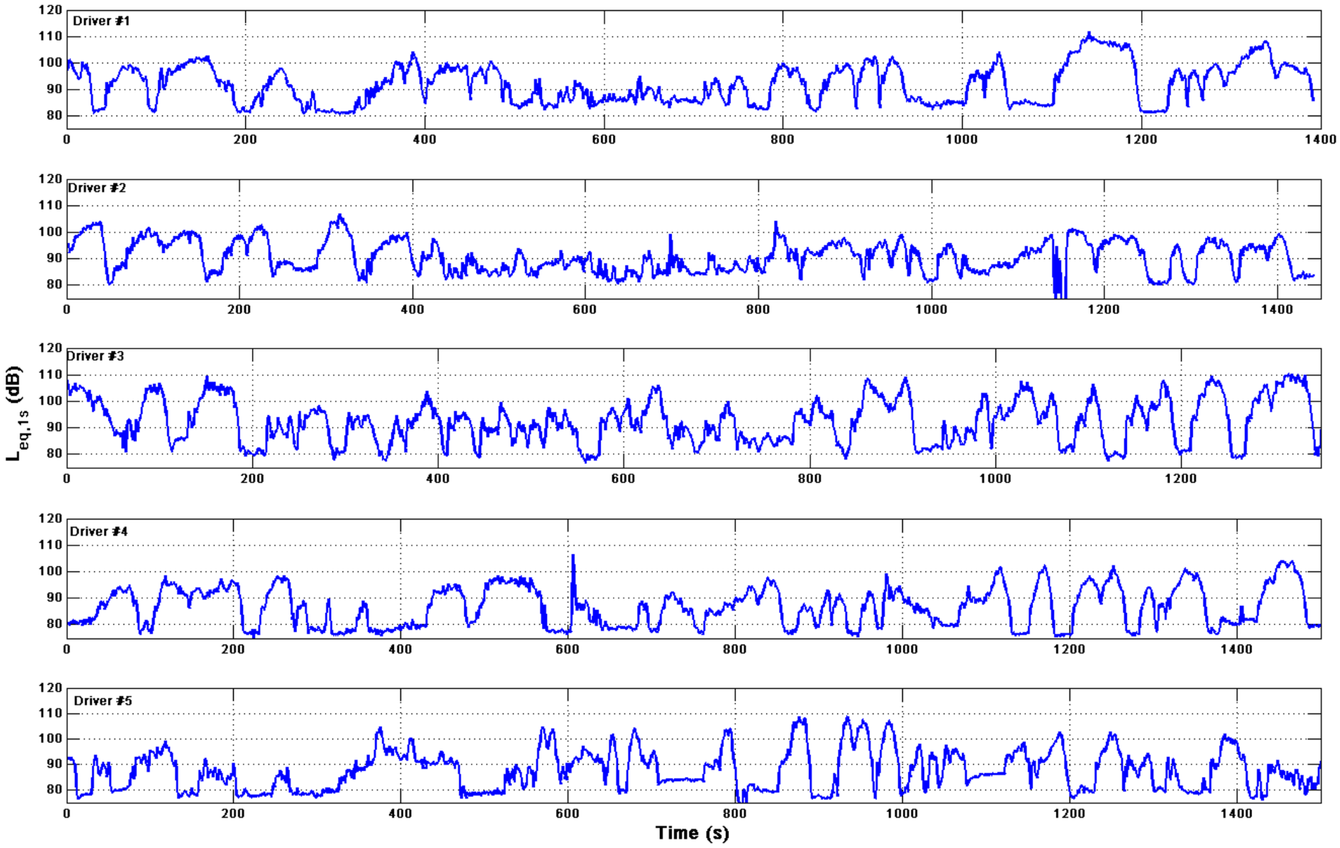

Fig. 11—Time evolution of the rolling noise $L_{eq,1s}$ for the five drivers of the petrol vehicle along the urban course.

with the average level histogram of drivers #1–#4, for the engine and rolling noises of diesel and petrol vehicles. Since the five drivers spend different time in doing the direction changing (depending on that they encounter the traffic light in either red or green), this part has been removed from the respective histograms. The histogram of driver #5 is remarkably displaced towards higher levels in both cases. As expected also,

Table 4—Driving parameters along the urban course with the diesel vehicle.

Driving parameter		Driver #1	#2	#3	#4	#5
Vehicle speed (km/h)	Average (km/h)	38.6	31.2	35.6	32.5	42.5
	Maximum (km/h)	76.7	59.8	74.7	55.4	97.1
	Standard deviation (km/h)	18	14.1	15.8	14.4	21.2
Engine speed (rpm)	Average	1390	1260	1355	1285	2027
	Maximum	3010	2890	2993	2880	4702
	Standard deviation	610	570	540	550	1070
Course	Distance (m)	8492	8475	8482	8461	8499
	Running time (min)	13.2	16.3	14.3	15.6	12.0
	Stopped time (min)	6.9	7.7	6.3	7.3	5.3
Time at gear position (%)	1st	7.1%	3.7%	4.0%	5.5%	11.1%
	2nd	22.1%	14.0%	22.9%	10.4%	43.5%
	3rd	21.8%	20.3%	28.2%	24.2%	6.2%
	4th	4.5%	8.4%	1.3%	16.4%	0.0%
	5th	0.0%	0.0%	0.0%	0.0%	0.0%
	Neutral	34.4%	32.1%	33.8%	31.8%	30.5%
	Gear changing	10.1%	21.5%	9.8%	11.6%	8.7%

Table 5—Driving parameters along the urban course with the petrol vehicle.

Driving parameter		Driver #1	#2	#3	#4	#5
Vehicle speed (km/h)	Average (km/h)	30.4	27.6	30.1	30.8	31.8
	Maximum (km/h)	77.9	58.1	62.4	64.7	84.2
	Standard deviation (km/h)	18	14	14.7	16	19.8
Engine speed (rpm)	Average (rpm)	1510	1590	1450	1555	1988
	Maximum (rpm)	3320	3300	3370	3290	5689
	Standard deviation (rpm)	725	710	690	620	1314
Course	Distance (m)	8350	8512	8739	8666	8573
	Running time (min)	16.5	18.5	17.4	16.9	16.2
	Stopped time (min)	7.3	8.4	8.3	9.2	9.4
Time at gear position (%)	1^{st}	7.7%	7.1%	6.6%	8.0%	21.0%
	2^{nd}	23.0%	13.8%	23.5%	16.6%	31.2%
	3^{rd}	16.0%	16.3%	27.5%	22.8%	3.0%
	4^{th}	4.3%	16.5%	2.1%	9.2%	0.0%
	5^{th}	3.8%	0.0%	0.0%	0.0%	0.0%
	Neutral	31.5%	34.6%	32.3%	35.8%	36.6%
	Gear changing	13.7%	11.7%	8.0%	7.6%	8.2%

this displacement towards higher levels is more significant for the engine noise. Notice also that rolling noise of the drivers #1–#4 is higher than the corresponding engine noise, in both diesel and petrol vehicles. Table 3 summarizes the overall L_{eq}, for engine and rolling noises, each driver, and diesel and petrol vehicles, along the suburban course. Again, the course L_{eq} for driver #5 is compared with the corresponding $\langle L_{eq} \rangle$ of

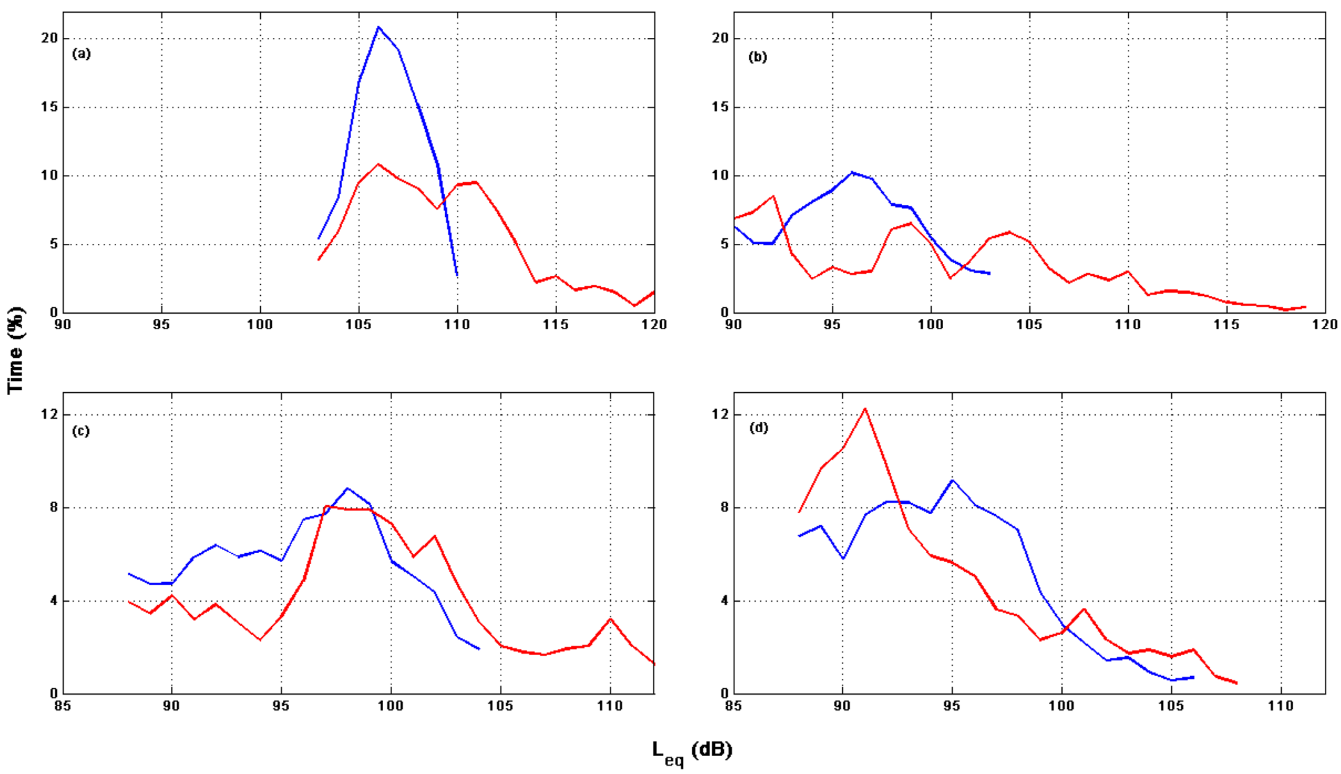

Fig. 12—Histograms of the averaged drivers #1–4 (blue) and driver #5 (red) for (a) engine diesel, (b) engine petrol, (c) rolling diesel, and (d) rolling petrol $L_{eq,1s}$ along the urban course.

Table 6—Equivalent engine and rolling noise levels (dB) of the complete urban course.

	Diesel				Petrol			
Driver	Engine noise		Rolling noise		Engine noise		Rolling noise	
#1	107	$\langle L_{eq}\rangle_{1-4}$	100	$\langle L_{eq}\rangle_{1-4}$	100	$\langle L_{eq}\rangle_{1-4}$	100	$\langle L_{eq}\rangle_{1-4}$
#2	107	107	97	99	95	100	97	99
#3	107		99		102		101	
#4	108		99		100		96	
#5	112		103		106		98	

drivers #1–#4. The driver #5 behaves, in average, 9 dB noisier for the engine noise, and 3–4 dB noisier for the rolling noise.

3.2 Urban Course

The two vehicles (diesel and petrol) were driven then by the five drivers along the urban course. Tables 4 and 5 summarize the parameters characterizing the driving style of the five drivers. As expected, this course is done mainly in 2nd and 3th gears, except for driver #5 who characterizes by a much more aggressive use of acceleration (2nd gear, high rpm regime). In this case, he spent less time than the other drivers, running at a higher mean velocity, for the diesel vehicle, but fails to be faster in the petrol vehicle. This driving behavior is common in urban scenarios. Aggressive drivers run faster between consecutive traffic lights, where they must remain stopped, being reached by the other drivers.

Figures 8 and 9 show the time evolution of the $L_{eq,1s}$ of the engine noise for the diesel and petrol vehicles, respectively, along the urban course. This circuit contains a lot of traffic lights, so that the vehicles must change gears frequently, staying roughly one third of the time in neutral (see Tables 4 and 5). This render alternate high and low noise levels along the time histories. As expected, minimum engine noise levels of the diesel vehicle (resulting from those with the engine out of gear), Fig. 8, are higher than the corresponding minimum engine noise levels of the petrol vehicle, Fig. 9. An apparent noise increase of the engine noise is seen in driver #5, in comparison with the other four drivers, for both the diesel and petrol vehicles.

Figures 10 and 11 show the time evolution of the $L_{eq,1s}$ of the rolling noise for the diesel and petrol vehicles, respectively, along the urban course. As rolling noise is more determined by the vehicle velocity, a slight noise increases is noted for driver #5 in comparison with the other drivers, for the diesel vehicle (higher mean velocity, Table 4). However, since mean vehicle velocities are roughly the same for the petrol vehicle (see Table 5), rolling noise time histories differences are insignificant.

For the sake of comparison, Fig. 12 shows the level histogram of time history of driver #5, in comparison with the average level histogram of drivers #1–#4, for the engine and rolling noises of diesel and petrol vehicles. Since the five drivers spend different time with the engine out of gear (depending on that they encounter the traffic light in either red or green), this part has been removed from the respective histograms. The histogram of driver #5 is displaced towards higher levels in both cases. As expected, this displacement is more significant for the engine noise. As compared with the same histograms for the suburban course, Fig. 7, the differences between driver #5 and the average of the other drivers is less for the urban course. Table 6 summarizes the overall L_{eq}, for engine and rolling noises, drivers #1–#5, and diesel and petrol vehicles, along the urban course. Driver #5 behaves, in average, 5–6 dB noisier for the engine noise, 4 dB noisier for the rolling noise of the diesel vehicle, and roughly equally noisy for the rolling noise of the petrol vehicle.

4 CONCLUSIONS

Vehicle noise emission is affected by driving behavior. In particular, there is a high correlation between road traffic noise annoyance and maximum noise levels. Therefore, decreasing the maximum noise levels produced by aggressive noisy drivers should have a significant effect in reducing the noise annoyance. An onboard measuring system has been presented in this paper that is able to measure the contribution of each vehicle to the road traffic noise, allowing the detection of noisy drivers. This system is based on two near field microphones, one for the engine noise and other for the rolling noise. Systematic measurements in realistic driving conditions, with diesel and petrol vehicles on medium size (segment B), in urban and suburban scenarios, have demonstrated that it is possible to differentiate noisy drivers from the mean traffic stream, using both the global equivalent level and the level histogram. Engine noise of aggressive drivers is roughly 5–6 dB, in urban scenarios, and 9 dB, in sub-urban roads, higher than the average level. The rolling noise of aggressive drivers is, on average, in both cases, 3–4 dB above the global traffic noise level.

Besides the application reported here, an onboard vehicle measuring system would facilitate a more precise approach to traffic noise studies, in more realistic conditions, including effects such as the vehicle segment, engine type, vehicle age and road maintaining. It would also provide a tool for a more fair administrative control of traffic noise, by the detection of noisier drivers in periodical vehicle technical inspections. Hopefully, this should encourage a quiet, fuel saving and friendlier driving behavior.

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