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Will high speed trains change Portuguese railway noise?

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This paper presents the *in situ* evaluation of noise from railway traffic on a modernized section of the Portuguese railway network. The measurements include noise spectra for four types of Portuguese rolling stock in terms of their maximum Transit Exposure Level (TEL), equivalent Sound Pressure Level and frequency content. The obtained data allows for a noise characterization of the various types of Portuguese trains and can be used in the validation of numerical noise prediction models. Due to the foreseen introduction of high speed railways in Portugal an analysis is done to check how the railway noise will change in the near future with these new trains.

1 INTRODUCTION

This paper provides experimental noise data from various types of passenger trains on the Portuguese railroads. Its objective is to present, and add to existing database, the quantification of the noise caused by the passing-by of the Portuguese passenger trains and establish some comparative data on them with near future high speeds trains. The goal is to answer if future high speed trains will change the present Portuguese railway noise.

2 PARAMETERS

The measured parameters in the in situ evaluation were: Sound Exposure Level (SEL), Transit Exposure Level (TEL) and Short-term equivalent continuous sound level ($L_{Aeq,T}$).

SEL (equation 1) is formed from the integral of the squared pressure over the pass by where the integration limits t_1 and t_2 are usually the points at which the level is 20 dB below the maximum[1] (Figure 1). SEL is also the sound pressure level measured for 1 second containing the same amount of energy as the original noise. As it is normalized to 1 second, the energy content of multiple different events can be compared with this parameter[2]. If the registered noise is A-filtered this parameter is known as L_{AE}, in dB.

$$SEL = 10\log_{10}\int_{t_1}^{t_2}\frac{p^2(t)}{p_{ref}^2}\,dt \quad [dB] \tag{1}$$

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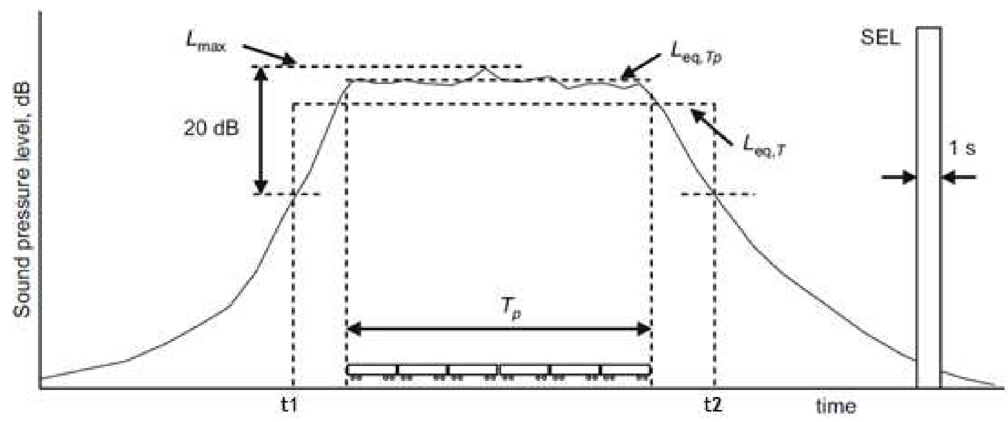

Fig. 1 - Notional time history of train pass-by noise indicating various quantities[1]

The TEL is similar to the SEL but is normalized to the passage time T_p. The passage time is the length of the train (m), over buffers, divided by its speed (m/s). TEL is used on the EN ISO 3095 to describe the noise produced by a railway vehicle as a whole[1].

TEL can be calculated with equation 2 which can be simplified to equation 3, where V is the speed of the train (m/s) and L is its length (m).

$$TEL = 10\log_{10}\left[\frac{1}{T_p}\int_{t_1}^{t_2}\frac{p^2(t)}{p_{ref}^2}\right] dt \quad [dB] \tag{2}$$

$$TEL = 10\log_{10}\frac{V}{L} + SEL \quad [dB] \tag{3}$$

Short-term equivalent continuous sound levels ($L_{Aeq,T}$) is defined with equation 4 where usually, t_2-t_1 corresponds to the time defined by the 20 dB from maximum level.

$$L_{Aeq,T} = 10\log\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_0^2}\,dt\right] [dB] \tag{4}$$

3 LOCATION AND MEASUREMENT SETUP

The measurements took place on a modernized section of the Portuguese railway network (Linha do Norte - PK 41+600, near Vila Nova da Rainha, Azambuja – Figure 2). Pass by noise from the trains was measured simultaneously with four microphones at various distances and height relative to the nearest track (Figure 3). Only the trains travelling on the nearest track were considered to the measurements. Microphones were positioned at 8.5, 25 and 50 m from the nearest track. They were at a height of 1.2 m with exception of one, at 25 m from the track, which was positioned at a height of 4.0 m (Figure 3 and Table 1).

Fig. 2 - Aerial view of measurement site (PK41+600, Linha do Norte, Vila Nova da Rainha, Azambuja)

Table 1 – Microphone Positions

Position	Distance to track (m)	Height (m)
1	8.5	1.2
2	25	1.2
3	25	4.0
4	50	1.2

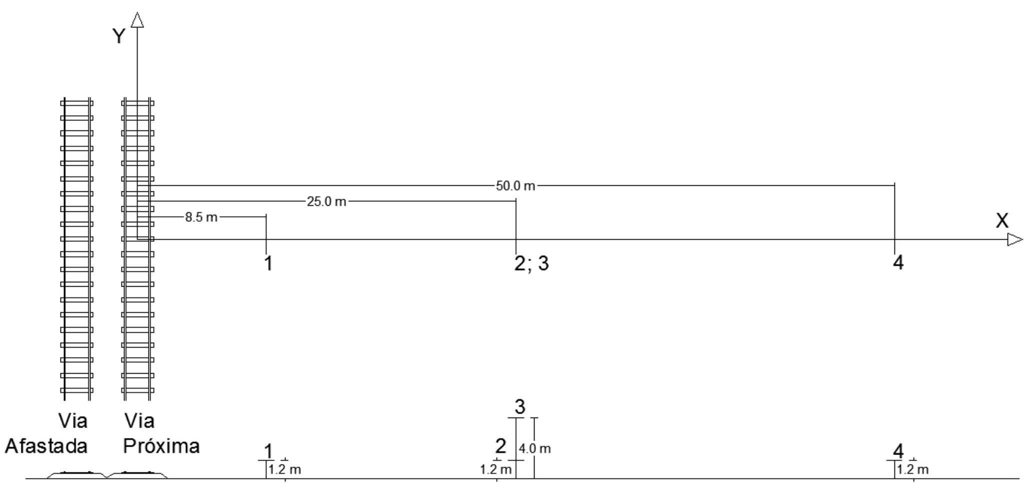

Fig. 3 - Experimental configuration – four microphone positions (plan and section)

4 ROLLING STOCK

The Portuguese rolling stock is managed by *C.P. Comboios de Portugal E.P.E.*[3] ("trains of Portugal") which is also responsible for the passenger transportation service. Different types of trains are used based on the type of service they provide (U, R, IC, A as described below). For local transportation services the trains used are called *Urbano* (Urban) (Figure 4). For medium range distances another type of trains is used. The vehicles, called *Regional* (Regional) are intended for longer travels and can reach higher speeds (Figure 5). For long range distances two types of trains are available: the *Inter-Cidades* (Intercity) and the *Alfa Pendular*. The *Inter-Cidades* is a train with variable length with each car measuring 23 m (Figure 6) with the *Alfa Pendular* being a more modern train (Figure 7). In Table 2 some technical characteristics are presented for these trains.

Table 2 – Technical characteristics of the Portuguese rolling stock[3]

Type	Entered Service	Maximum Speed (km/h)	Length (m)	Power Output (kW)	Electric Systems	Gauge (mm)
Urbano	2004*	120	70	1230	25 kV - 50 Hz	1668
Regional	1999	140	106	3475		
Inter-Cidades	1993	200	variable	5600		
Alfa Pendular	1999	220	160	4000		

* renovated

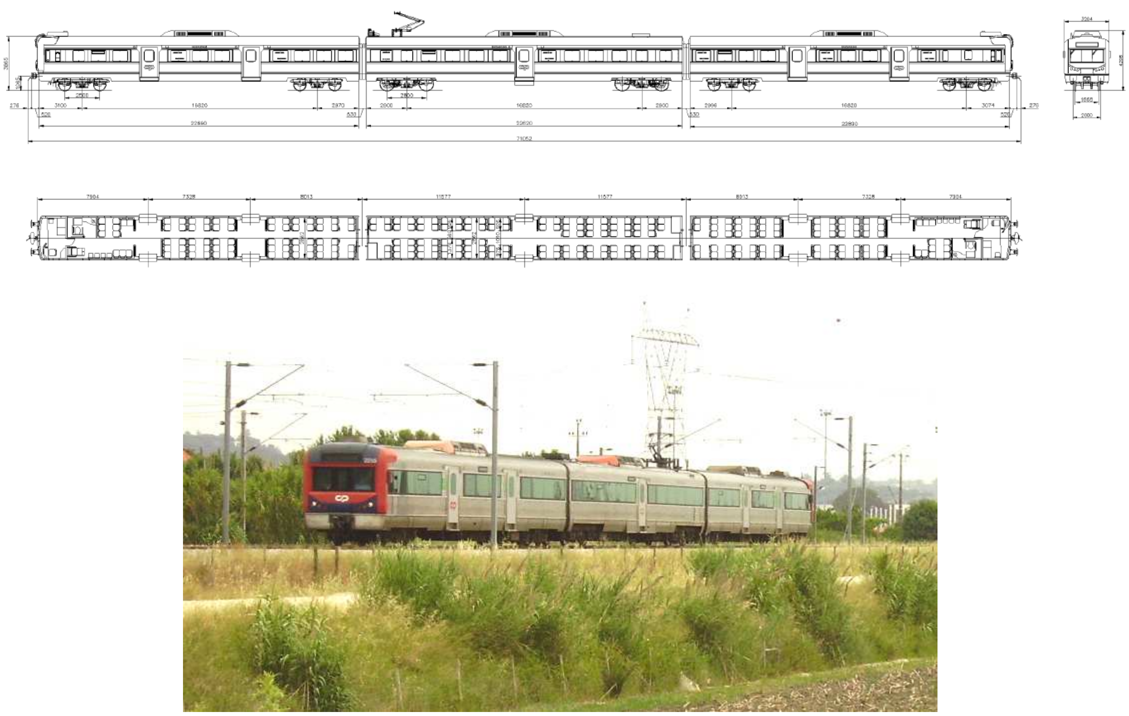

Fig. 4 - Sorefame/Alstom – CP Urbano (U) 2241/2297[3]

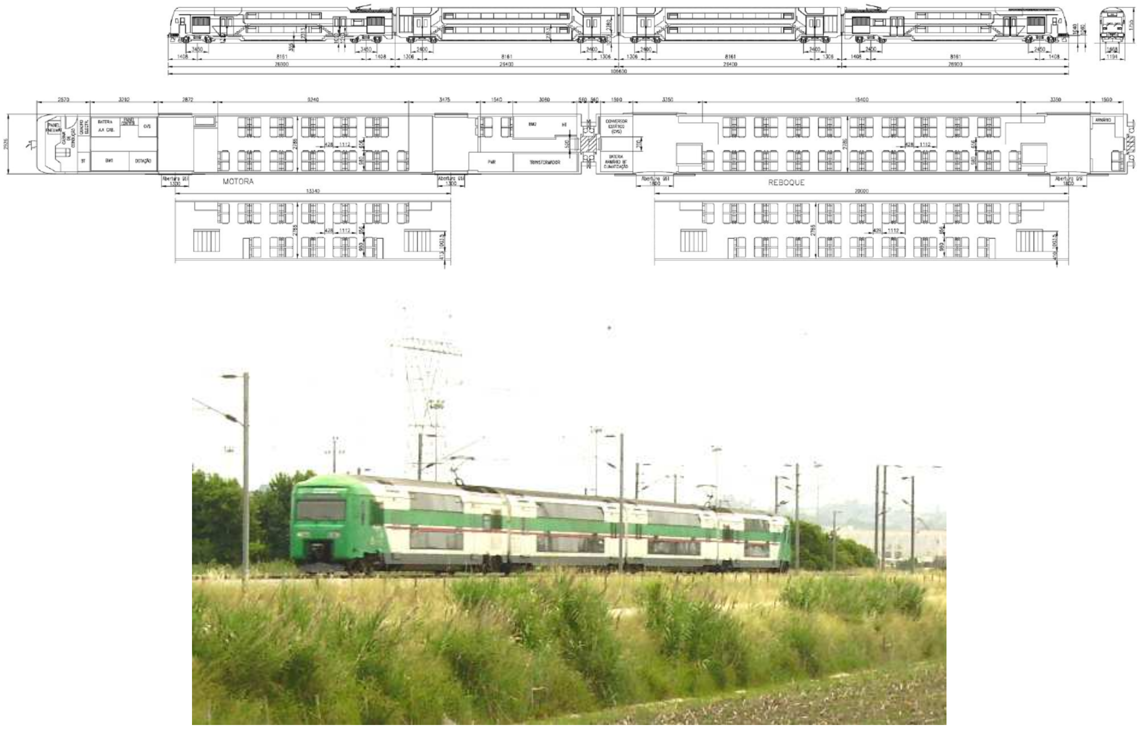

Fig. 5 - CAF/Alstom CP Regional (R) 3519/3530[3]

Fig. 6 - Siemens CP Inter-Cidades (IC) 5600 Series[3] *can have multiple cars*

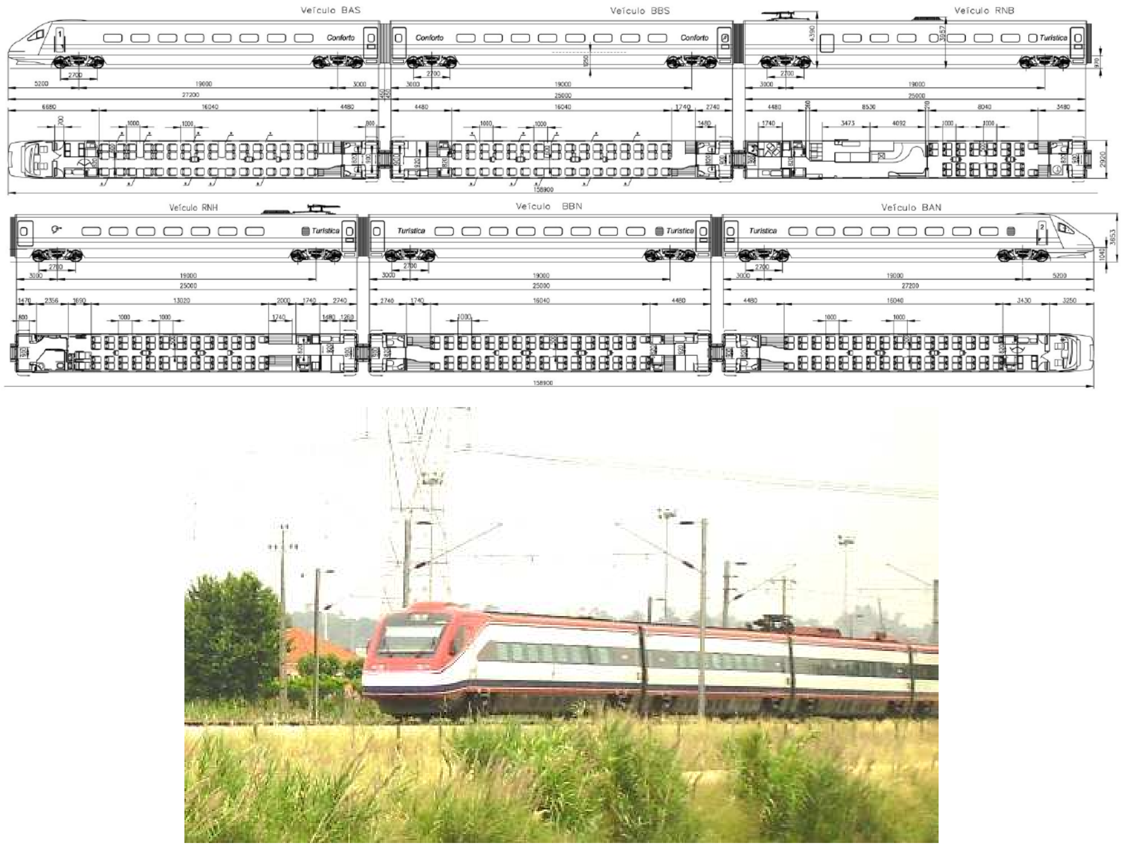

Fig. 7 - FIAT/Siemens CP Alfa Pendular (A) 4001/4010[3]

5 RESULTS

Nineteen measurements were recorded corresponding to the pass-by noise of five *Urbanos* (U), six *Regionais* (R), five *Inter-Cidades* (IC), and three *Alfa Pendular* (A).

In Figure 8 the A-filtered TEL is expressed as a function of the pass-by speed of the various trains, measured at 25 m from the track, at a height of 4 m (Position 3). There is a clear relationship between the registered noise and the speed at which the train passes (Figure 8). Therefore, for a given speed, a single value of TEL is expected. This is valid within each type of train with the exception of the U-type trains probably due to a greater variability on the maintenance conditions of these trains.

Comparatively, the IC-type trains are the noisiest with a TEL between 95 to 100 dB(A) at about 200 km/h. On the other hand, the A-type are the trains that travel at the highest speed. However, they are less noisy than the IC-type trains by about 10 dB(A) with a TEL between 85 and 90 dB(A).

The R-type trains are as noisy as the A-type trains while travelling at only 125 km/h. Lastly, while travelling at about 120 km/h, most of the recorded TEL were between 75 and 80 dB(A) although the registered values for this type of trains was a bit disperse.

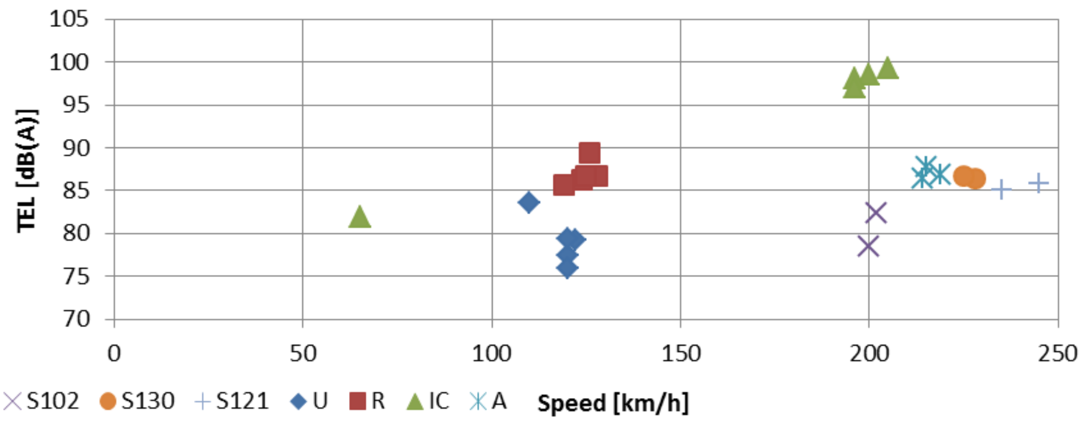

Fig. 8 - TEL vs Speed registered at position 3. U – Urbano; R – Regional; IC – Inter-Cidades; A – Alfa Pendular; S102, S130, S121 – High Speed (Spanish trains)

Figure 9 shows the average noise spectra of an *Alfa Pendular* train recorded with all four microphones. They are obviously different due to the different distances from the track at which the microphones were positioned. Nevertheless, the noise spectra remained similar among the various microphones positions. One can then assume that the noise spectra shape remain fairly similar as the distance to track increases, not accounting for the obvious attenuation from geometrical divergence (and air absorption).

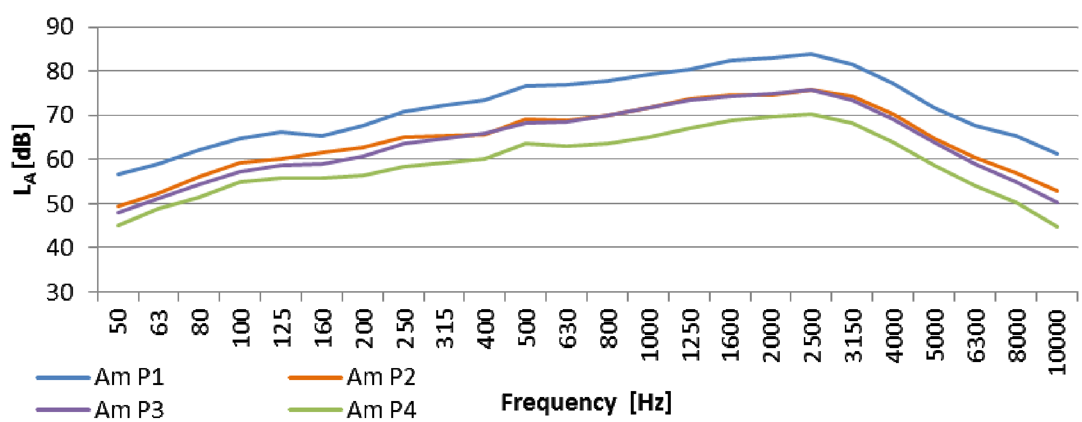

Fig. 9 - Average noise spectra of an Alfa Pendular train in four measurement positions (P1 to P4)

Figure 10 presents the noise spectra for A-type trains and IC-type trains, measured at 25 m from track at a height of 4 m (Position 3). At low to medium frequencies both train types are similar in terms of noise as the sound level increases as the frequency also increases. At about 630 Hz the IC-type trains become noisier than the A-type trains. This difference is about 10 dB(A) at 1000 Hz. Both trains maximum noise level occur at the 2500 Hz 1/3 octave frequency band. As the frequency continues to increase the difference between both trains starts to decrease although the IC-type train remains noisier. These trains travel at similar speeds. However there is a noticeable difference between the two in terms of noise. This may be justified to the more aerodynamical shape of the *Alfa Pendular* as well as a more sophisticated bogey, wheel and brake technology.

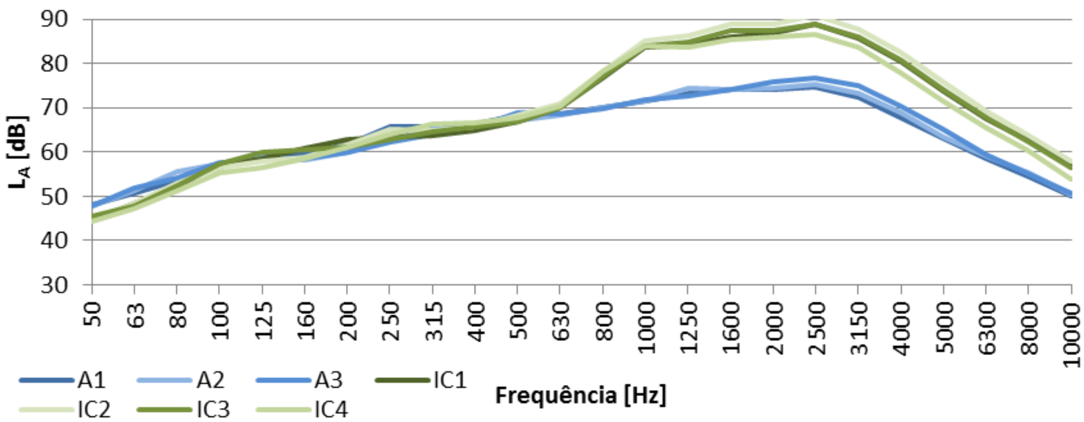

Fig. 10 - Alfa Pendular, A (blue) and Inter-Cidades, IC (green) noise spectra registered at measuring position 3

In Figure 11 noise spectra for R-type trains and U-type trains, measured at 25 m from track at a height of 4 m (Position 3) are presented. These vehicles were recorded while travelling at very similar speeds (125 and 120 km/h respectively). The spectra of the various U-type trains are distinct from each other. This is concurrent with the high variability of these trains presented in Figure 8. On the other hand the R-type measurements are similar with each other. The maximum noise level occurs at the frequency of 1250 Hz for these trains. The R-type trains are up to 10 dB(A) noisier than the U-type trains and this is particularly evident between the 400 and 1600 Hz. At low frequencies both vehicles are quite similar although two U-type trains were clearly louder. Urban trains are generally less noisy than Regional trains. Their respective spectra are also different although their maximum noise levels occur at the same frequency band (2500 Hz).

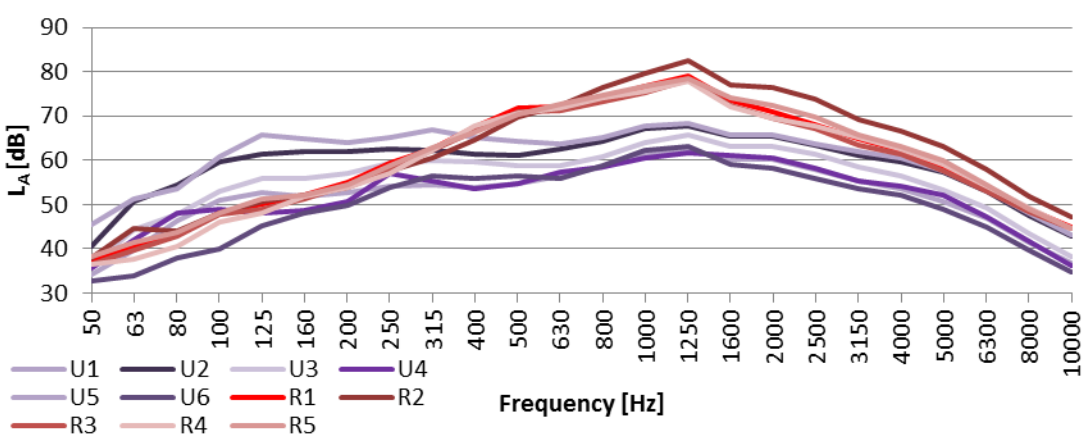

Fig. 11 - Regional, R (red) and Urban, U (purple) noise spectra registered at measuring position 3

6 HIGH SPEED TRAIN NOISE

In Figure 12 average noise spectra (position 3) from the fastest Portuguese trains (*Alfa Pendular* and *Inter-Cidades*) are compared with those of three Spanish High Speed trains (S) travelling at various speeds measured near Valladolid, Spain in the same conditions (Figure 13). The *Inter-Cidades* continues to be the noisiest train. Also, it can be observed that the *Alfa Pendular* has a noise spectrum very similar to the Spanish high speed trains while being generally louder. These trains benefit from newer developments in terms of car and bogie noise therefore being less noisy trains despite their generally higher speeds.

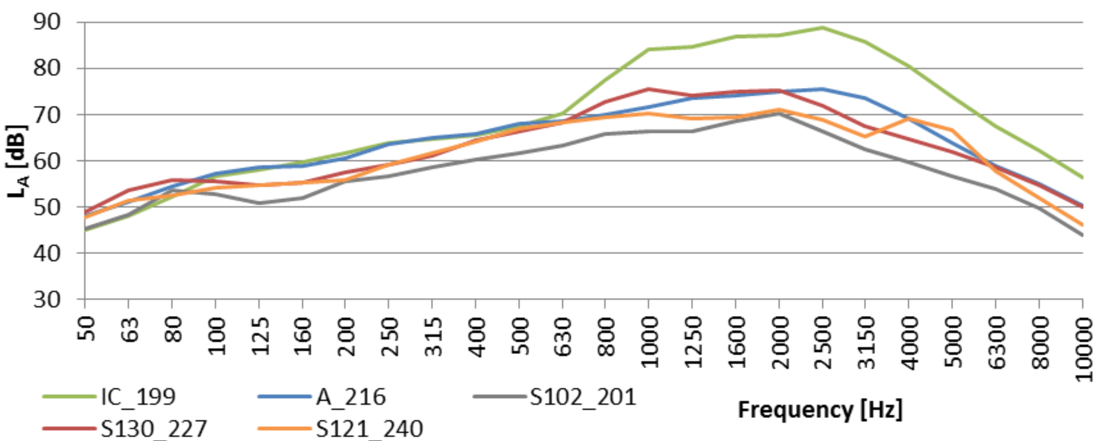

Fig. 12 - Average noise spectra registered at position 3 of Alfa Pendular, A (blue) and Inter-Cidades, IC (green) compared with those of three Spanish High Speed Trains in the same measuring position: Orange - Renfe AVE LANZADERA S121 (240 km/h), Red – Renfe Alvia S130 (227 km/h), Grey – Renfe AVE S102 (201 km/h)

Fig. 13 - Example of a Spanish High Speed train – Renfe Alvia S130

7 CONCLUSIONS

Several noise spectra from four types of Portuguese trains were presented. IC-type trains are clearly the noisiest trains in Portugal. Meanwhile the A-type trains are up to 10 dB(A) less noisy than the IC-type trains despite the higher travelling speed. R-type trains are about as noisy as the

A-type trains although they travel at much lower speeds. Comparing with noise spectra from high speed trains one can conclude that they are about the same as the A-type trains. Newer trains will most likely be less noisy than their predecessors. With the future addition of High Speed Trains to the Portuguese rolling stock it is not expected that there will be any increase on the current noise levels from the now existing fast trains.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

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