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HARMONOISE project - WP4 experimental campaigns: comparison among methods to separate road traffic noise from extraneous noise

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Abstract [282] In the context of the European Commission funded HARMONOISE Project ("Harmonised, Accurate and Reliable Methods for the EU Directive on the Assessment and Management of Environmental Noise"), four experimental campaigns were carried out from October 2002 until October 2003, in two different sites in France (La Crau and St-Berthevin) and for two different season conditions. The measurements were performed over one or two weeks period and aimed at collecting acoustical data from road and railway traffic produced by a straight four-lane highway traffic and by a rail line, micrometeorological data at several different distances from the line source, traffic counts, impedance variations in space and time, etc. Comparison among different approaches to separate traffic noise from extraneous noise are discussed and compared together in order to verify the validity of each method. The analysis will focus on the manual separation method, the statistical and the pattern recognition approaches through common criteria. The results of the analysis will be discussed and presented in this paper.

1 INTRODUCTION

The new harmonised European noise propagation model need to be rigorously validated by comparison with both numerical and experimental data. The WP4 members of the HARMONOISE project have been in charge of collecting experimental data to be used as reference data for model validation.. Those data are relative to equivalent energetic sound pressure levels ($L_{eq\ global(A)}$, $L_{eq\ 1/3oct}$, L_{10}, L_{50}, L_{95}), micrometeorological data (vertical gradients of wind and temperature, atmospheric turbulence), ground impedance evolution in time and space, sound source characterisation (traffic counts and classification, road surface temperature), etc.
Time coherence is given for all those data, recorded on 15 min samples. However, some extraneous noise (wind, animal or human presence, klaxons, aircrafts, etc.) can occur for each 15 min samples.

This can not be considered as traffic noise (neither road nor railway traffic) so post-processing is required on the recorded data, in order to separate sound sources from the total noise and to provide only validated and reliable data. In this context several methods have been used by JRC, ARPAT and LCPC, e.g. «manual» (JRC, ARPAT & LCPC), «pattern recognition» (JRC, ARPAT & LCPC) and «statistical» (JRC) methods.

The *manual* method is simply based on the separation of the parasite signals by an operator. This method is the most rigorous but it is also very much time consuming. Moreover, it needs the knowledge of all the extraneous noises at each microphone position during the whole experimental campaign. The *pattern recognition* is based on spectral information of the noise source. To automatically identify noise sources, sound recordings are taken, from which typical patterns for each noise source are derived. The *statistical* method uses percentile spectra with a resolution of 10 Hz together with a statistical approach of the level distribution within each frequency band. Using this method also sources with levels close to the background can be separated. This is essential for measurement locations far from the source.

This paper deals with the comparison among the results provided by the respective methods.

2 COMPARISON BETWEEN JRC PATTERN RECOGNITION METHOD AND JRC STATISTICAL APPROACH TO SEPARATE EXTRANEOUS NOISE FROM ROAD TRAFFIC NOISE

The pattern recognition approach and the statistical approach are two solutions to separate noise, and the following figure and discussion makes a comparison between these two methods.

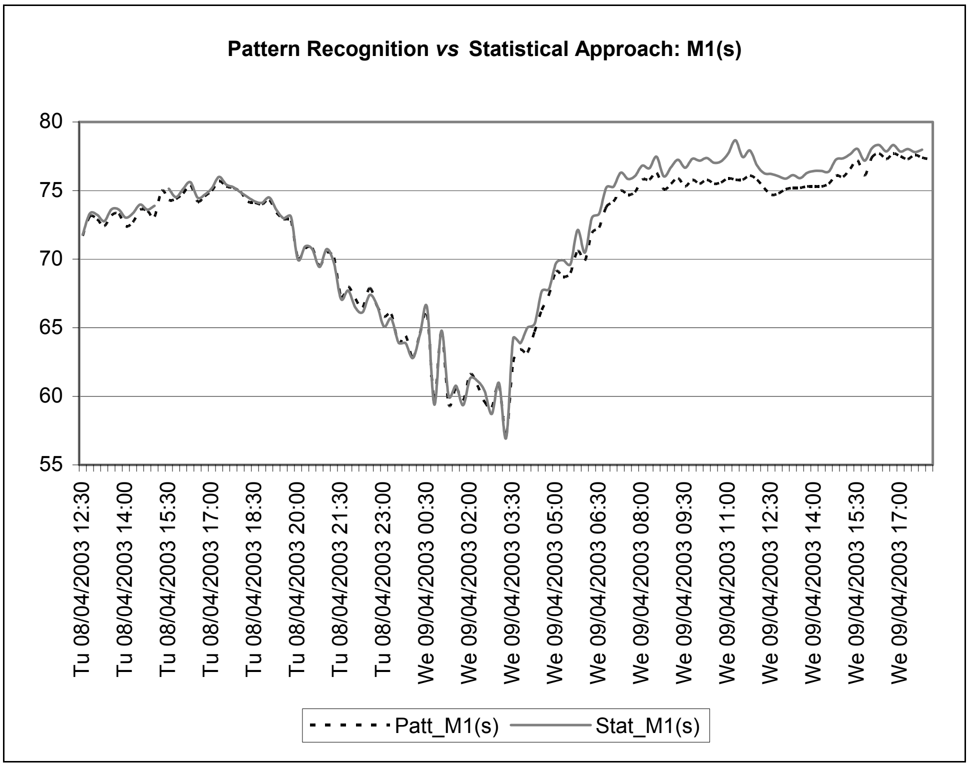

Figure 1 – La Crau #2 - JRC - Comparison: pattern recognition vs statistical, at 15 m from the source. Height of the microphones: 4m; Impedance (air flow resistivity)=250-300 $kNsm^{-4}$.

The source is represented by a 2+2 lanes highway. It can be easily seen (Figure 1 and Figure 2) that the two approaches give very similar results, both at short and at long distance from the source. It

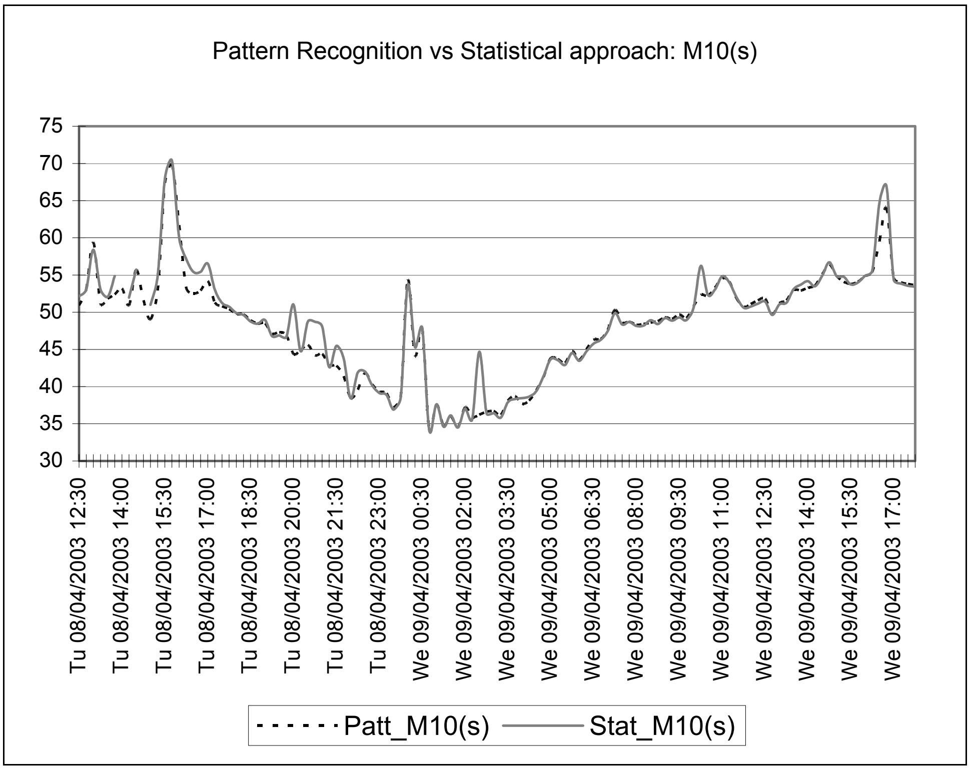

Figure 2 - La Crau #2 - JRC - Comparison: pattern rec. vs statistical (L_{eq_source}), at 600 m from the source. Height of the microphones: 4m; Impedance (air flow resistivity)=250-300 kNsm^{-4}.

should be underlined the fact that the pattern recognition approach was "controlled" in the post-processing phase, because almost all the recorded audio data has been listened to again to detect whether the software was correctly separating the noise. Therefore we can conclude that the pattern recognition approach has a very low percentage of errors (<3%). Comparing the pattern recognition approach with the statistical one we can conclude that the statistical approach has also performed correctly.

One important aspect identified is that the statistical approach, at a first view, seems more "sensitive"; this is revealed by some peaks that appear at specific time points.

However, the particular situation in the experimental campaign of St. Berthevin, in which the noise from the highway was measured, has to be considered. In fact for this situation the sensors line was adjacent (at 30m parallel) to a railway track. Under these conditions, when a train was passing the level of the running L_{eq} was increasing by 15-20 dB. An easy way to detect the passage of trains in this particular situation (1 train passing every 18-20 minutes with passage duration of 20-30 sec.) is to look at the values of the percentile level L_{01}. When this level increases, it is reasonable to assume that a train passed. It's interesting to notice that the statistical approach seems to fail (or to be too sensitive) when the train passes away. In this case part of the noise from the train is assumed by the statistical approach to be part of the noise coming from the highway (see Figure 3).

In situations like this, in which there is a strong extraneous noise level, but of short duration (such as a rail noise) the statistical approach is not as accurate as in other situations.

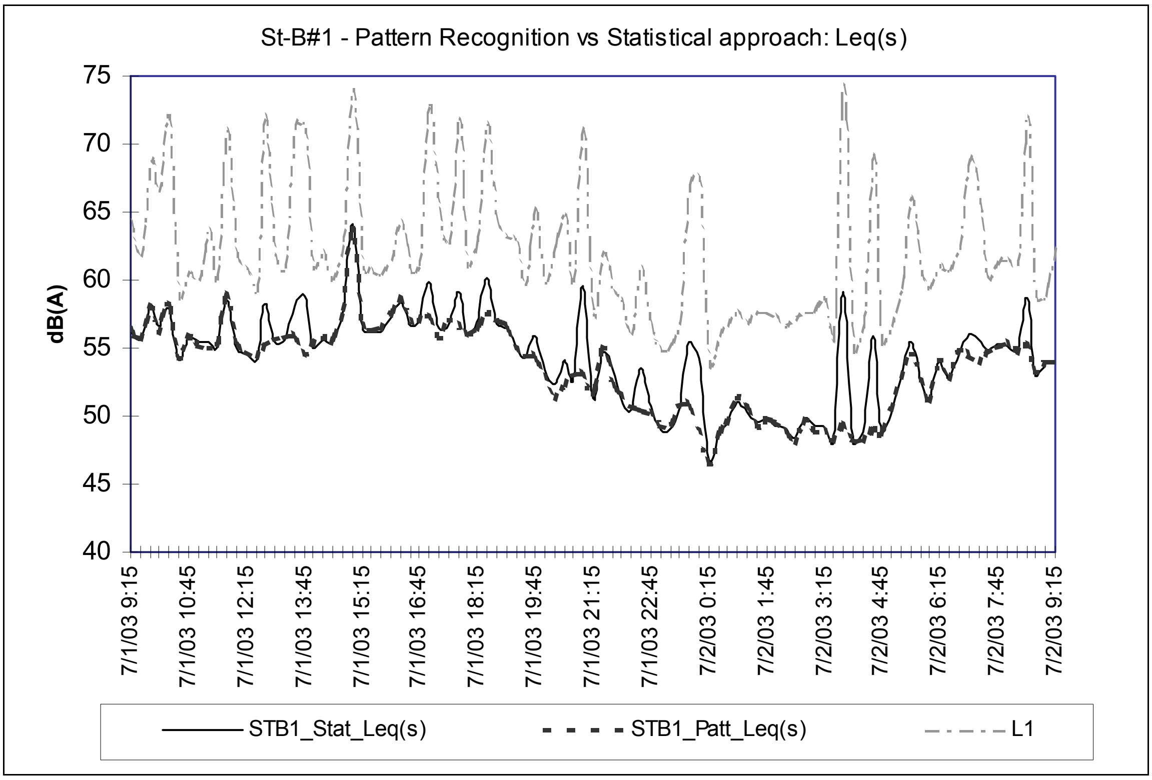

Figure 3 - St-B#1 - JRC - Comparison: pattern rec. vs statistical, at 300 m from the source. Height of the microphones: 4m; Impedance (air flow resistivity)=195-260 kNsm^{-4}.

3 COMPARISON BETWEEN LCPC AND JRC PATTERN RECOGNITION METHODS

3.1 LCPC Pattern Recognition Method

The method used by LCPC to study the respective contribution of «Extraneous» and «Residual» (road traffic) noise to the total noise at one microphone is based on pattern recognition. It requires the knowledge of the experimental site (topography, ground impedances, heights, distances, etc.) and the know-how of the operator (typical extraneous sound sources signatures, micrometeorological data correlation, S/N ratio, etc.).

Numerical sound files from 1/3-octave bands sonometers (temporal evolutions) are used. Each file, corresponding to 24h noise recording at one microphone, is first meticulously studied, in order to determine the amplitude of its 1s L_{eq} variations on the whole day/night period in «normal» acquisition conditions. This preliminary study is very important and is carried out for several 1/3 octave bands the central frequencies (from 25Hz to 20kHz) of which are directly connected to typical parasite («Extraneous») sound sources, such as, high wind (very low and very high frequencies); far (very low frequencies) or near (low frequencies) mechanical sound sources such as aircrafts or helicopters; human voices (medium frequencies); animal presence (medium frequencies); birds (high frequencies), etc.
Thus the operator is able to settle a threshold for each of those typical 1/3 octave bands above which the acoustic signal can not be only caused by road traffic. All those 1/3 octave thresholds are of course determined for each microphone, depending on the medium characteristics (topography, heights, distances and ground impedances involved) and on the propagation conditions (micrometeorological data).

Then the software allows to code automatically the acoustic signal on the whole 24h period, for each 7 days and for each microphone, whether the considered 1/3 octave 1s L_{eq} is above («Extraneous») or below («Residual» i.e. road traffic noise) the associated threshold. We can also fix the width of the automatic coding window, which is linked to the considered parasitic sound source. A particular 1/3 octave 1s L_{eq} coding generates the same codified 1s L_{eq} for all the 1/3 octave bands from 25Hz to 20KHz and, as a result, for the A weighted global level. The software can also give the associated percentiles, e.g. L_1, L_{50} and L_{95} for the HARMONOISE project. Finally, we calculate, for each 15min1 L_{eq} samples the respective contributions of «Extraneous» and «Residual» (road traffic) noise to the total noise recorded at one microphone position. This is given through the energetic ratio "R" between the considered signal (traffic noise) and the total noise (traffic noise + extraneous noise) where :

$$R = \frac{10^{\frac{LevelSource}{10}}}{10^{\frac{LevelTot}{10}}} . \qquad (1)$$

This parameter "R" is very important in the validation process of the data. Its calculation can be easily implemented, either for the global (A weighted) noise or for each 1/3 octave bands between 25Hz and 20KHz. Thus, an objective criteria can be fixed for the 15min samples: acceptation (e.g. $R \geq 90\%$) otherwise rejection (e.g. $R < 90\%$).

3.2 RESULTS

Before looking at the results coming from the comparison between the post-processed data, it is interesting to consider the comparison before the data treatment, in order to verify that that data start from the same initial conditions.

It can be noticed that there are some small differences between the LCPC data and the JRC data, before the treatment (noise separation) has been done. This might be due to some of the following reasons: difference between frequency responses of the microphones that could lead to have different results especially at high-frequencies. At low frequencies, instead, there could have been a problem with the particular shape and dimensions of the JRC trolley, which in some cases could resonate thus causing some undesired effects at these low frequencies. During particular wind directions, the same JRC trolley could be also considered acting as a noise barrier for the LCPC microphone, which was positioned at about 15 m away from the JRC trolley.

This means that all possible differences among the comparisons performed after data post-treatment have to take into account this fact.

The error was calculated as:

$$Delta = SPL_{JRC} - SPL_{LCPC} \qquad (1)$$

Results give a 'delta' of about 1 dB.

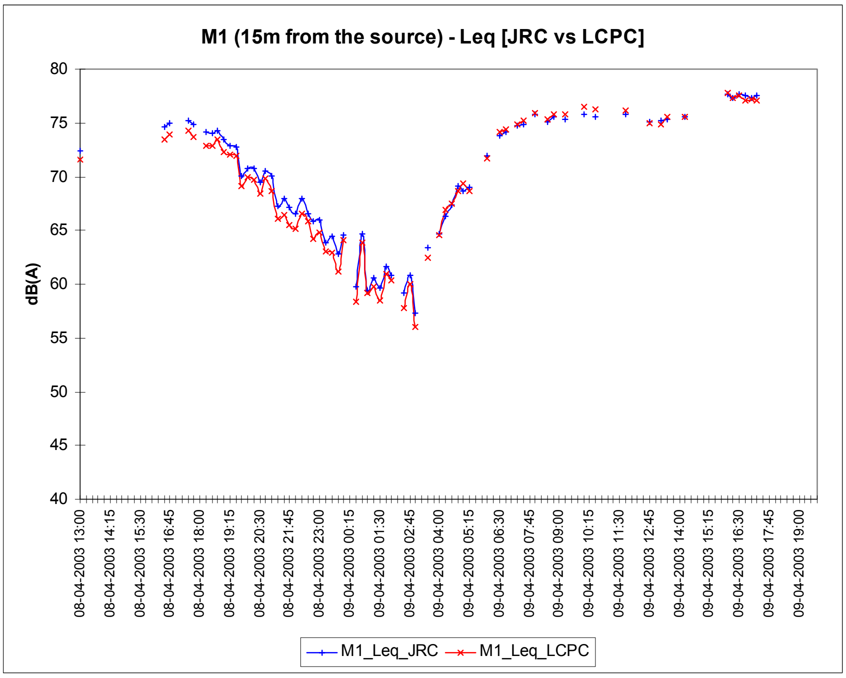

Figure 4 – Comparison between $L_{eq\text{ - }tot}$ from LCPC and JRC, *before* the data treatment during a 2 days measurement period; Distance from the source: 15m; Height of the microphones: 4m; Impedance (air flow resistivity)=250-300 kNsm^{-4}.

Comparing of the two methods used by JRC and LCPC after the *data* treatment (which separates extraneous noise from the noise of the source) it can be easily noticed that there is always a difference of 1 dB between the two, which is also the same difference (delta) observed when the L_{eq_tot} of the pre-treated data has been compared.

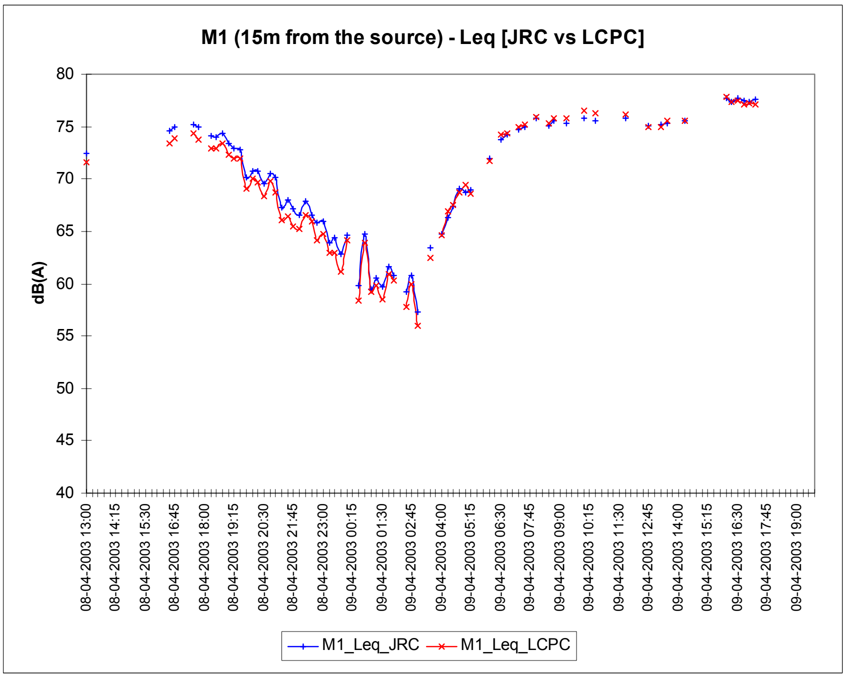

Figure 5 – $L_{eq\text{-}source}$ – La Crau: comparison (after data treatment) between two different methods to separate extraneous noise from road noise. Distance from the source: 15m – Height of the microphones: 4m; Impedance (air flow resistivity)=250-300 kNsm^{-4}.

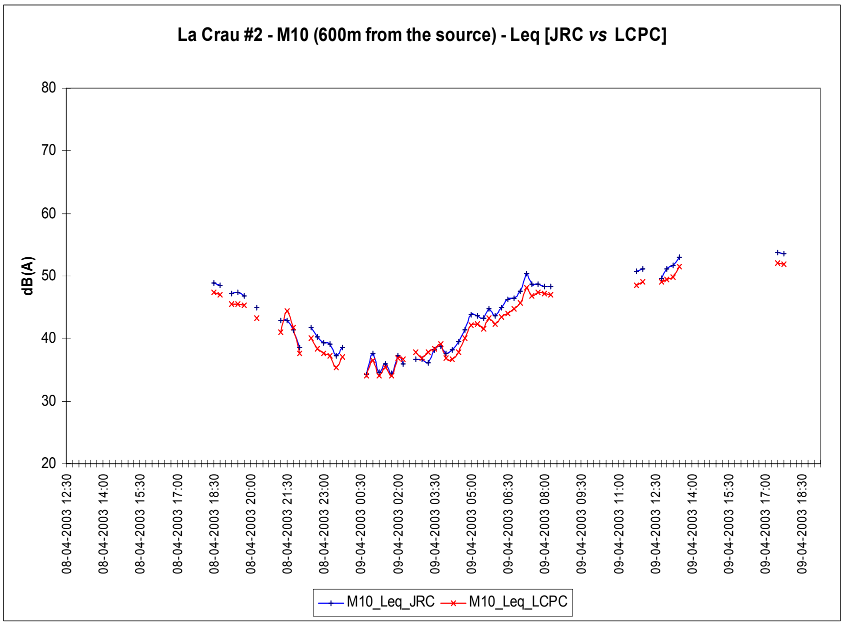

Figure 6 - $L_{eq\text{-}source}$ – La Crau: comparison (after data treatment) between two different methods to separate extraneous noise from road noise. Distance from the source: 600m – Height of the microphones: 4m; Impedance (air flow resistivity) =250-300 kNsm^{-4}.

Similar results can be plotted for the rest of the measurements as well.

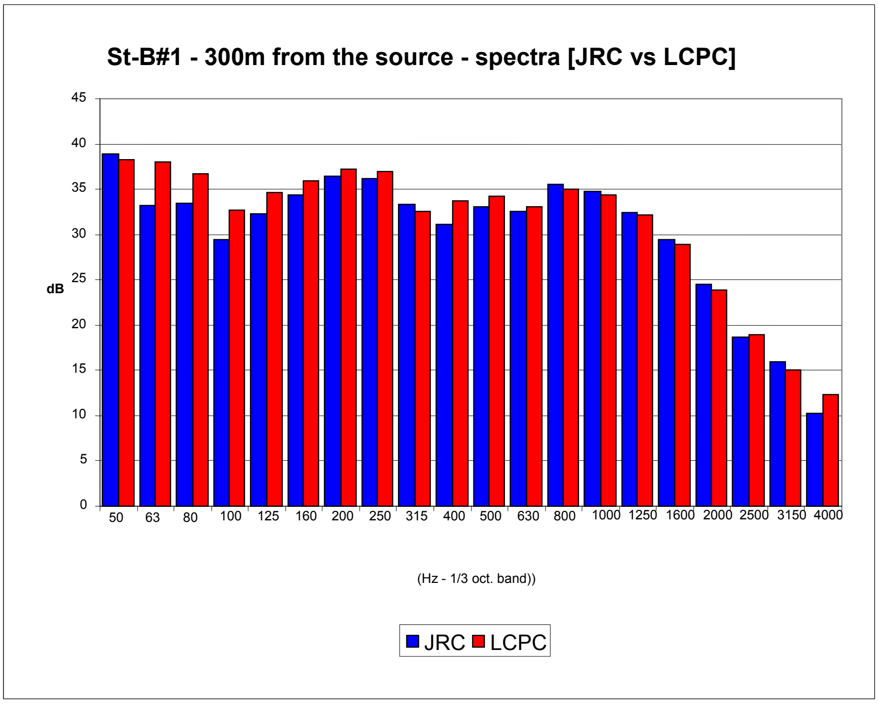

Figure 7 - $L_{eq\text{-}source}$ - Comparison of the spectra at 300m from the source, in St. Berthevin, during one particular period of 15 min. (6-7-03, h2:45) – Height of the microphones: 4m; Impedance (air flow resistivity) 195-260kNsm^{-4}.

Figure 7 shows the comparison, during a particular period of time, of the spectra coming from post-treated data at 300m distance from the source in St. Berthevin. The spectra is referred to the source and not to the extraneous noise. Some differences (2-3 dB) can be noticed in the mid frequency range, but apart from this, the comparison shows that the two methods for separating noise are almost identical, also considering the fact that some small differences were observed already in the pre-treated data (L_{eq-tot}).

CONCLUSIONS

Concerning the experimental campaigns under consideration, the pattern recognition and statistical methods performed well with a very low percentage of error when considering a flat terrain situation and road traffic being the main noise source, both close and away from the source. However, in situations when the main noise source is a combination of road traffic and railway noise the statistical approach seems to fail (or to be too sensitive) compared to the pattern recognition one. Some differences have been observed among the comparisons performed on the post-treated data by the WP4 partners which reflect small differences of the pre-treated data due to a number of possible reasons. This difference is in a range of 1dB. Some differences in the order of 2-3 dB have also been obsereved to the spectra of the source in the mid-frequency range. Overall, the reliability of the methods used to separate road traffic noise from extraneous noise has been extensively tested among the WP4 partners and the best performing method has been employed for each measurement situation to deliver good quality data to the other WPs needed for model validation.

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