Noise source characterization on a TGV-Duplex running at up to 350 kph by means of a 2D acoustic array

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Introduction

Within the frame of an acoustic field test campaign organised by the SNCF on a TGV-Duplex running at up to 350 kph on a high speed line in France, some specific measurements were carried out to locate and characterize the main sources on the train which radiate noise in the environment : the implemented technique was an acoustic 2D array apparatus combined with a beamforming processing including dedopplerisation. Another objective was also to improve the measurement method itself by testing a new device and also a new post-processing technique.

This paper proposes at first to describe the two measurement devices implemented, and then to compare their performances. Some repeatability tests and the influence of the post-processing parameters are also examined. In a third part, a few results concerning the noise sources on the TGV-Duplex are provided, and a first hierarchy proposed, based on their relative strength as a function of the frequency.

Description of the Measurement devices

The SNCF 2D acoustic array, is made of 29 microphones regularly spread over 8 beams which form a star shape – see **Figure 1**. The data acquisitions are performed synchronously at a sampling rate of 30 kHz and are coupled with a wheel passing detector device which allow to locate the train wheelsets during the train pass-by.

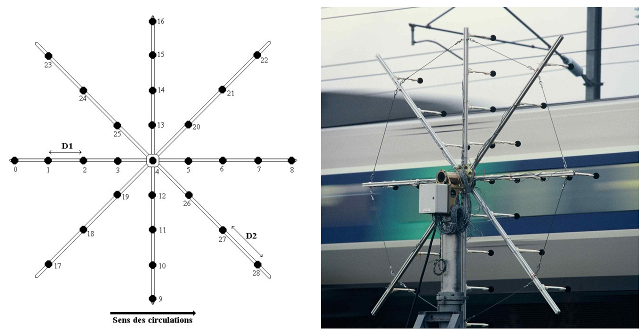

Figure 1: Star shape acoustic array

As most of the others conventional array devices, it requires several configurations of captors and therefore several train pass-bys to be able to analyse the whole frequency range of interest (200- 4000Hz) : the captors spacing and the overall dimension of the array define its frequency limit and spatial resolution. An alternative device was then tested at the same time to overcome this drawback : a 3 by 3 m array support, equipped with a set of 30 captors irregularly distributed. The sampling rate is 48 kHz.

The position of the set of captors is optimised by a calculation process which consists in simulating the array response due to an artificial moving point source

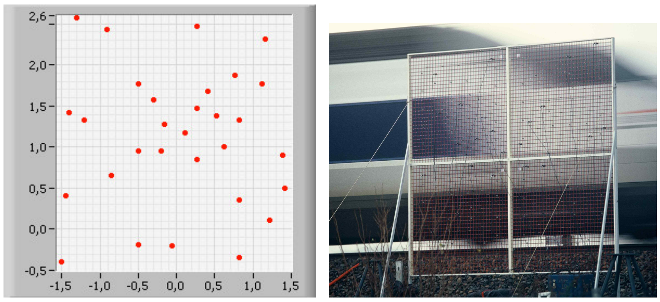

Figure 2: Alternative array with an irregular geometry

The main purpose of this new configuration is on one hand to decrease the amplitudes of the sidelobes and on the other hand to extend its passband by limiting the aliasing phenomenon.

Comparison of the array performances

Results presented hereafter are noise map sources for each third octave band (sound pressure levels at 1m of the sources).

When using similar post-processing algorithms and parameters, it has been demonstrated that both devices achieve comparable results in terms of source location.

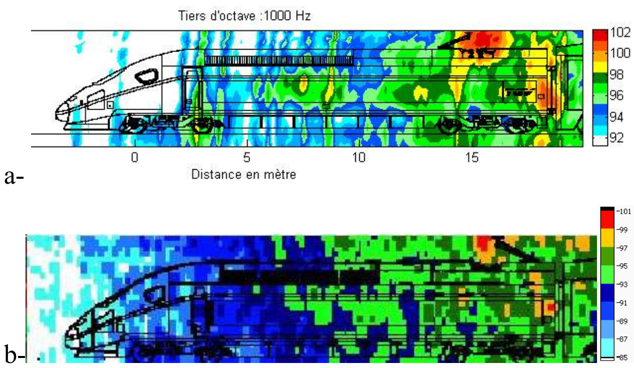

Figure 3: Noise source map on the rear power car at 350kph in the third octave band 1000Hz

a- classic array (star shape)
b- alternative array (irregular geometry)

For instance in **Figure 3** three main sources are highlighted on the rear power car in the third octave band 1000 Hz : the pantograph, the louvers and the noise source near the intercoach gap. In this case, even the maximum levels of each sources are of the same order of magnitude.

Besides, if the new technology of array tested (irregular geometry) demonstrate its capability to extend the array bandwidth for a given number of captors, it failed in covering the whole frequency range : a bandwidth of 100 to 1250 Hz was finally achieved where two configurations of star shaped array would have been required. More captors would then be necessary to fulfil this objective.

Both measurement methods also meet difficulties in quantifying accurately the levels of the acoustic source : the parameters of the spatial Fourier Transform performed (signal duration, averaging, FFT block size) combined with the characteristics of the sources (speed, horizontal directivity) have a significant effect on the .results. The reproducibility seems to be good in the localization process but is still to be improved for the levels assessment. Then each result need to be confirmed by an analysis of several similar pass-bys : a test train remains mandatory.

Moreover, none of the method identify the rail as an acoustic radiator during the pass-by whereas the track is known to have an important contribution in the rolling noise between 500 and 1500 Hz. A first hypothesis is that it is due to the type of source model assumed in the post-processing (monopoles, spheric waves).

Finally, the acoustic array is considered as an operational tool to position the noise sources on trains during pass-bys and also roughly assess their levels.

Identification and hierarchy of the TGV noise sources

Based on the analysis of all noise maps issued from the star shape array measurements, sources spectra are derived from their maximum level in each third octave band.

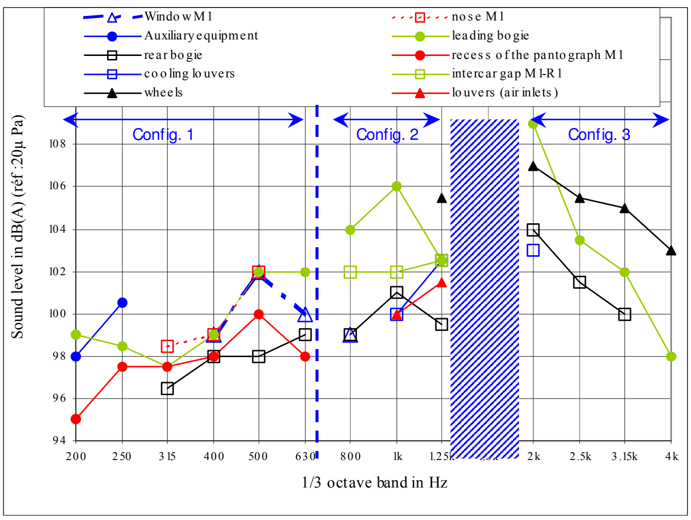

Figure 4 : Noise sources spectra on the leading power car at 350 kph

The results are presented in **Figure 4** for the leading power car. All spectra show two discontinuities (between 630-800 Hz and 1.25- 2 kHz) which correspond to the use of several configurations of array (maximum levels are not comparable between the different arrays). The graph illustrates the importance of the first bogie in the noise radiated. Two separate sources seem to be involved : a rather low frequency aerodynamic source due vortices generated by the turbulent flow in this area, and a rolling noise source above 2kHz which comes from the vibrations of the wheel due to wheel/rail contact force. Besides, a “new” aerodynamic source has been found out, located on the windscreen and which emerges significantly from third octave bands 400 Hz to 630 Hz. It matches with the location of the wiper on the front of the power car (see location in Figure 5).

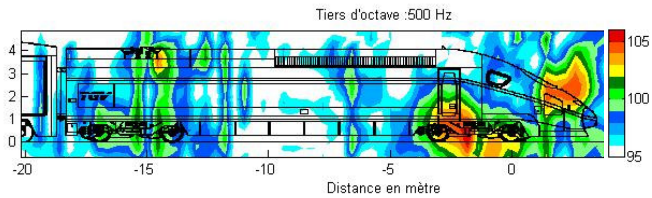

Figure 5 : Noise source map on the leading power car at 350kph in the third octave band 500 Hz

The noise map proposed in Figure 6 for the trailing cars show that at high frequencies (3150 Hz), the whole wheels becomes very emissive, as expected by the background knowledge on the rolling noise theory.

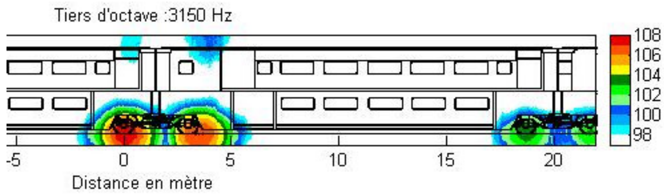

Figure 6 : Noise source map on trailing cars at 350kph in the third octave band 3150 Hz

Conclusions

The 2D acoustic array technique has proved its capability to characterize the noise sources on a TGV-Duplex passing-by at 350 kph : location and spectrum of each source identified on the power and trailing cars were collected.

This measurement method however requires further developments so as to be used as an engineering tool for investigation purpose. The reproducibility and accuracy of the results provided would need improvements. Some developments are then in progress at the SNCF which concern both the design of the apparatus and also the post-processing software.

References

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