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# THREE-DIMENSIONAL LOCALISATION AND CHARACTERISATION OF ACOUSTICAL SOURCES IN A TRUCK CABIN

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## ABSTRACT
In a framework of acoustic comfort, an accurate localisation – in range and angles – of the sources transmitting noise to the driver has been investigated. Such a localisation permits to reduce the predominant sources in priority, in a given frequency range. An experiment has been conducted on a real truck cabin with a single point of excitation. The mechanical excitation was achieved using a shaker, and frequency-modulated signals have been used covering a very wide frequency. Two crossed line arrays of 112 microphones have been employed for reception. Standard wideband beamforming and beam steering have been used on both arrays. For each frequency, the 3D localisation of sources has been achieved. The major sources have been isolated using the Radon transform. A fine analysis was then performed in order to provide their spectral content, in addition to their 3D localisation.

## 1 - INTRODUCTION: DEFINITION OF THE PROBLEM
The problem of sources characterisation in a truck must be divided into two parts, as illustrated on figure 1.

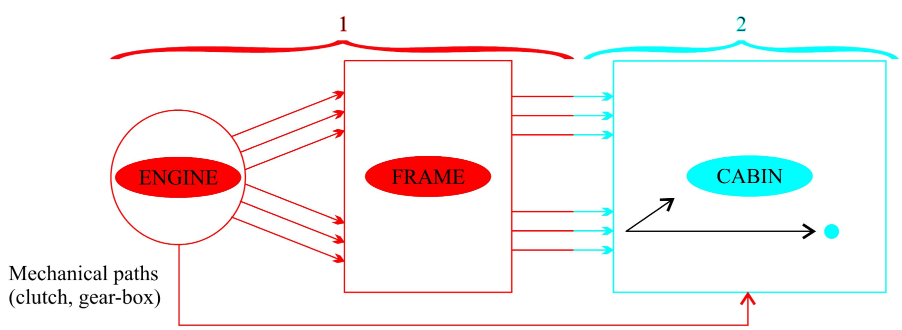



**Figure 1:** Guided propagation in the structure.

In the first part, the cabin is defined as a "black box". In this case, only the vibration paths between the motor and the frame, and between the frame and the cabin are of interest. The aim is to trace the flow of vibroacoustic energy from a source to a given receiver location, through a set of known structure-borne paths.
The second part of the analysis concerns directly the investigated problem, i.e. the localisation of the sources transmitting noise to the driver. The sources are either vibrating ones corresponding to a given excitation point, or virtual ones corresponding to complex propagation and multiple reflections on the cabin elements. From this definition, the goal of this work is to determine the contribution of the major sources to the total pressure sound measured in a known point in the cabin (with a single point excitation).

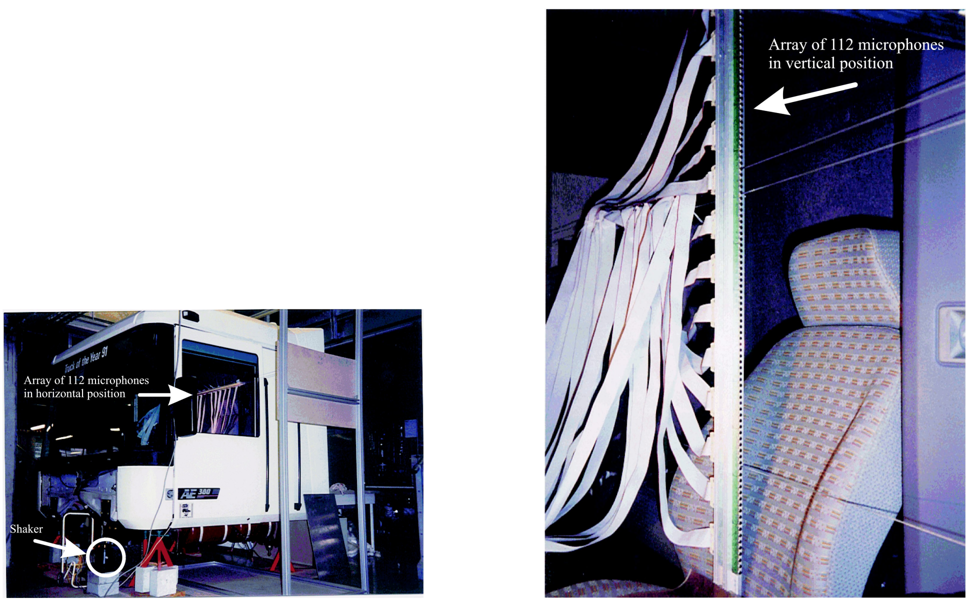
## 2 - RESOLUTION OF THE PROBLEM: TEMPORAL APPROACH

To isolate a given source in a multipath environment, a dual band approach has been achieved. The processing is defined into three steps:

- first, temporal localisation of echoes associated with major transfer paths is achieved thanks to the beamforming method (time domain). This has been performed in a high frequency range, out of range of the main resonances of the system (HF $[5 - 15$ kHz$]$);
- second, a 3D spatial identification is achieved by ray-tracing technique;
- third, the bandwidth is extended to the low frequency range (LF $[0.03 - 15$ kHz$]$). The previous localisation results are then used assuming that the propagation paths are frequency independent in position. Wavefronts separation is then achieved thanks to the Radon transform [1], in order to characterise the low frequency spectral content of signals associated to each path.

## 3 - PRESENTATION OF AN EXPERIMENT ON A REAL CABIN

This section describes the experiment developed on an isolated cabin (figure 2). This one is mounted on the vibration absorbers. The mechanical excitation is achieved by a shaker. The transmitted signals are linear frequency modulated chirps, covering a wide frequency range: 30 to 15000 Hz. They are associated to a matched filter, so as to obtain a good temporal resolution comparable to an impulsive system [2]. Both active correction (using an accelerometer) and digital post-correction are used to compensate for the equipment frequency response. An array of 112 microphones has been constructed and calibrated in amplitude and phase. Two positions have been used in the cabin: horizontal and vertical.




**(a)** **(b)**

**Figure 2:** Experiment description.

## 4 - EXPERIMENTAL RESULTS

Some results obtained for the driver position are presented [3].

### 4.1 - Temporal localisation of echoes in HF range

In order to locate in time the signals corresponding to the various sources, beamforming has been achieved for both the horizontal array and the vertical array. The 3D localisation is achieved by multiplying both outputs and by integrating on a given path length (figure 3, with a path length between 3.2 and 3.4 m, for instance).

### 4.2 - 3D identification of major acoustical sources in low frequency range

The geometrical characteristics of the paths are extracted from the beamforming output, in terms of angle of arrival and distance. With a threshold of 6 dB, 71 paths can be located in the angle-angle plan (figure 4).

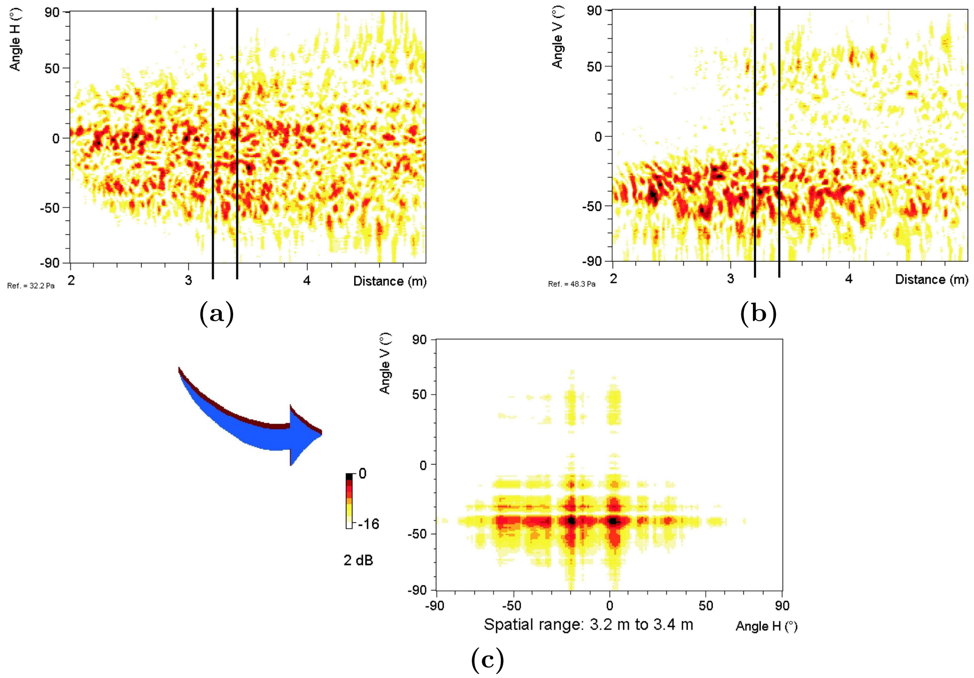



**Figure 3:** Envelope of the beamforming in the time domain for the horizontal array (a) and vertical array (b); bottom image is the average product of the two upper ones for a given spatial range; the colour scale is the same for the three images (2 dB/level).

Inverse ray-tracing method using these geometrical data is then applied to locate the sources position. Back propagation from a given receiver (centre of the array) to the different elements of the cabin is used and allows to identify the parts on the truck where the noise is originated from. The main sources are the deck and the dashboard, in particular the steering-shaft (frequency range $[30 - 100$ Hz]). A minor source was also found corresponding to the windscreen (less than -3 dB, frequency range $[30 - 300$ Hz]).

### 4.3 - Isolation of LF major events

In the last step, the difficulty is to isolate an identified front corresponding to a particular source. This is illustrated on the figure 5 (a), issued from the array output. To achieve the wavefront separation, the Radon transform [1] is used and applied to the spatio-temporal image. Then, a spatio-angular filter is used to isolate a given zone corresponding to the main wavefront. After applying the inverse Radon transform to the filtered image, the corresponding wavefront can be reconstructed. This allows to characterise the source associated to this path, for instance by calculating its spectrum and comparing it to the acceleration signal measured on the shaker.

## 5 - CONCLUSION

A dual band method developed for a 3D localisation of "acoustical sources" has been described and applied to the experiments on a real truck. After the spatio-angular identification of the main events in high frequency domain, the major wavefronts have been isolated using the Radon transform. This permits the spectral characterisation of low frequency sources: the dashboard and the deck ($[30 - 100$ Hz], -3 dB) and the windscreen ($[30 - 300$ Hz], -6 dB).

## ACKNOWLEDGEMENTS

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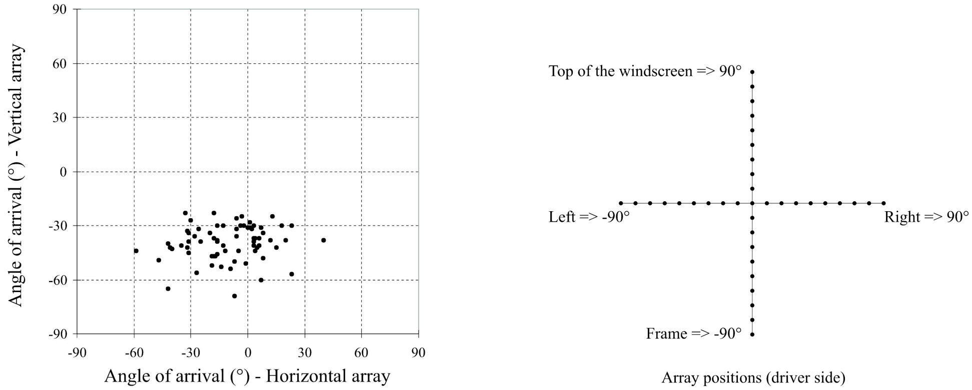
## REFERENCES

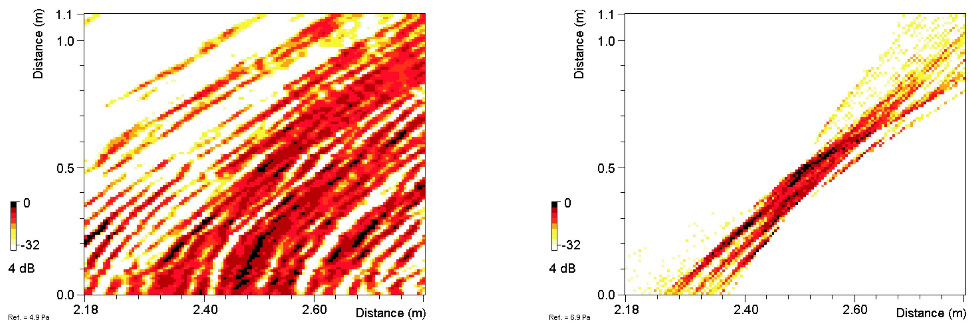
1. **S. R. Deans**, *The Radon transform and some of its applications*, Wiley-Interscience, pp. 289, 1983

2. **J. Max**, *Méthodes et techniques de traitement du signal et applications aux mesures physiques - Tome 1: principes généraux et méthodes classiques*, Masson, pp. 354, 1985




**(a)** **(b)**

**Figure 4:** Angular localisation of main echoes in low frequency.




**(a)** **(b)**

**Figure 5:** Isolation of LF major event; the left image (a) is issued from the array signals; the right image (b) describes the reconstructed main wavefront, isolated by the Radon transform (horizontal axis: propagation distance, vertical axis: position on the array).

3. **P. Dubail**, *Caractérisation acoustique de sources d'origine mécanique dans un habitacle de véhicule*, PhD Thesis, Institut National des Sciences Appliquées de Lyon, pp. 214, 1999