Numerical investigation of jet noise sources with a virtual microphone array technique

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Introduction

Advanced computational aeroacoustics gives promising tools to understand the physical mechanisms generating noise sources. Accurate simulations of complex acoustic propagation phenomena could also help in the design of more informative experimental devices, like phased microphone array. Such an approach is demonstrated in the present work. A high-fidelity numerical configuration is implemented in order to compute the acoustic pressure field from a double-stream mixed nozzle installed in a T-tail configuration representative of a business jet. The time-resolved sound signals are then synthetized on a discrete set of virtual microphones placed on the far-field of the nozzle. These serve as input to an inverse problem aimed at locating and quantifying the noise contributions generated by the jet stream. The inversion is performed using the regularized DAMAS-C deconvolution technique, which exploits the correlation between all the equivalent sources to be identified. Results are compared with microphone measurements from the wind-tunnel test campaign carried out as part of the DJINN project.

Aeroacoustics simulation

The Figure 1 shows the numerical scenario. In the following, the coordinate system is centred with the bypass engine's outlet. A total of 116 virtual microphones take place all around the nozzle in the T-tail configuration. The noise source localization task is performed using the flyover array BE-CE and the sideline array BE-SL, placed above the tail. Each array is a uniform line of 46 microphones regularly spaced by 5/3°, and covers a polar angle range from θ = 45° to 120°. The other set of far-field microphones, denoted by BS-CE and BS-SL in Figure 1, are used here as reference to evaluate in a second step the quality of the source identification result.

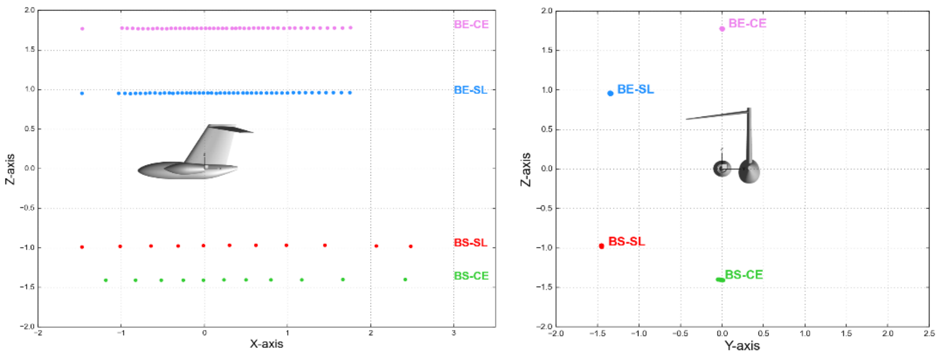

Figure 1 Distribution of the virtual microphones wrt. the DJINN coordinate system (X-Z view on the left, Y-Z view on the right)

The computational pipeline comprises first a high-fidelity hybrid RANS/LES simulation, based on the unstructured solver of the elsA software [1]. The output fluctuating flow fields surrounding the jet are then directly processed using the Ffowcs Williams and Hawkings integral formulation in order to retrieve the time pressure histories at the location of each virtual microphones. More information about the simulation can be found in [2].

Array processing

The DAMAS-C deconvolution technique is an extension of DAMAS [3] to tackle the case of extended and directive acoustic noise sources, by introducing the hypothesis of a fully correlated distribution of equivalent monopoles to locate. Our implantation of the DAMAS-C technique follows that proposed by Fleury and Davy [4], which has been already applied on data from jet stream measurements. Here, the parameters for the Cross Spectral Matrix (CSM) computation at virtual microphones must be carefully defined due to the short temporal length of the simulated signals. In addition, due to the ill-posed nature of the problem, a regularization weighting is introduced to control the numerical stability of the estimate. The parameter value is chosen using a heuristic L-curve strategy [5].
The Figure 2 shows the deconvolved acoustic map obtained with DAMAS-C. The equivalent sources are sought over a regular linear grid of 101 points along the jet axis. The acoustic propagation is assumed to occur through a uniform moving media with constant flow speed and sound celerity, as modelled by the convected Green's function [6]. In comparison with the deconvolved map obtained with experimental data in Figure 3, the sources are well estimated in the vicinity of the nozzle's output with quite similar power level. Note in the experimental case the presence of the mid-frequency spurious source downstream of the jet at $x_s = 2.5m$, near the inlet of the wind tunnel collector. The final presentation will include the acoustic projection from the estimated CSM of the sources over a spherical surface surrounding the nozzle to evaluate the far-field noise radiation of the jet and the ability of the virtual array technique to separate the most emergent sources from the simulation.

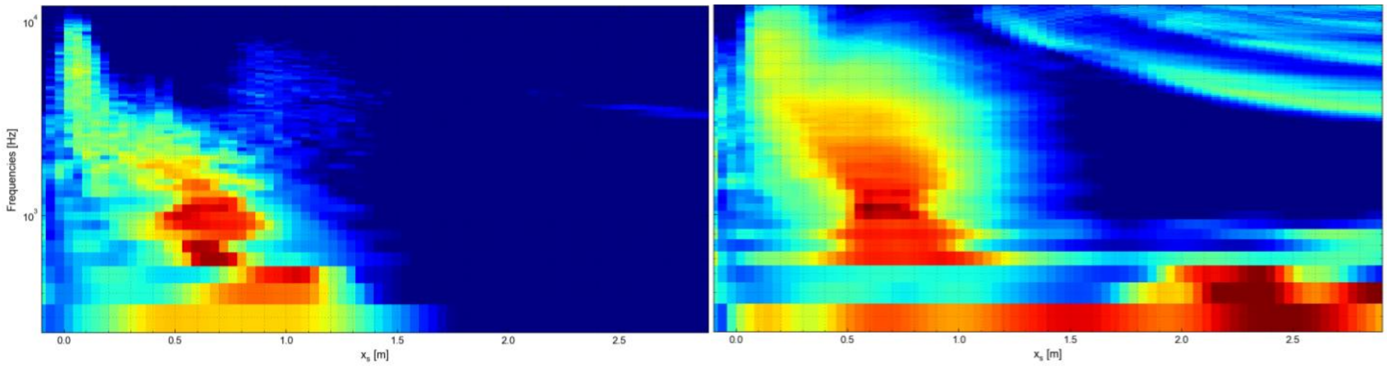

Figure 2: Space-frequency deconvolved acoustic map along the jet axis from the numerical data (on left) and experimental data (on right)

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