A nonlinear toy model for jet noise modelling and control

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Modelling and controlling jet noise are a notoriously difficult tasks, particularly at subsonic levels, due to the subtlety of noise-generating mechanisms. Developing reduced-order models to study these mechanisms and possible mitigation strategies is a well-established practice.

In this study, we focus on developing a toy model for jet flow which incorporates the jitter effect to predict noise generation and, eventually, control it. There exist similar flow models based on Ginzburg-Landau equation[1], parabolised stability equations[2], resolvent analysis[3], etc. However, none of these models have an inherent nonlinearity similar to the jitter in real jets. To include this effect, our model uses a train of free vortex rings.

We perform a direct numerical simulation of discrete vortex rings shed from the edge of the nozzle as a low-fidelity flow model, incorporated with Howe's acoustic analogy to calculate the noise generated by these vortex rings. The interaction between the vortex rings is calculated using the Biot-Savart law, leading to a nonlinear and chaotic behaviour akin to the jitter observed in jets. The difference between laminar and turbulent jets is mimicked by introducing random modulations in vorticity strength at the nozzle edge. This random modulation affects the chaotic behaviour of the vortex rings and, thus, the generated noise. The nonlinear nature of the model presents a realistically challenging problem for noise control. The acoustic field generated by this vortex train model is shown in Figure 1. The top plot shows the power spectral density (PSD) obtained at various directivity angles. At each angle, the spectrum peaks around $St = 0.1$, with higher PSD levels at lower directivities. A directivity plot is shown at the bottom indicating a superdirectivity akin to that of a jet. In the final paper, we will use various control approaches on this toy model and evaluate their efficiency, which will help develop noise control strategies for real jets.

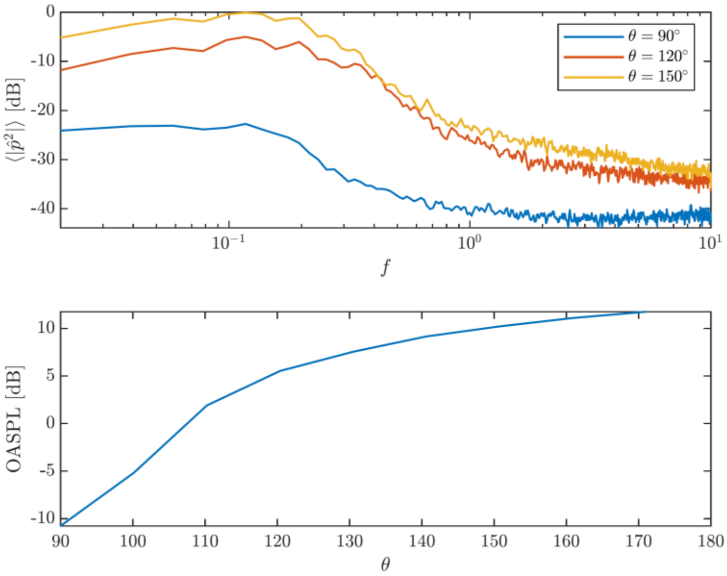

Figure 1: Farfield spectra of the acoustic field generated by the toy model at various angles (top) and the directivity (bottom).

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