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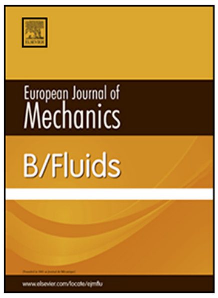

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Transfer mechanisms from stochastic turbulence to organized acoustic radiation in a supersonic jet

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Abstract

We examine the three-dimensional energy-exchange mechanisms between stochastic turbulence and an organized radiating wavepacket, and subsequent scattering and transmission of acoustic energy. A validated round-jet large-eddy simulation (LES) is subjected to Kovásznay-type decomposition into hydrodynamic, acoustic and thermal modes, as encapsulated in the generalized framework of the momentum potential theory (MPT). The results are first assimilated with known and postulated aspects of jet-noise dynamics to provide an alternative perspective. Subsequently, new insights are derived on acoustic-energy generation and transport processes. The prolonged axial and azimuthal spatio-temporal coherence of the jittering acoustic mode, which manifests as a wavepacket, and the localization of its energy to the low-order azimuthal modes ($m = 0, 1$ and 2) are shown to arise naturally in the decomposed field. The spatial supports of the internal and radiating components of the acoustic-mode are identified with dynamic mode decomposition (DMD). The resulting spectra are observed to be similar to those of the global instability modes of the mean flow. In contrast, the hydrodynamic mode, which is the primary source of energy in this cold jet, has broadband spectral structure and limited spatio-temporal coherence. This knowledge is then leveraged to analyze and quantify sound scattering versus transmission through energy interactions between the relatively chaotic hydrodynamic mode and its stimulation of an ordered response in the acoustic mode. Surface integral analyses reveal the mechanisms by which the omni-directional nature of the turbulent scattering is established. The acoustic mode plays a central role in imparting directionality to the acoustic transmission process, with its axisymmetric component contributing to downstream and shallow angle radiation and higher azimuthal modes contributing increasingly to sideline radiation. Volumetric integral analyses combine these observations to show that the unorganized hydrodynamic mode generates localized noise-producing regions, resulting in a coherent form of sound radiation from the jet.

Keywords: Jet noise, Large-eddy simulation, Acoustic energy