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A numerical study on multimode sound propagation in lined ducts and radiation to the far field

Rie Sugimoto, R Jeremy Astley, Claire McAleer and Iansteel Achunche
ISVR, University of Southampton, Highfield, SO17 1BJ Southampton, UK

In previous articles, the authors developed a hybrid scheme for analysing bypass duct noise, in which a numerical analysis using finite element method for in-duct propagation and an analytic radiation code with fully represented effects of bypass shear layer are coupled. Such procedure permits detailed study on the interaction between duct configurations, such as geometry and acoustic liner impedances, and modal propagation and attenuation, and also the effects on the radiation pattern, within practical timescale and at modest computational cost. The scheme has been applied to realistic aero-engine bypass ducts and has been integrated with an optimisation programme. The numerical results obtained so far have revealed that for ducts with acoustic liners highly attenuated modes are not necessarily those with high mode angles, which is contrary to general anticipation. The aim of the study in the current paper is to understand the physics behind this phenomenon and its effect on the radiation to the far field. Detailed investigation on modal attenuation is performed by using the hybrid scheme. The effect of modal power distribution at the duct exit on the directivity pattern of the radiated noise to the far field is also discussed.