# Experimental Aeroacoustic Assessment of Coaxial Drone Propellers

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Keywords: Aeroacoustics, propeller noise, coaxial propellers

## Abstract

This study outlines the development of an aeroacoustic testing facility designed for investigating single and coaxial propeller propulsion systems for drone applications within the framework of the ENODISE (ENabling Optimized DISruptivE Airframe-Propulsion Integration Concepts) project. The experimental setup has been designed in the ALCOVES anechoic laboratory of the von Karman Institute for Fluid Dynamics in Belgium.

The need for quieter, more efficient drone technologies is a subject of increasing importance in contemporary research. The advantages of coaxial multicopter configurations result in redundancy for component failure, as well as higher flight endurance and payload with respect to single propeller systems**[1]**. Nevertheless, the main obstacle to the wide implementation of these services is their high level of noise emissions and the consequent impact on the environment and human perception**[2]**. Understanding and characterizing these disturbances represents a crucial matter for designing quieter technologies that conform to stringent noise regulations and do not disrupt urban or natural settings. While offering numerous advantages, coaxial propellers introduce unique noise phenomena resulting from interactions among the closely spaced propellers, and the airframe, making it difficult to predict the noise, let alone to propose mitigation strategies. Hence, a significant scientific challenge towards quieter coaxial propellers is the identification and prediction of the dominant sources of noise. McKay *et al.* carried out an extensive parametric investigation of contra-rotating commercial propeller configurations**[3]**. Results of OASPL (Overall Sound Pressure Level) showed that configurations with mismatched blade numbers produced less noise. Similar findings were found when using the upstream propeller with a smaller diameter than the downstream one. The effect of spacing was observed in decreasing OASPL, mostly due to decreasing interaction tones rather than broadband noise. The overall thrust, instead, did not vary with spacing. The authors suggested a possible change in the dominant noise generation mechanisms as a possible consequence of varying distances. A recent study on the optimum separation distance for minimum noise of contra-rotating rotors with zero net torque at hover was carried out by Chaitanya *et al.* **[4].** Minimum noise was found in configurations with high aerodynamic efficiency, where the separation distances ($z$) ranged from 0.25 to 0.5 times the diameter ($D$) of the propellers.

The presence of two distinct test stands for each propeller represents a commonly suggested experimental setup in existing literature, but it can potentially introduce additional sources of noise due to the presence of the test stands, which have the potential to divert the propeller's slipstream. Alternatively, the rotors can be mounted along the same axis, resulting in challenges when attempting to adjust the distance between elements, yet it recalls the actual arrangement of stacked rotors found on drones.

Unlike conventional experimental setups for coaxial propeller research, the design presented herein allows for aeroacoustic exploration of coaxial propeller systems while mitigating external noise sources. The adaptability of the test rig enables the investigation of different factors, such as adjusting the number of blades, varying rotor spacing within a specific range, and changing the rotational speed. It is equipped with aerodynamic sensors for the analysis of performance. Furthermore, a square-shaped microphone array is used to characterize the noise in the far-field. The preliminary database includes the aerodynamic and acoustic characterization of DJI 9450 and Mejzlik 2-blade propellers. Eventually, the goal is to provide a benchmark to validate both low- and high-fidelity numerical approaches.

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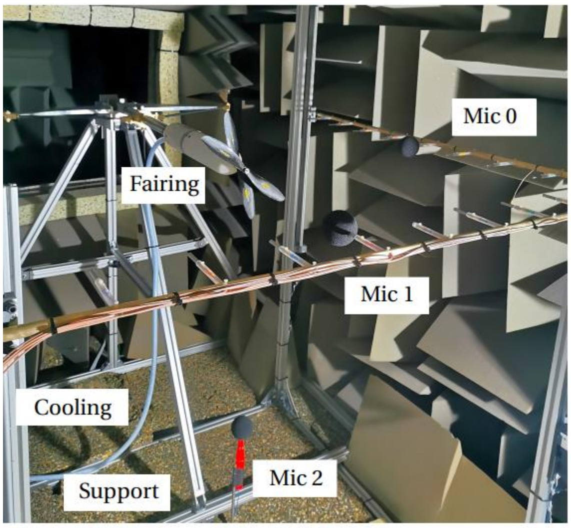


**Fig. 1** Fairing, cooling hose, supporting stand and microphones setup in the anechoic room ALCOVES.

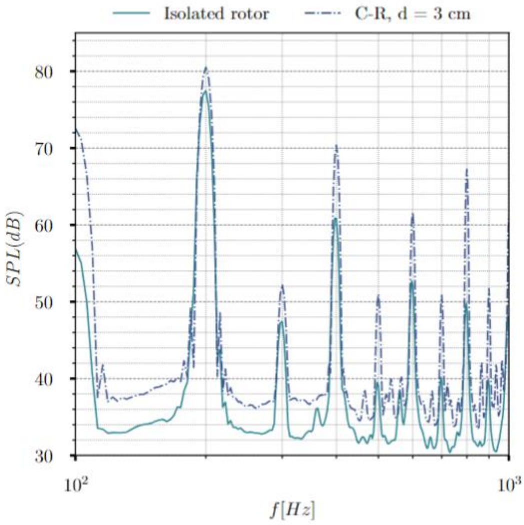


**Fig. 2** SPL noise measured with isolated and contra-rotating Mejzlik 2-blades propeller.

## Acknowledgements

The present investigation has received funding from the European Union's Horizon 2020 research and innovation program under the project ENODISE (ENabling Optimized DISruptivE airframe-propulsion integration concepts), grant agreement No. 860103.3.

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