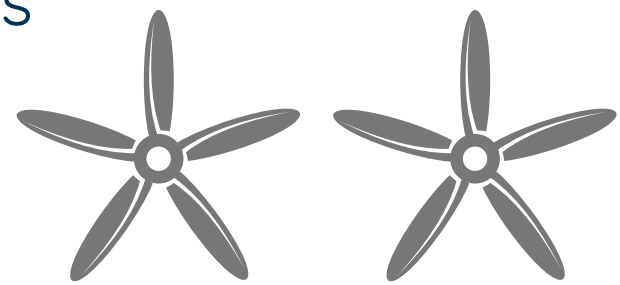
AEROSPACE

Acoustic Effects of Differential Rotor Speeds on Twin-Propeller UAV Systems



CUSTOMER / ORGANIZATION
University of Bristol
School of Civil, Aerospace and Design Engineering, United Kingdom

PRODUCT
GRAS 40PL
¼" Microphones for far-field acoustic measurements

GRAS 42AA
Pistonphone Calibrator for microphone calibration prior to testing

ARTICLE
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Challenge

As UAVs and future Urban Air Mobility (UAM) vehicles become more common in populated areas, noise remains one of the key barriers to public acceptance and regulatory approval. Twin- and multi-propeller systems generate strong tonal noise at the blade passing frequency (BPF), which can be particularly noticeable and annoying to people. While previous studies had investigated synchronized and non-synchronized propeller operation under static conditions, there was limited understanding of how rotational speed mismatches affect acoustic performance and perceived annoyance during realistic forward-flight operation.

The challenge was therefore to accurately measure and quantify the aerodynamic, aeroacoustic, and psychoacoustic effects of differential rotor speeds in a twin-propeller UAV system and determine whether controlled non-synchronization could serve as an effective noise mitigation strategy.

Application

Aeroacoustic characterization of a twin-propeller UAV system operating under static and forward-flight conditions, with emphasis on the effects of asynchronous rotor speeds on noise generation and psychoacoustic annoyance.



Figure 1. Conceptual flight path for a UAV in smart cities.

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GRAS Solution

The research team employed:

- **GRAS 40PL ¼" Microphones** for far-field acoustic measurements
- **GRAS 42AA Pistonphone Calibrator** for microphone calibration prior to testing

The microphones were arranged in a 14-channel array positioned 1.75 m from the twin-propeller configuration and covered observer angles from 65° to 130°. The system enabled accurate measurements across a frequency range of 10 Hz–20 kHz with a dynamic range of 142 dB.



GRAS 40PL-10 CCP Free-field Array Microphone, High Pressure
It is a low-cost microphone for general purpose measurements in arrays and matrices.

Read more
GRAS 40PL-10 >



GRAS 42AA Pistonphone, Class 1
The GRAS Pistonphone 42AA is a battery-operated, precision sound source for accurate and reliable calibration of measurement microphones, sound level meters, and other sound measuring equipment.

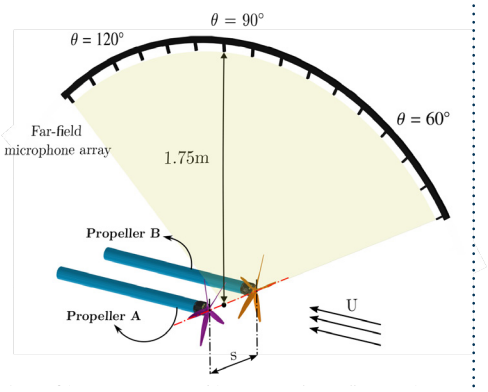
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Test Setup

Experiments were conducted in the University of Bristol's closed-loop aeroacoustic wind tunnel. Two identical five-bladed UAV propellers (9-inch diameter) were operated with rotational speed differences ranging from 0 to 300 rpm under:

- Static thrust conditions (0 m/s inflow)
- Forward flight conditions at 14 m/s
- Forward flight conditions at 24 m/s

The objective was to quantify aerodynamic, acoustic, and psychoacoustic effects caused by non-synchronized propeller operation.







Key Findings

The study demonstrated that introducing a controlled rotational speed mismatch between propellers can significantly reduce tonal noise:

- Approximately **2 dB noise reduction** under static and high advance-ratio conditions.
- Up to **5 dB noise reduction** at low advance ratios.
- Psychoacoustic annoyance decreased by approximately 5% under static conditions and up to **15% during forward flight at low advance ratios**.
- The dominant blade-passing-frequency tone was split into two components, reducing tonal reinforcement and perceived annoyance.

Value of GRAS Equipment

The GRAS measurement system provided the precision and dynamic range required to:

- Capture subtle changes in blade-passing-frequency tonal components.
- Analyze tonal beating effects caused by asynchronous rotor speeds.
- Support psychoacoustic assessments including loudness, tonality, fluctuation strength, and annoyance metrics.
- Deliver reliable far-field acoustic data for advanced UAV noise research.

Outcome

The results show that controlled non-synchronization of UAV propellers can serve as a practical noise mitigation strategy for future distributed-propulsion and urban air mobility platforms. The study highlights how high-accuracy acoustic measurements using GRAS microphones enable researchers to evaluate both objective noise levels and subjective human perception of UAV noise.

Publication

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About GRAS Acoustics

GRAS is a worldwide leader in the sound and vibration industry. We develop and manufacture state-of-the-art measurement microphones to industries where acoustic measuring accuracy and repeatability is of the utmost importance in R&D, QA and production. This includes applications and solutions for customers within the fields of aerospace, automotive, audiology, and consumer electronics. GRAS microphones are designed to live up to the high quality, durability and accuracy that our customers have come to expect and trust.
GRAS Acoustics is represented through subsidiaries and distributors in more than 40 countries and is part of Axiometrix Solutions, a leading test solutions provider comprised of globally recognized measurement brands.

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