Drone propeller noise under static and steady inflow conditions

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Small unmanned aerial systems (sUAS), also known as *drones* are becoming increasingly useful for commercial, private and military activities. Despite their usefulness, drones create noise that is annoying to the public [1, 2] as well as reducing military stealth. Surprisingly, there are a lack of adequate safety and noise regulations for drones [3]. Given the need to reduce noise and develop appropriate standards, new research is required to understand the nature of drone noise production and develop novel methods of control.

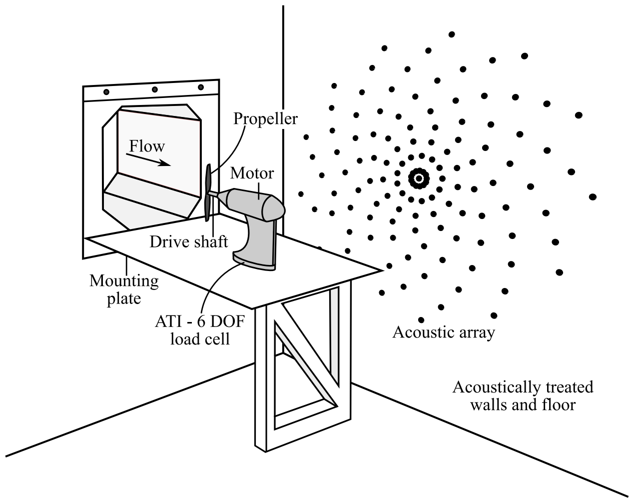
Drone noise is dominated by the small propellers used as part of their propulsion systems. Acoustic signatures consist of strong harmonics occurring at multiples of the blade pass frequency as well as a broadband component [4, 5]. The sources of drone propeller noise are loading noise (steady and unsteady) and thickness noise. Steady loading noise and thickness noise are the main contributors to the harmonic content. If the propeller blades encounter a gust, wake or pass close to the airframe, unsteady loading noise is created which adds more harmonic content to the acoustic spectrum.

Broadband noise is also a form of unsteady loading noise and is caused by the interaction of turbulence with the blade. Inflow turbulence creates unsteady lift on the propeller blades which radiates as broadband sound. Similarly, propeller boundary layer turbulence can interact with the trailing edge of the blade and create broadband noise. If the blade boundary layer is laminar, then broadband noise from the trailing edge can be quite high. Additionally, tones associated with the shaft rotation frequency (and harmonics) are superimposed on top of the aerodynamic noise.

The main focus of this paper is to experimentally measure drone propeller noise under static and simulated in-flight conditions. While there have only been a few acoustic studies for drone propellers [4, 5, for example] there are no published studies concerning drone propeller noise under flight conditions in a wind tunnel.

The experiments were conducted in the UNSW 455 mm $\times$ 455 mm open-jet Anechoic Wind Tunnel (UAT, see figure1(a)). A drone propeller mounting system was used to house the drone electric motor. Drone propellers were attached to the output shaft using a conventional self-tightening mechanism. Aerodynamic load was measured using a 6-component force balance. Noise was recorded using a 64-channel microphone array and inflow turbulence levels were measured using a single-component hot-wire. A variety of drone propellers have been tested; in this paper, the results tests utilising 2-blade APC-style 8 and 12 inch rotors under static and steady, uniform inflow will be presented, for a variety of advance ratios ($0 \leq J \leq 0.2$). The steady flow velocity was varied over the range $0 \leq V_\infty \leq 30$ m/s. The complete paper will provide a comprehensive description of the experiments as only a very brief description has been provided here.

In addition to the experimental methods, a semi-analytical, frequency-domain noise prediction code has been coupled with a Blade Element Momentum Theory (BEMT) code for the purpose of understanding drone acoustic signature production. This code will be used to help identify the source mechanisms in the experimental results.



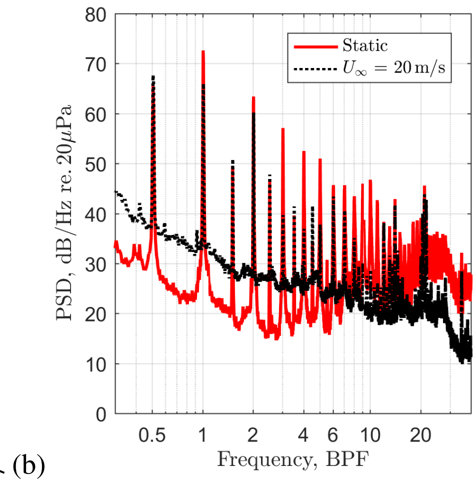


Figure 1: (a) Drone propeller noise measurement in the UNSW Anechoic Wind Tunnel; (b) Drone propeller noise measurement for APC-style 12 inch rotor under static and uniform $V_\infty = 20\,\mathrm{m/s}$ inflow, 7000 RPM.

As an illustration of the experimental results that will be presented, figure 1(b) shows a comparison of drone propeller noise under static and steady inflow conditions at a freestream velocity $U_\infty = 20\,\mathrm{m/s}$. The harmonic content is clearly visible in the static ($U_\infty = 0\,\mathrm{m/s}$) case. When placed in the uniform ($U_\infty = 20\,\mathrm{m/s}$) flow, two changes are noticeable. First, the broadband noise level rises by about 10 dB (below approximately the 4th BPF harmonic), which is presumably due to the interaction of the turbulence in the wind tunnel flow with the blades and tunnel background noise. Second, the harmonic levels change , and this is most likely due to changes in the steady loading on each blade.

The full paper will provide a more detailed examination of the acoustic signatures and the effect of operating conditions on them.

References

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