Creating and Comparing Source Models of UAS in Various Flight Patterns

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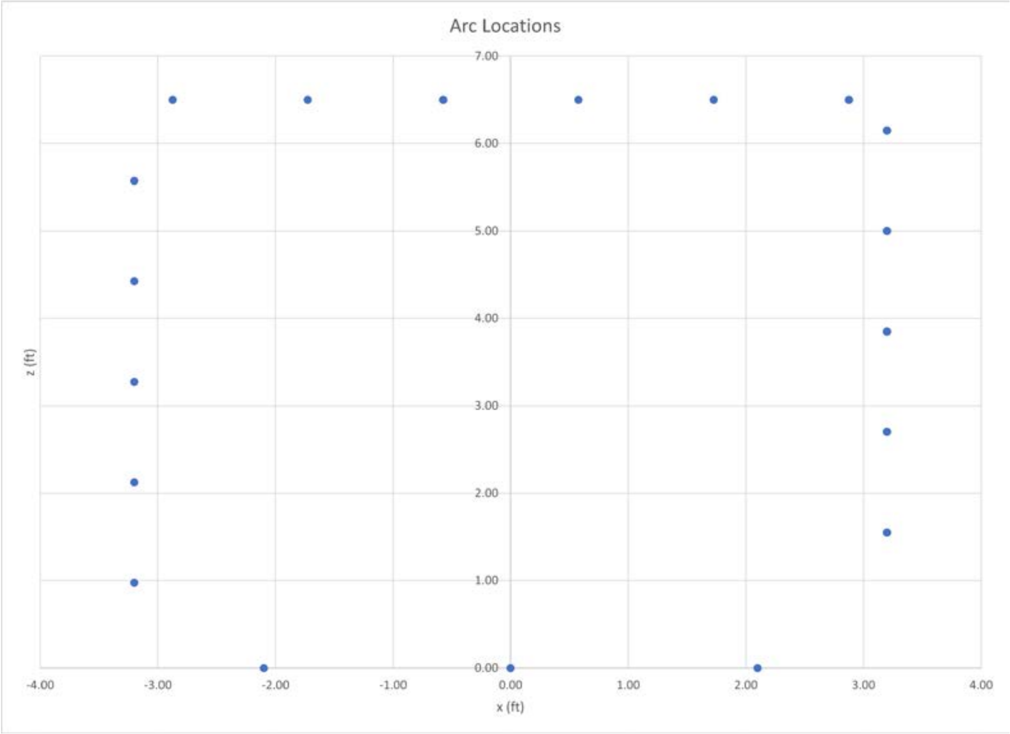
Background

- Private, Commercial, and Personal use of drones (UAS) is on the rise
- Drones as a delivery system are already in use, and will begin to deliver on a larger scale
- Drone noise is complex – 4+ blades which can rotate at different frequencies for various maneuvers
- Some research done, but existing models for noise prediction are lacking
- Many different types of commercially available drones – no consistent models

Images via: https://www.parrot.com/en/drones/anafi

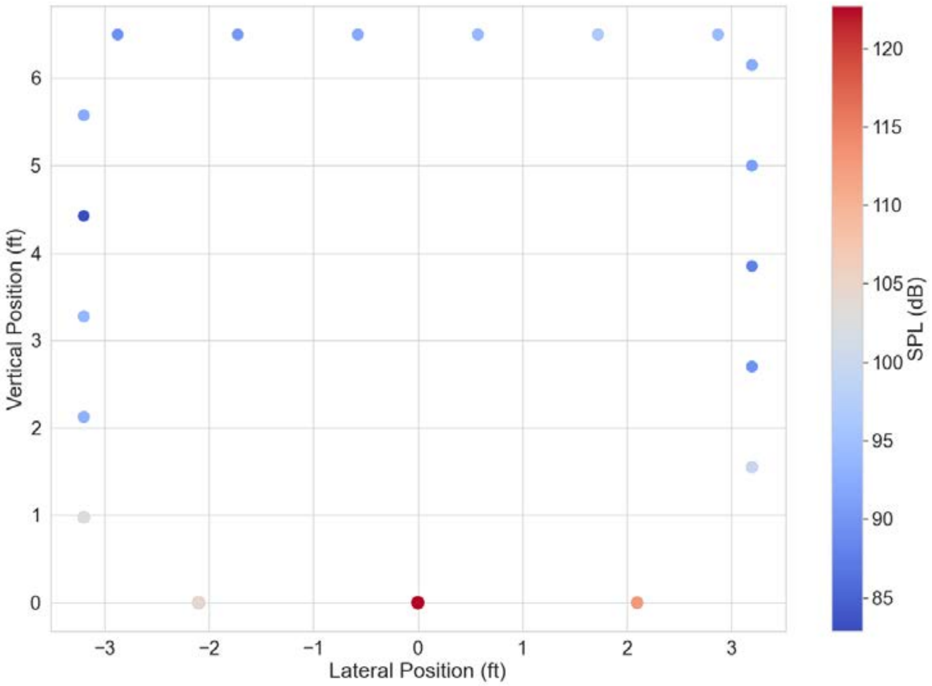
Flythrough Measurement

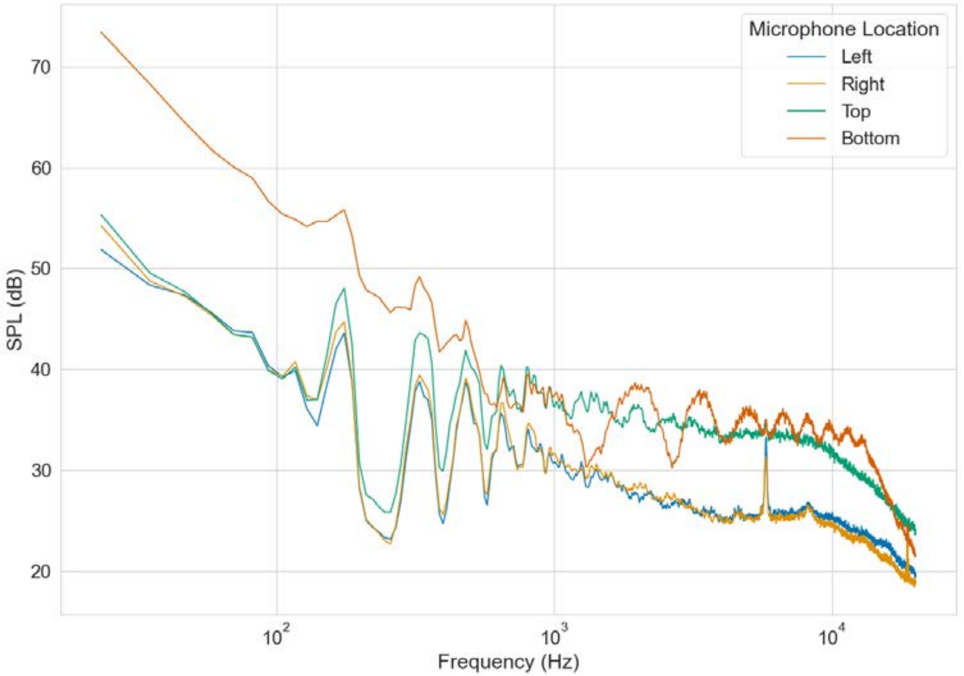
Photo courtesy of AFRL



- 19-microphone array
- GRAS 46AO prepolarized ½” microphones
- Multiple fly-throughs and fly-overs at various altitudes

Flythrough Measurement Results

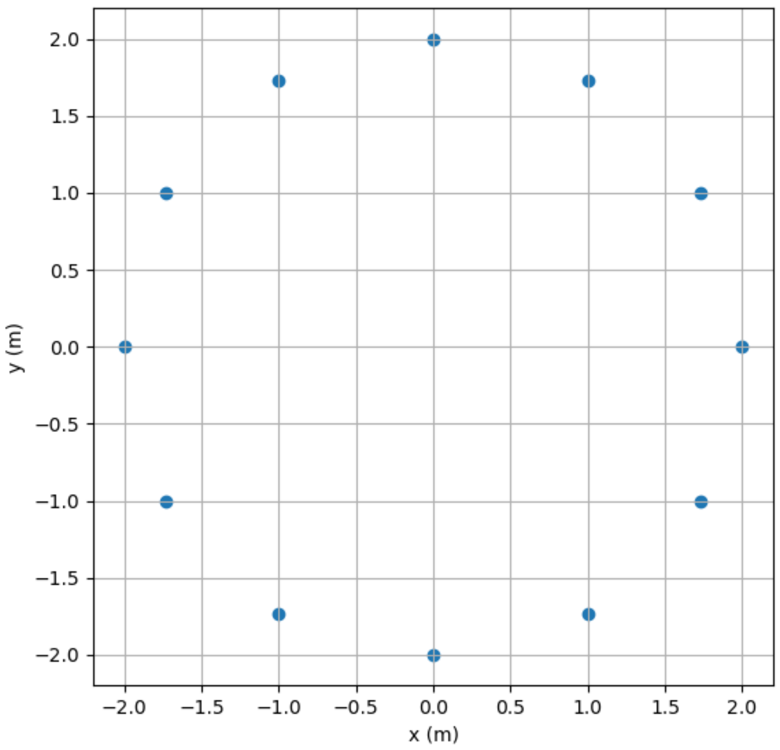




- Levels on the ground much higher than to the sides
- Levels are the lowest directly to the sides of the array
- Spread of 35 dB between left and bottom without weighting

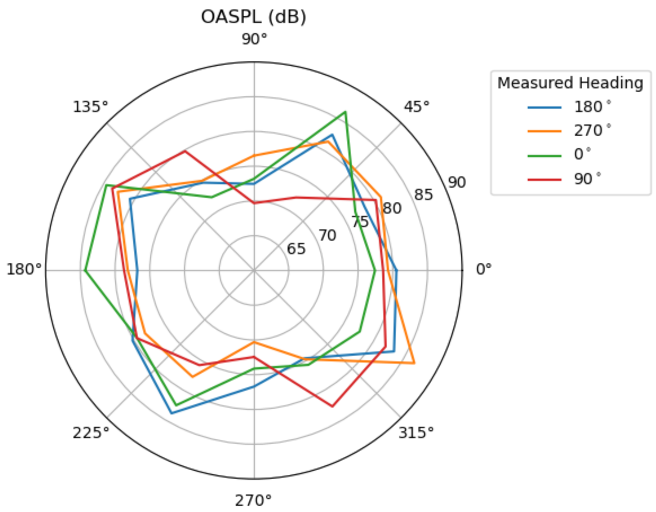
- Significant energy from downwash seen on ground
- Harmonics due to blade pass frequency
- High frequency ringing on ground microphone – likely ground effects (comb filter)
- A-weighting brings energy below drone closer to (but still above) other locations

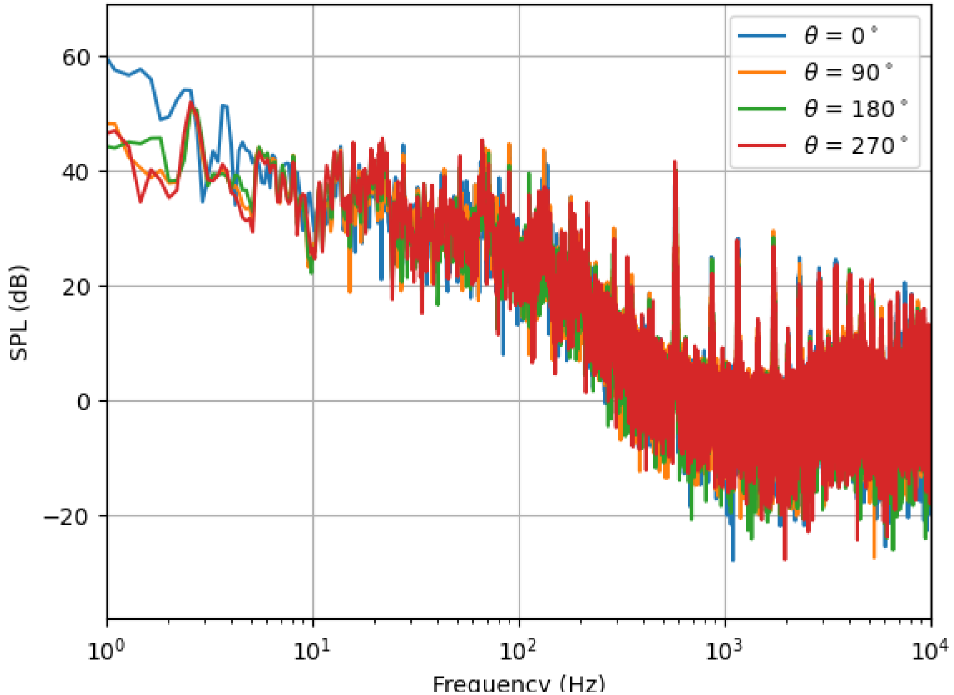
Flight Pavilion Measurement



- Inside Sinclair’s Flight Pavilion (practice facility)
- 12 microphones every 30° in a 2 m radius circular arc. Microphones placed on the ground with grazing incident angle
- Flights at 1m, 3m, and 5m above the ground
- Hovers at the four cardinal directions and continuous rotation about the z-axis
- Various Drone types (size and rotor number)
- Multi-drone configurations with one drone above x = +/- 2 m
- Most analyses shown in this presentation are of the Parrot ANAFI USA drone. It is a quad-copter of relatively small size, and publicly available

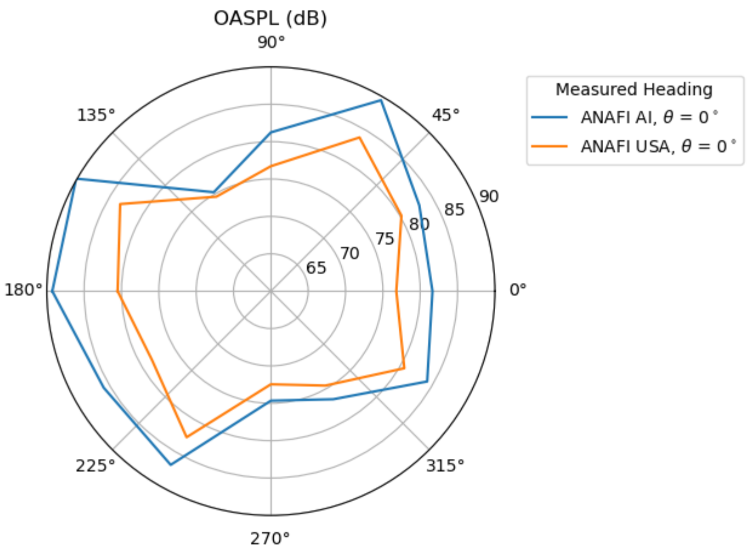
Flight Pavilion Levels and Spectra

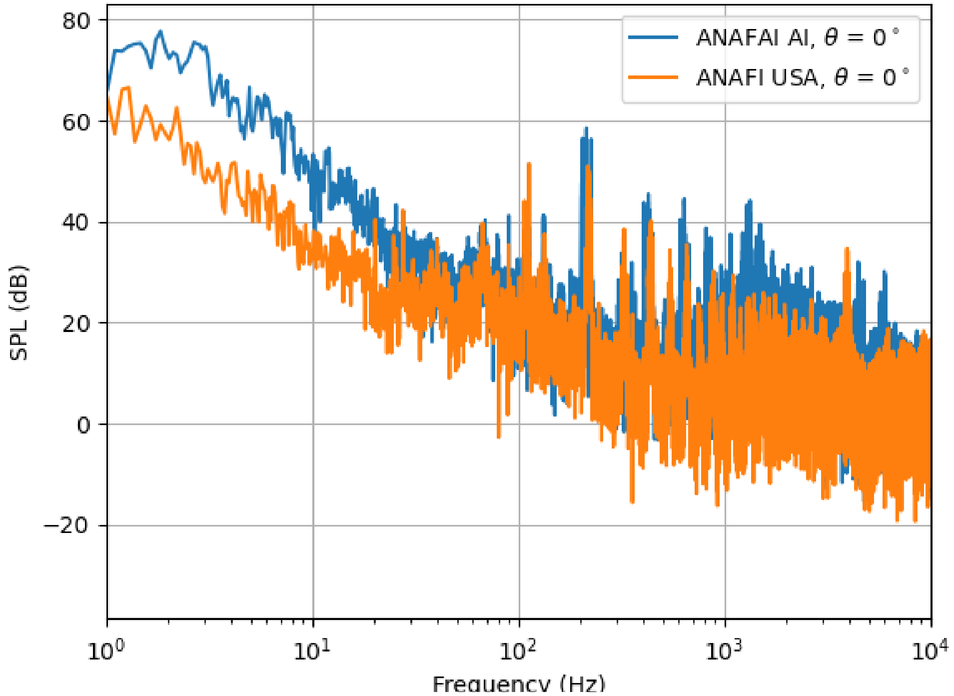




- Using each cardinal direction and rotating it in post-processing back to the original heading, comparisons show deviation in levels/directionality
- Spectra are consistent across four different measurements

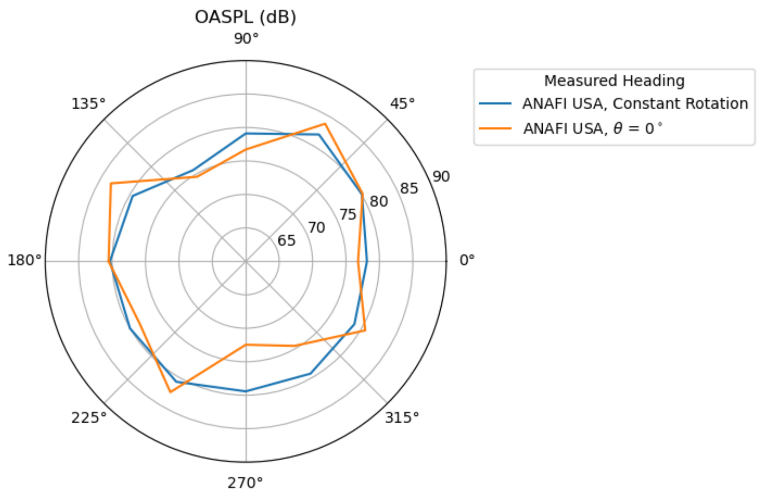
Scalability

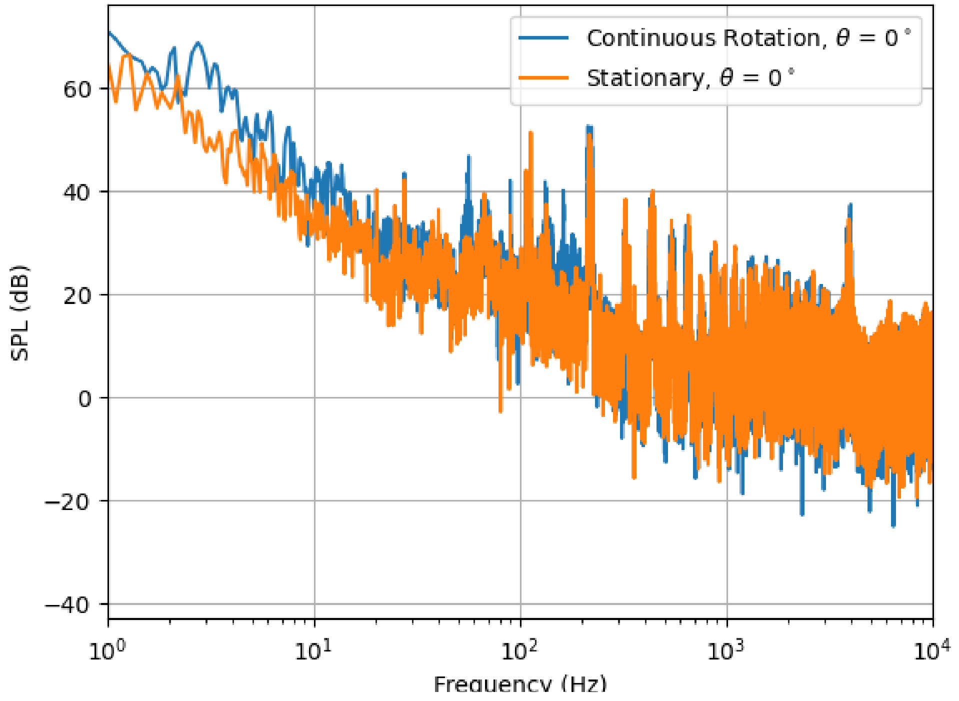




- The ANAFI AI is roughly 900 g, while the USA is 500 g. Assuming similar thrust requirements, one would expect a ~5 dB increase in level
- Similar directivity however not perfectly scalable
- Spectral content is also slightly different, likely due to rotor rotational speeds required for hovering

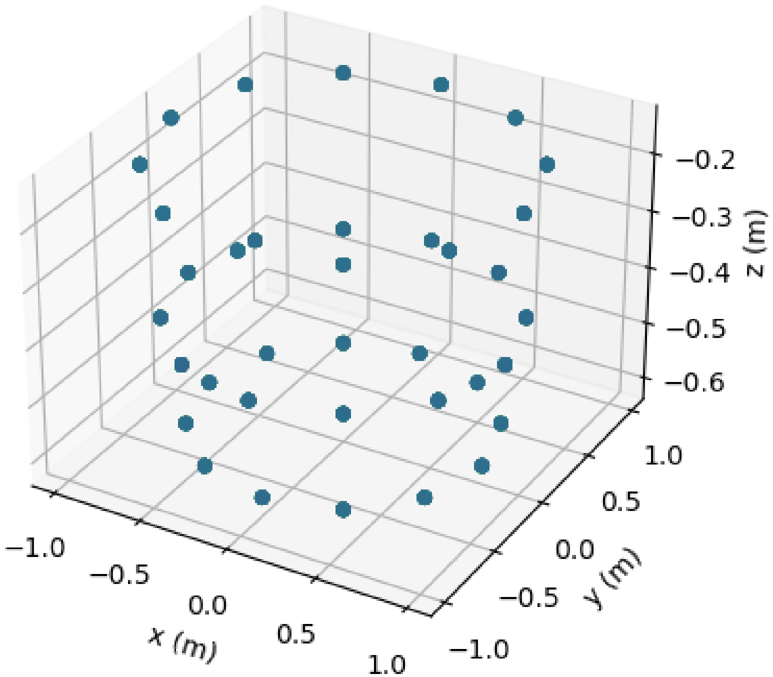
Rotation Effects

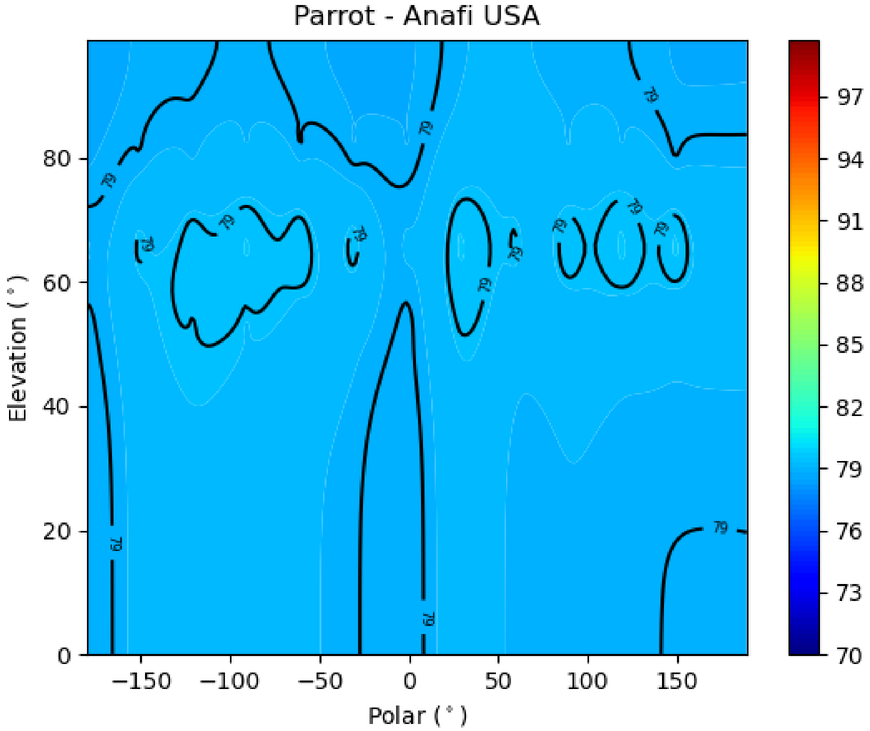




- While rotating, directivity pattern is much more uniform
- Levels are increased on average as well by 1-2 dB
- Frequency content differs – to rotate the UAS, rotors must move at different speeds
- Promotes the idea of models being complex, with sources based on not only drone type, but flight plans

Source Creation

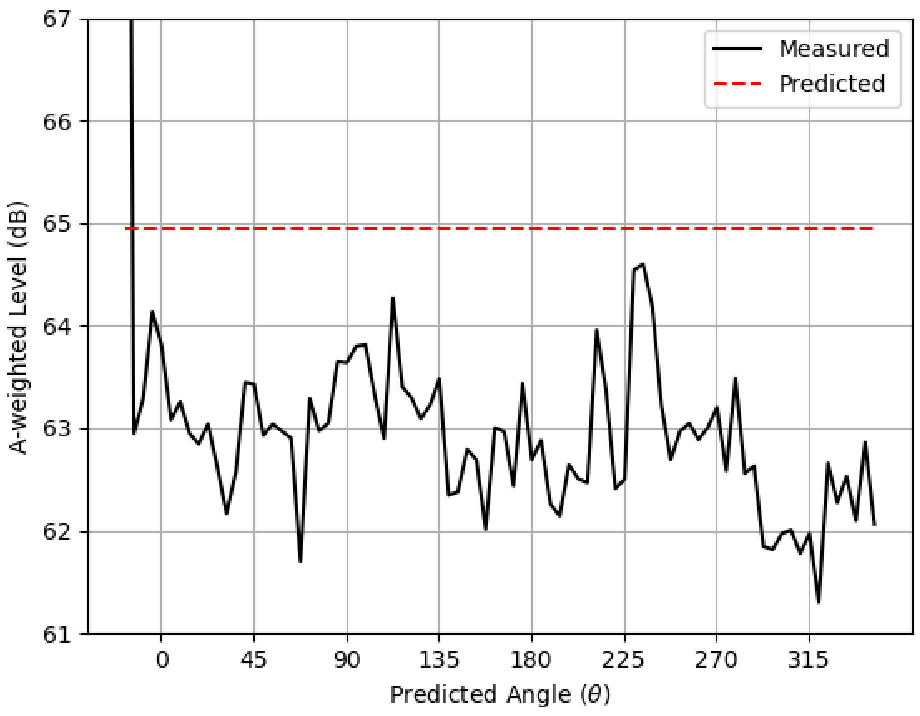




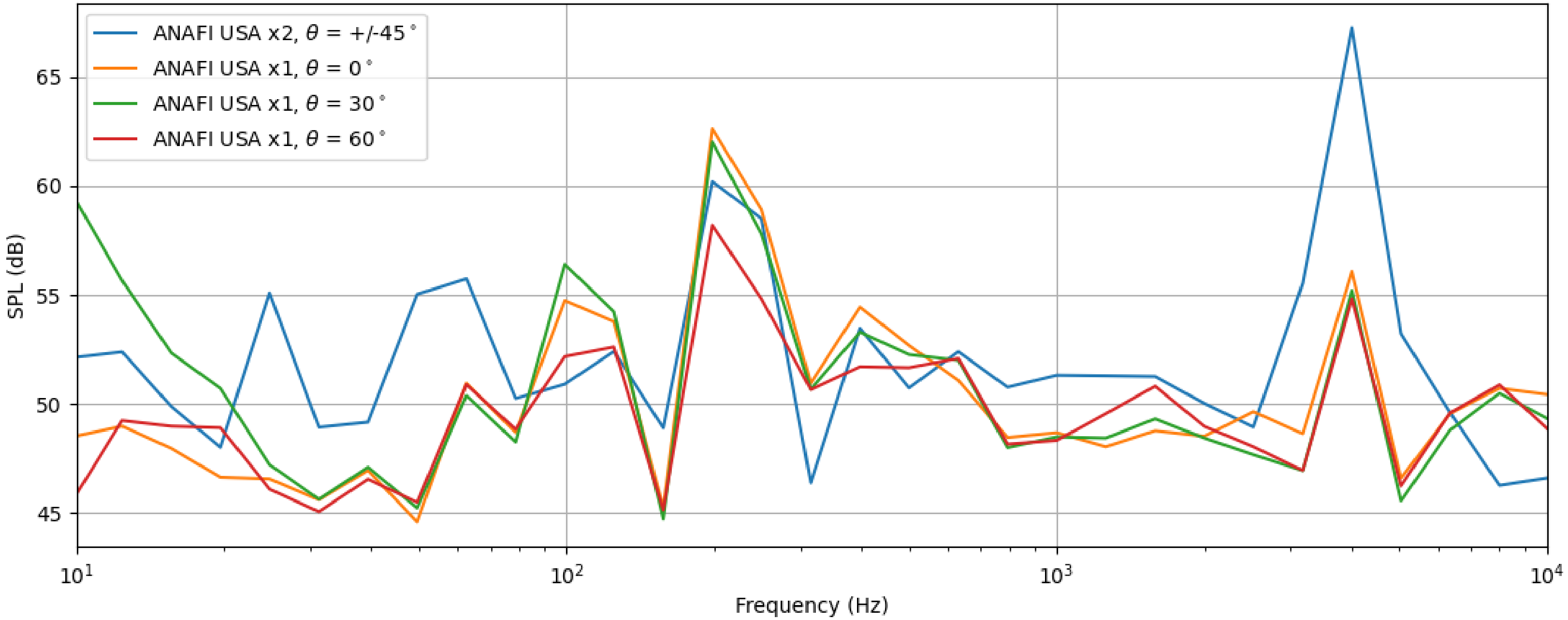
- Using all three heights and backwards propagation, a 1 m sphere of points can be created from which a source can be derived
- Sources are made through interpolation and can be made for any metric or frequency band
- Downwash effects are minimal if not non-existent due to limited data points directly below the source

Using the Source to Predict Levels

- By taking a created source and propagating it while also rotating it, we can compare the predicted levels at recorded locations versus recorded values
- The source slightly overpredicts for the A-weighted metric by 1-2 dB
- While an imperfect prediction, an overprediction can be valuable in both regulation and prevention of detection
- Rotational versus stationary versus more complex maneuvers supports further measurement and analysis



Multi-drone Effects



- Multi-drone scenarios are even more difficult
- Below 100 Hz, frequency content does not differ too much from a single source
- Increased level at the likely blade-pass frequency from two sources
- More research is being done on multidrone scenarios and perception

Conclusions

- Drone Noise is complex (not a monopole)
- Drone Noise is not perfectly scalable i.e. increasing drone weight does not perfectly correlate to acoustic energy
- Creation of Drone Sources is also complex – should they include downwash effects?
- Rotational effects also increase source creation difficulty
- Multi-drone scenarios also do not scale
- Further investigation and measurements are recommended

Image via: https://www.parrot.com/en/drones/anafi