Update on Electric Motor Noise

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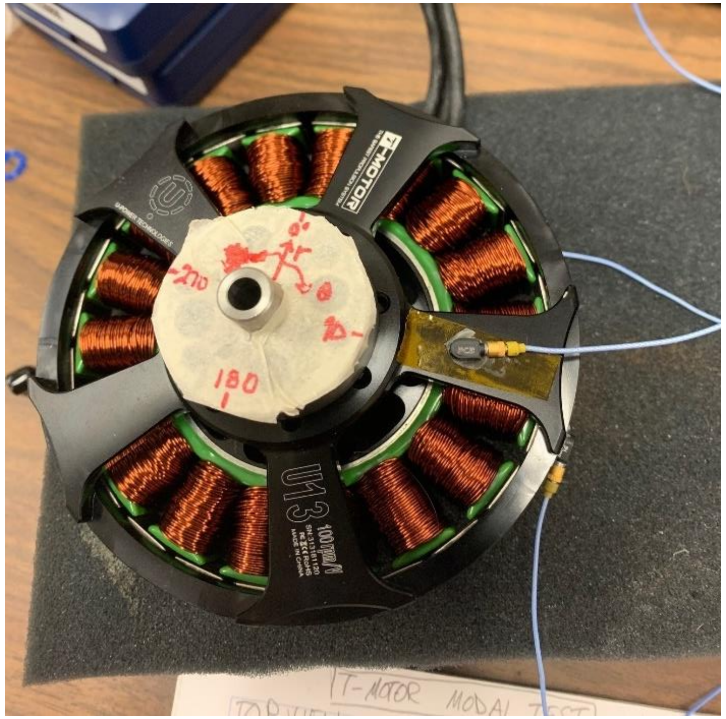
Outline and Objectives

- Develop a noise prediction tool for system type studies
  - Electromagnetic forcing model
  - Create a validated rotor geometry simulation
    - Used to predict mode shapes and frequencies
    - Validated by comparison to experimental modal analysis
  - Electric motor rotor acoustic propagation model
    - Framework presented at Fall 2021 ATWG
    - Validation data has been acquired
- Determine if electric motor noise is an important noise source for UAM vehicles
  - Start with Moog/SureFly vehicle
  - Develop test procedure for motors installed in vehicles
  - Looking for opportunities to make measurements

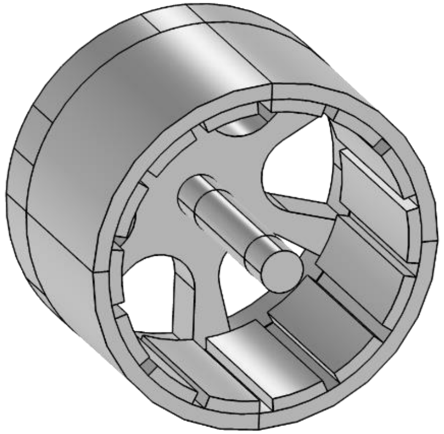
Experimental Modal Analysis



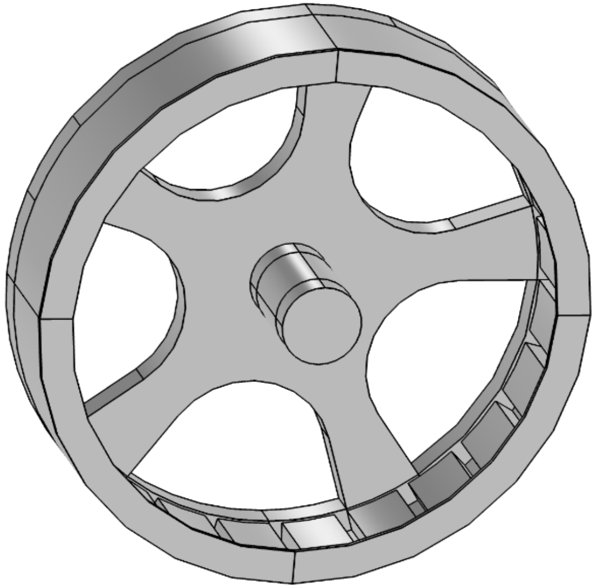
Accelerometers being installed on U13 rotor.

- Instrumented with accelerometers
  - Around rotor circumference
  - On spokes
- Rotor excited by modal impact hammer
- Rotors tested alone and installed onto the stator
- Clean modes detected over a wide range of frequencies

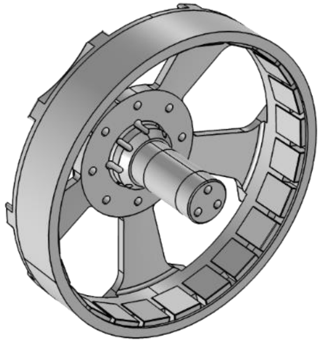
Radial Flux Rotor Parameterized Geometry



Parameterized Scorpion



Parameterized U13

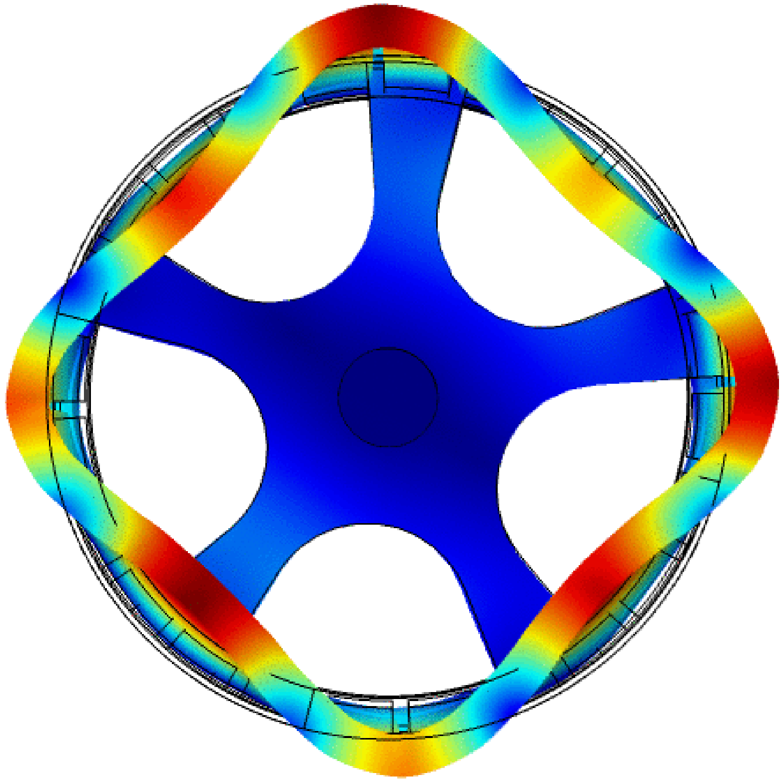


High Fidelity Model for Comparison

User Defined Parameters

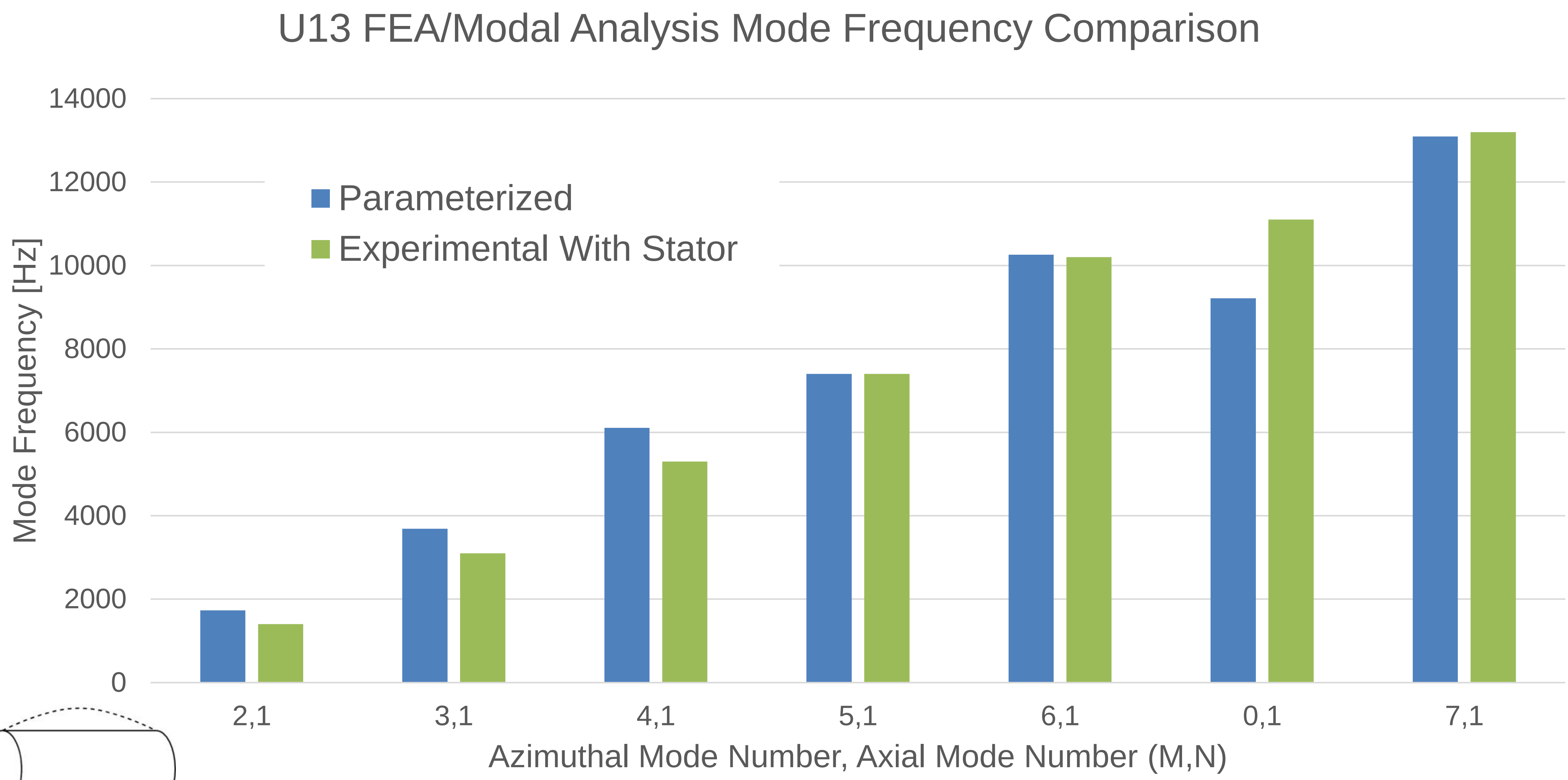
- Outer Diameter
- Wall thickness
- Rotor Height
- Number of Magnets
- Number of Spokes
- Material Properties
- Shaft Diameter
- Magnet Circumferential Area Fraction
- Spoke Thickness

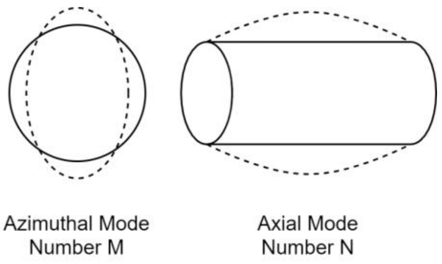
U13 Experimental/Simulation Mode Shape Comparison



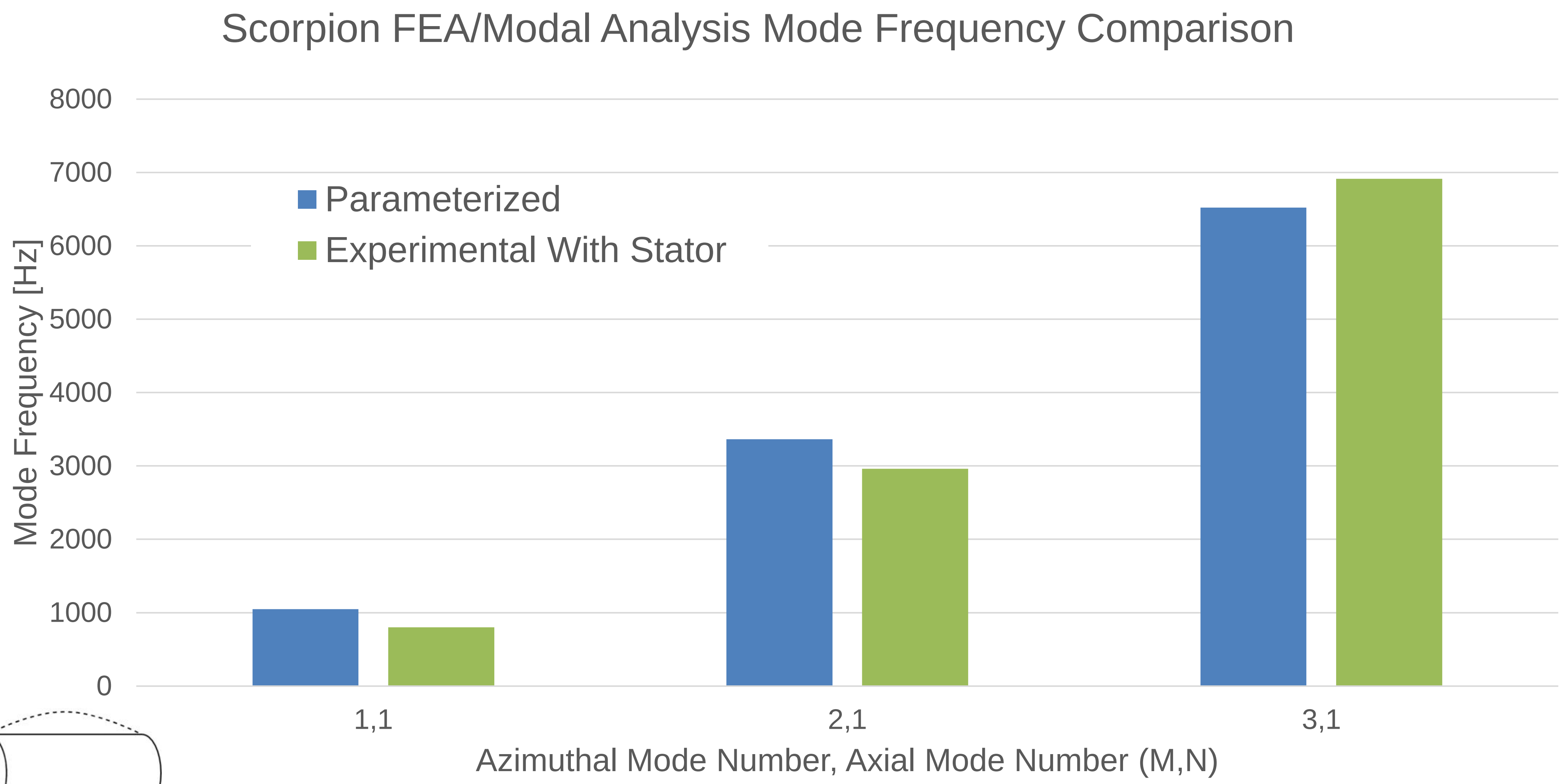
Azimuthal mode 4 vibrations showing similarity of rotor vibration shape between experiment (left) and simulation (right)

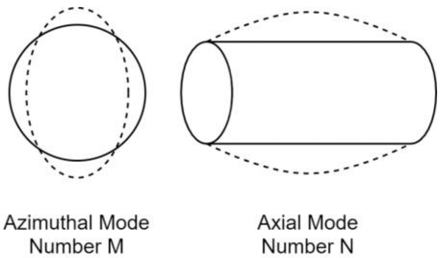
U13 Model Experimental Comparison





Scorpion Model Experimental Comparison





Upcoming Work

- Modal analysis of an EMRAX® motor of the type used in the Moog SureFly® vehicle.
- Comparison of EMRAX modal analysis to simulation.

Acoustic Validation Data for 1 – 4kW Electric Motors

Electric Motor Noise Measurements

- Identify critical speeds for a range of motors
  - Aspect ratio is of particular interest
  - Sharpness of resonance peaks
  - Amplitudes of peaks
  - Frequency of peaks
- Acquire acoustic near-field data at critical speeds
  - Validate finite element model frequencies
  - Support acoustic propagation model development

1 – 4kW Motors

Lumenier LU8lite

Lumenier LU12II

Lumenier LU10plus

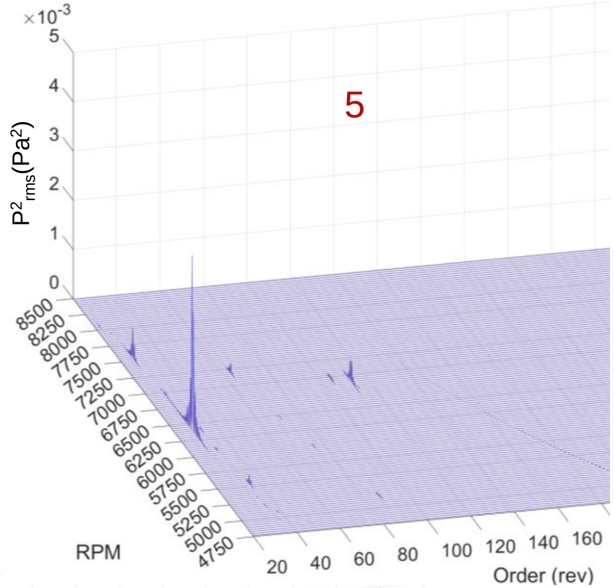
T Motor U12

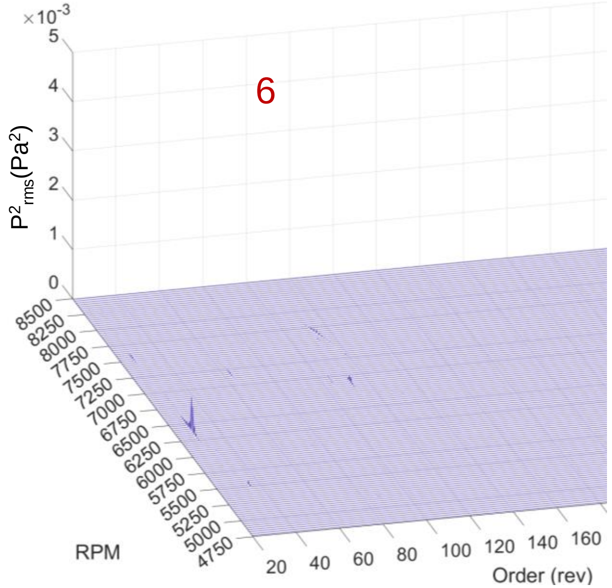
Lumenier LU11II

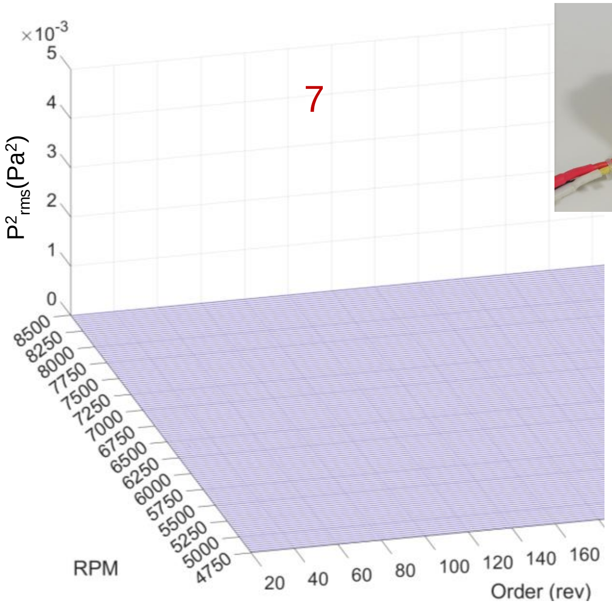
T Motor U13

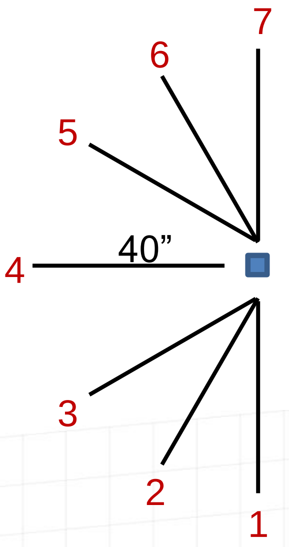
Scorpion SII-4020

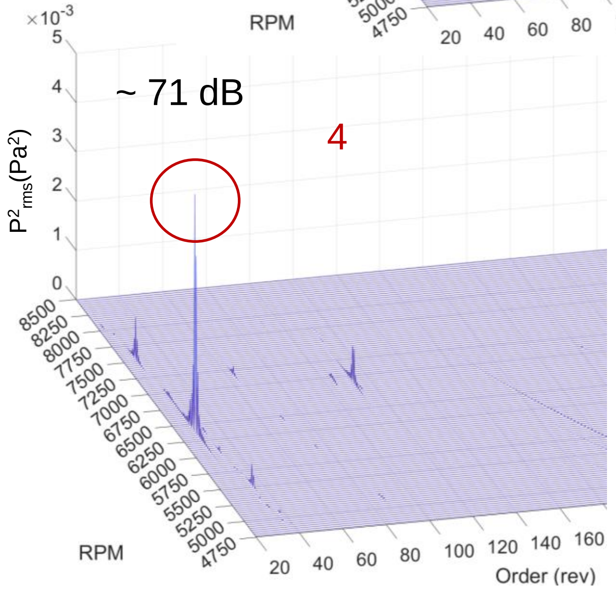
Scorpion Motor



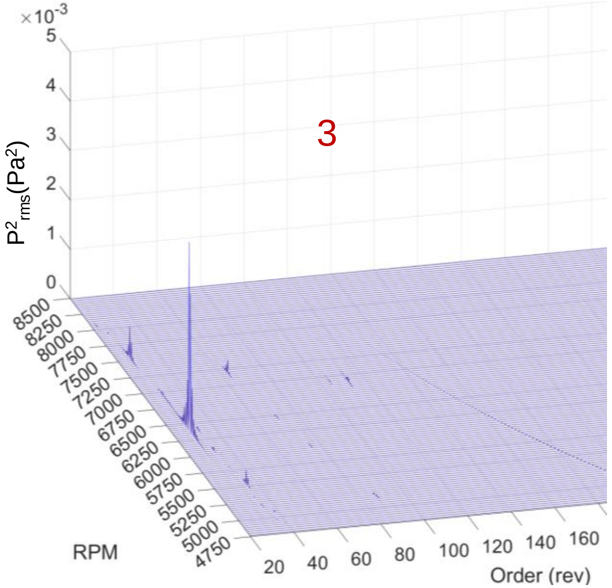


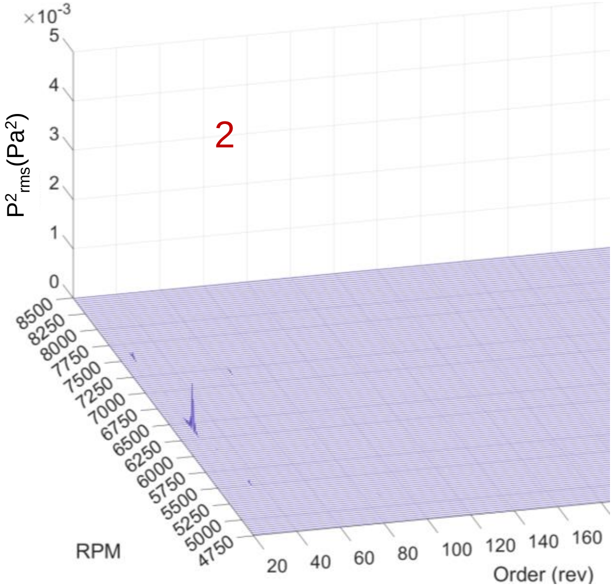


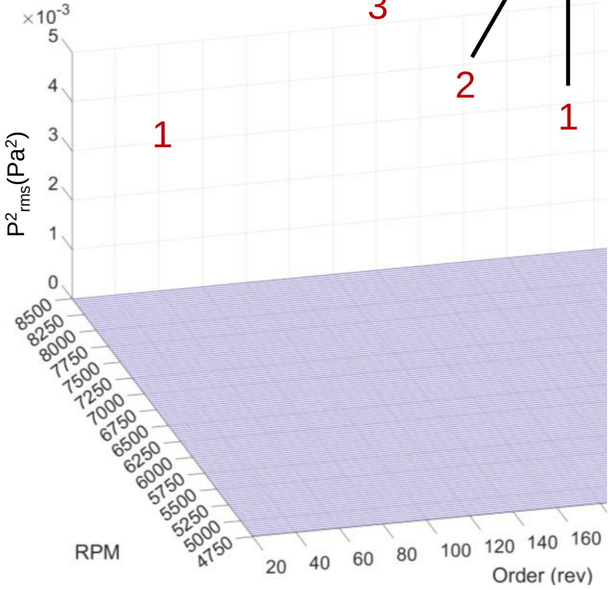




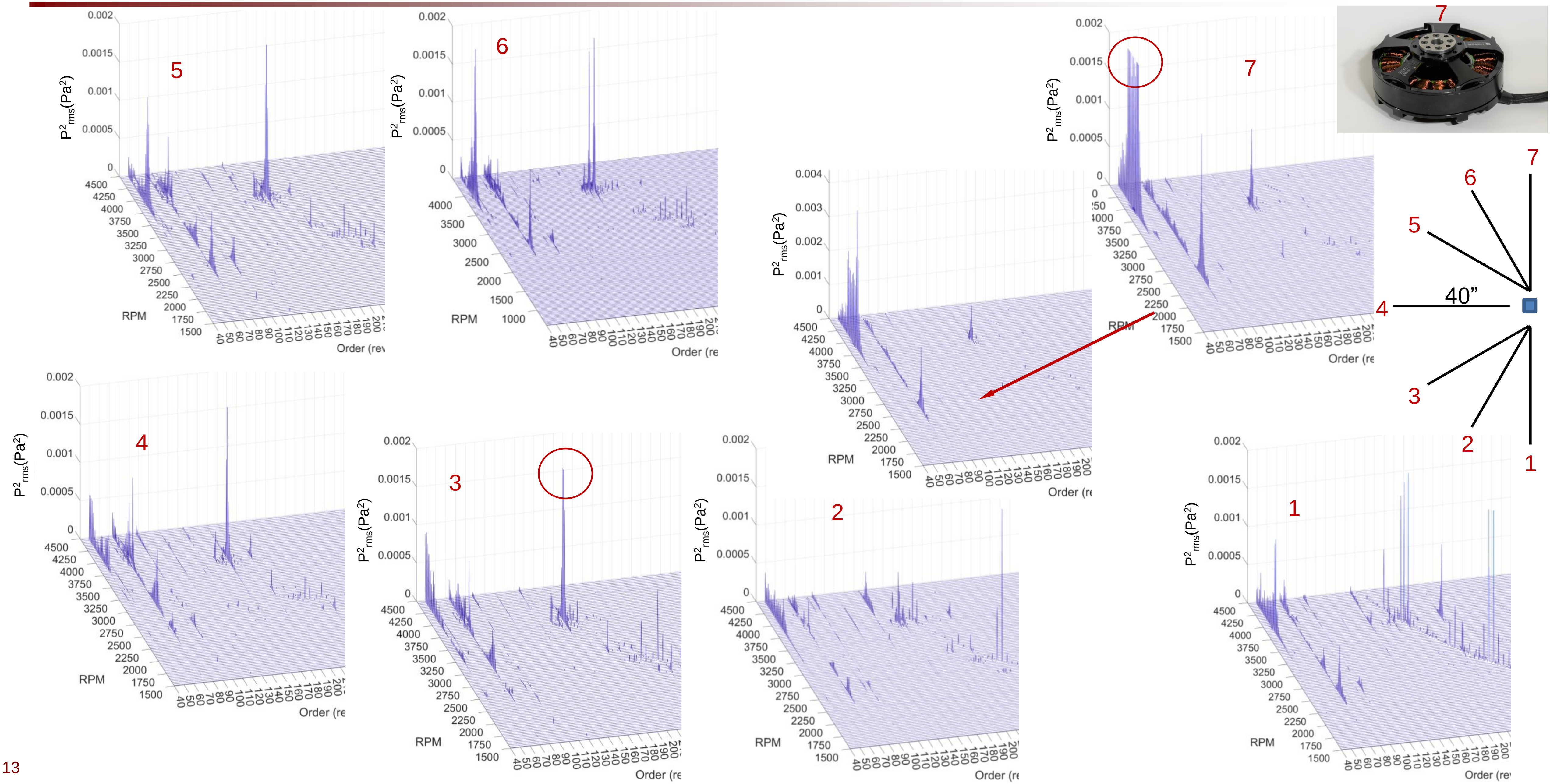
Acoustic levels at lower speeds are not significant



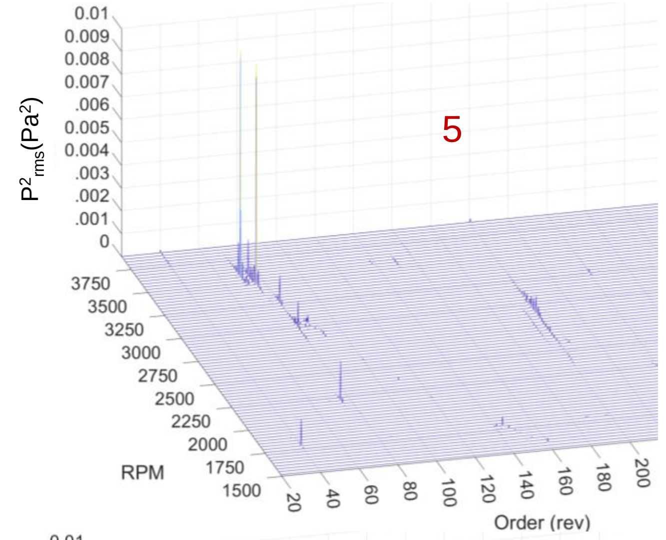


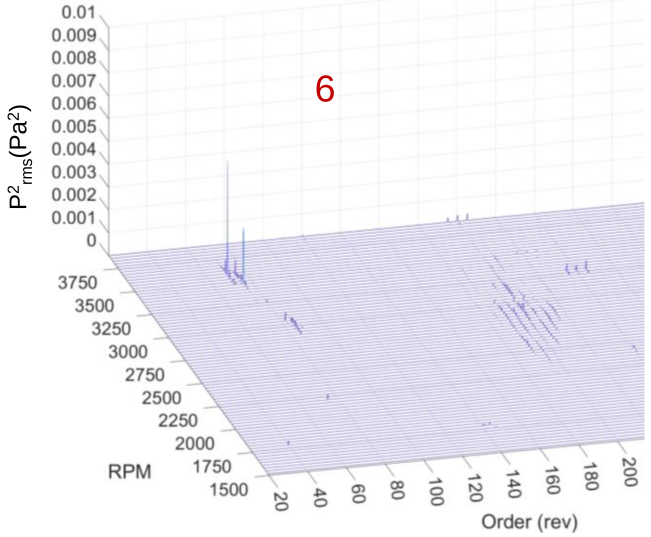


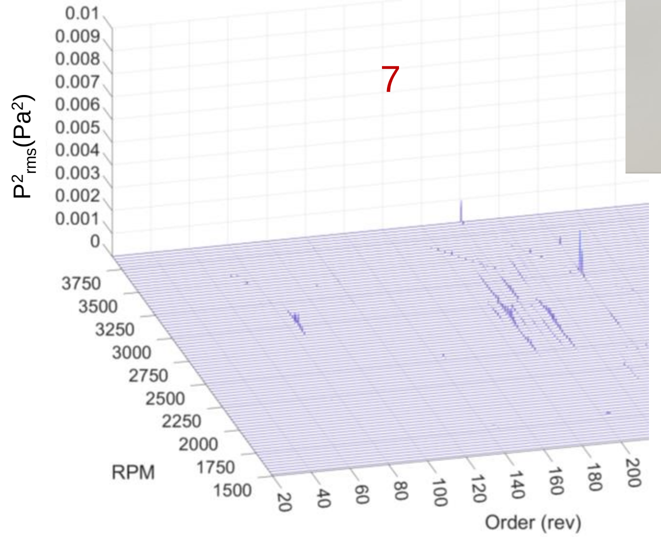
U13 Motor (T Motor)

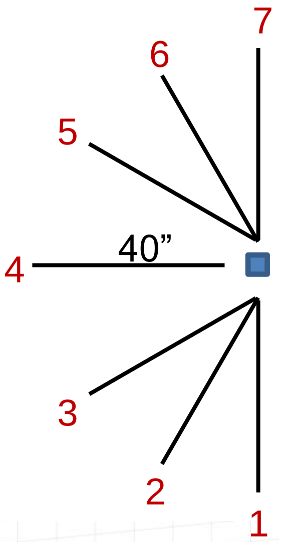


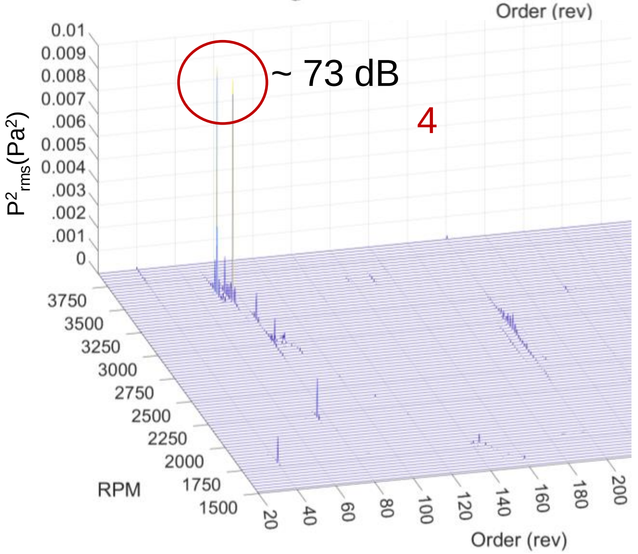
U12 Motor (T Motor)

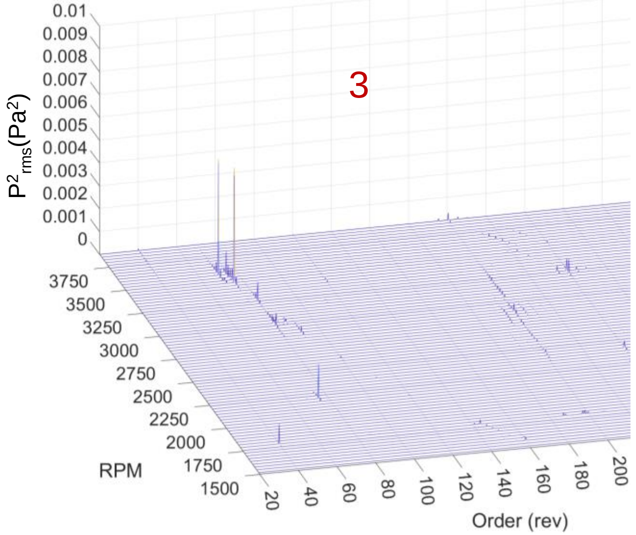


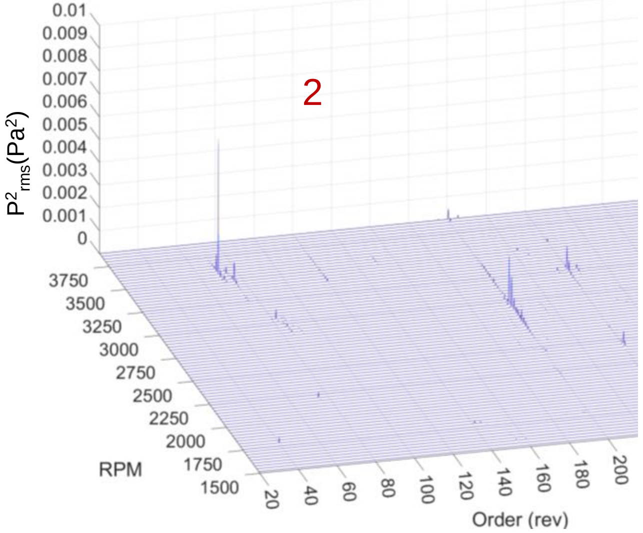


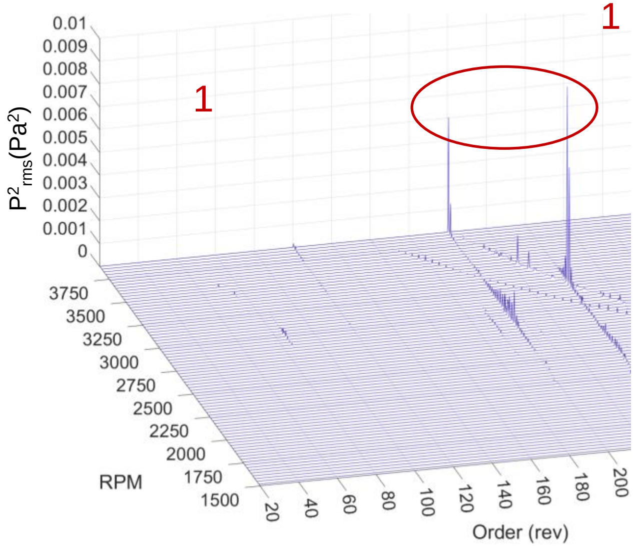




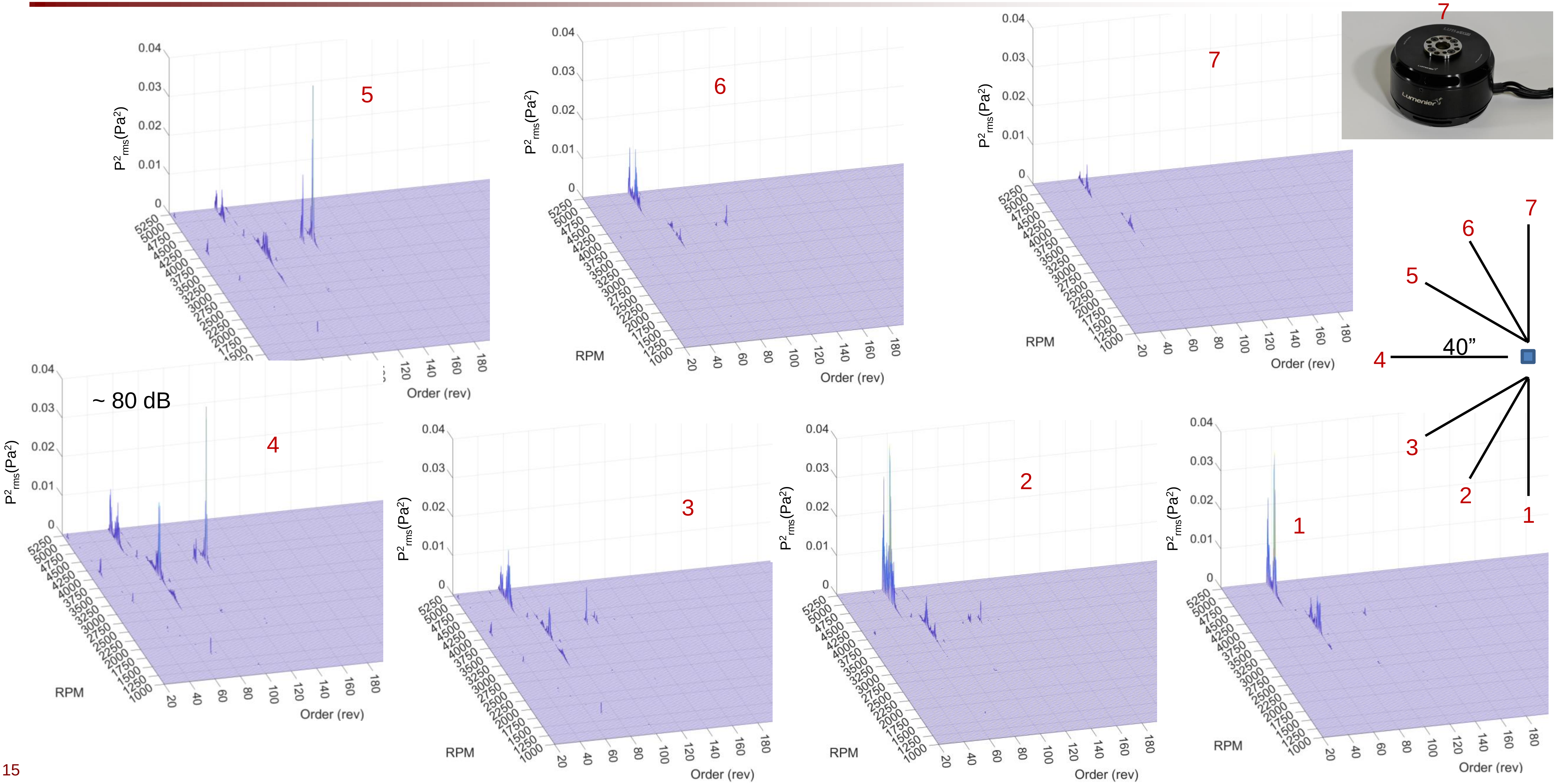




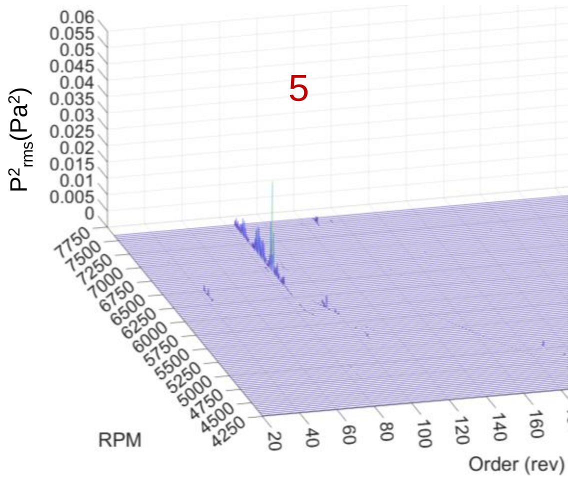


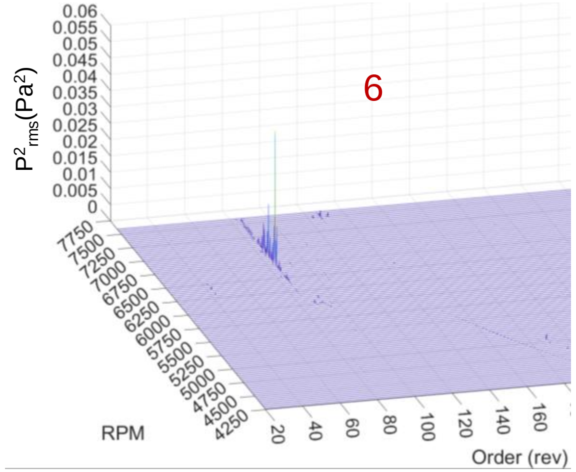


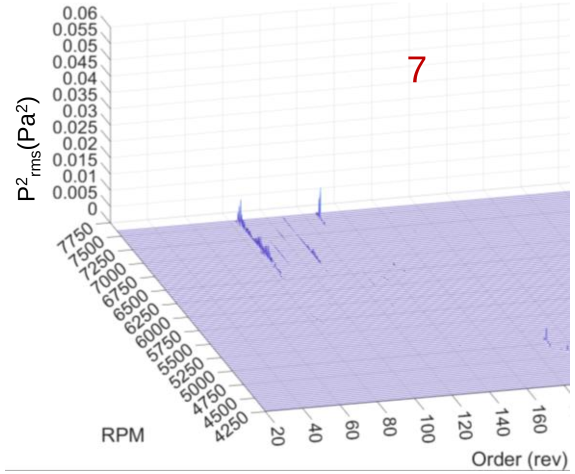
LU11II (Lumenier)

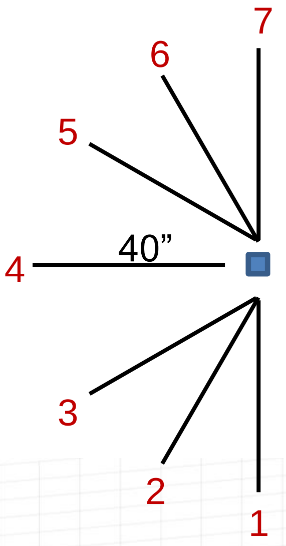


LU8Lite (Lumenier)



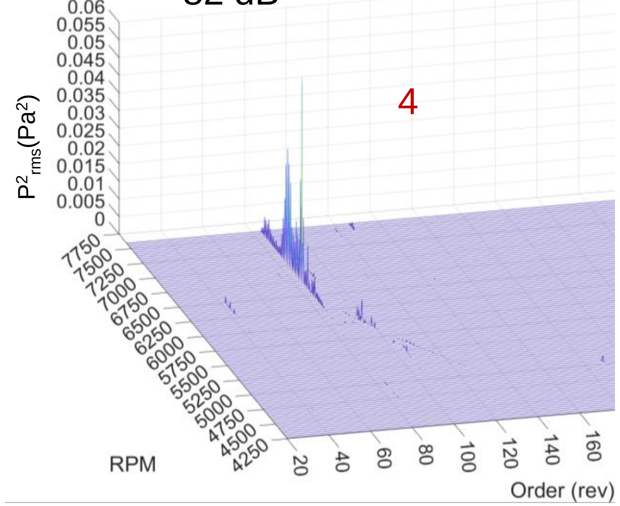


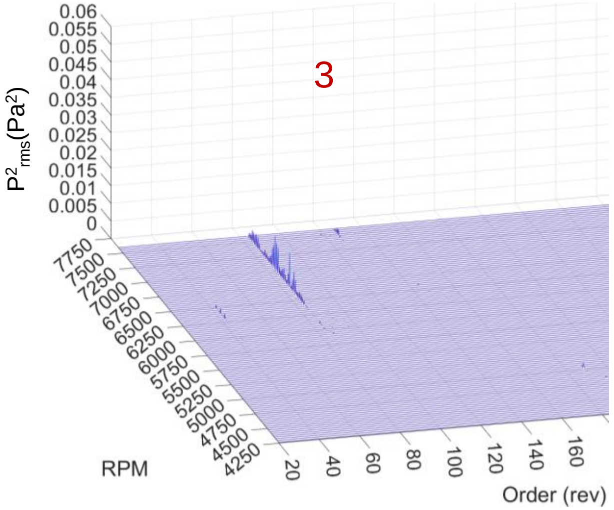


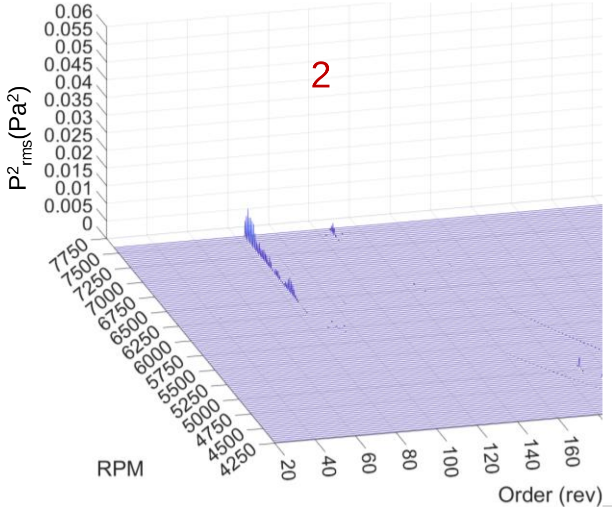


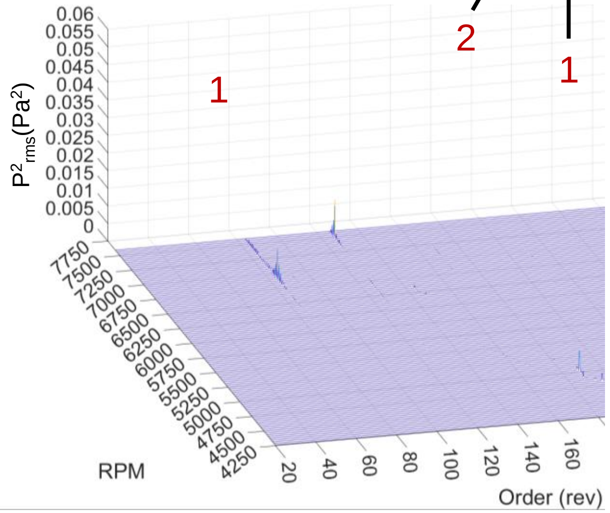
Acoustic levels at lower speeds are not significant

~ 82 dB



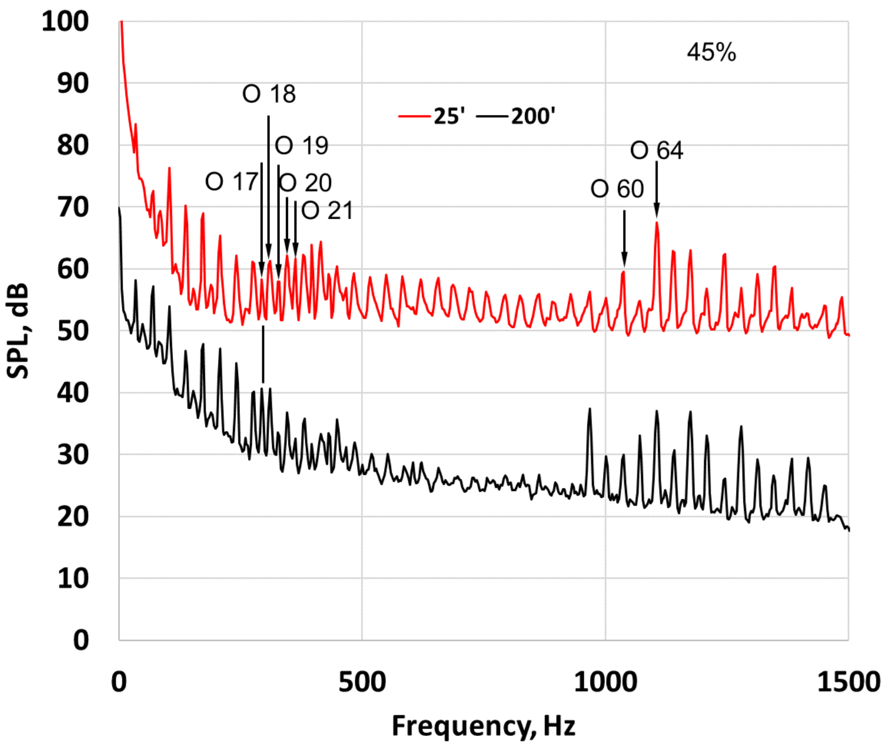


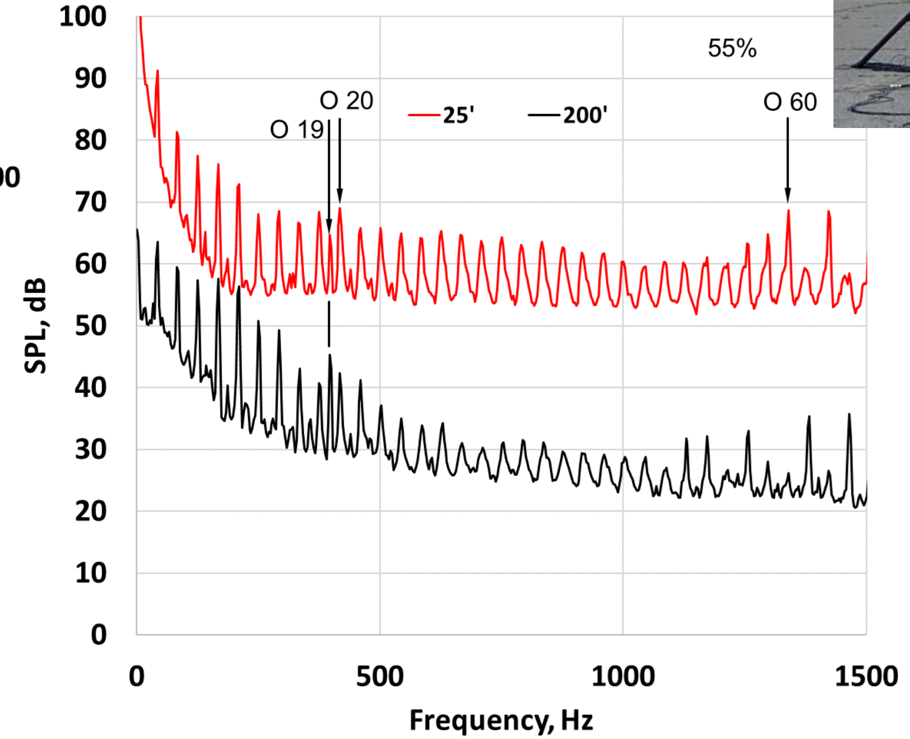


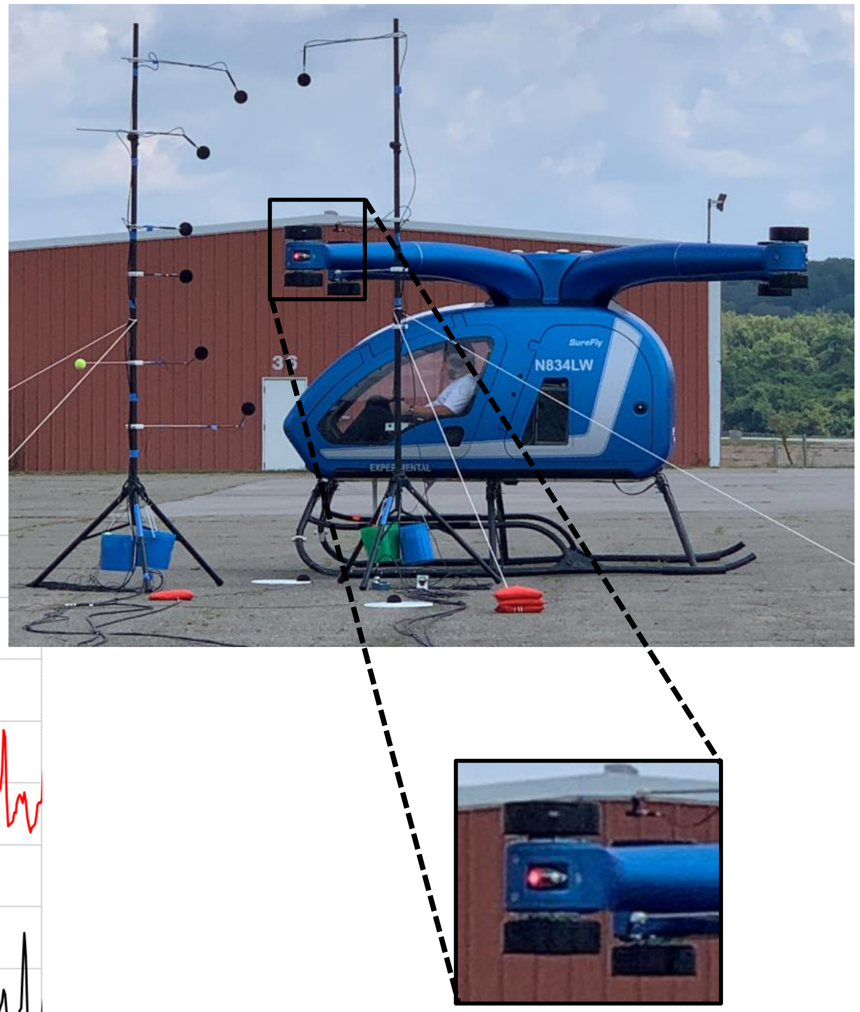


Moog/Surefly Update

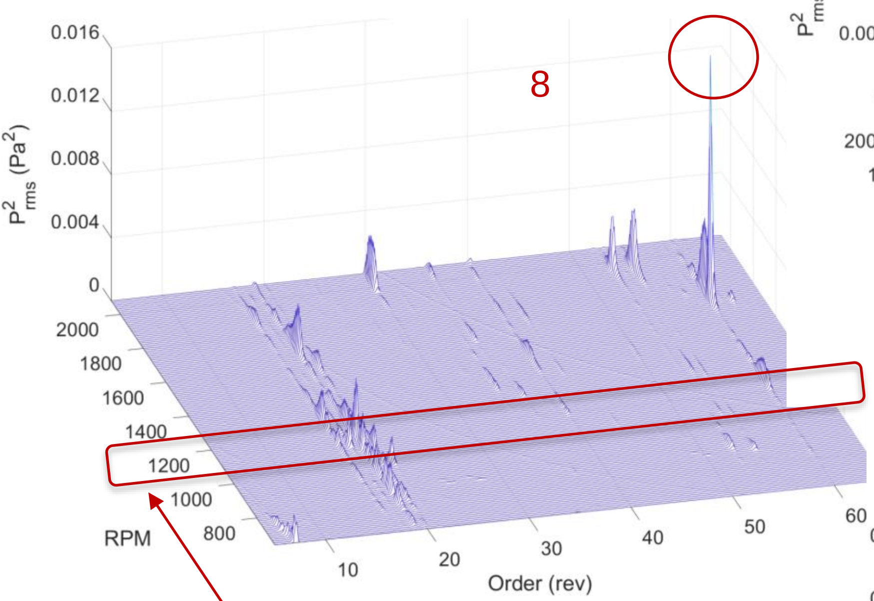
SureFly Motor (EMRAX)



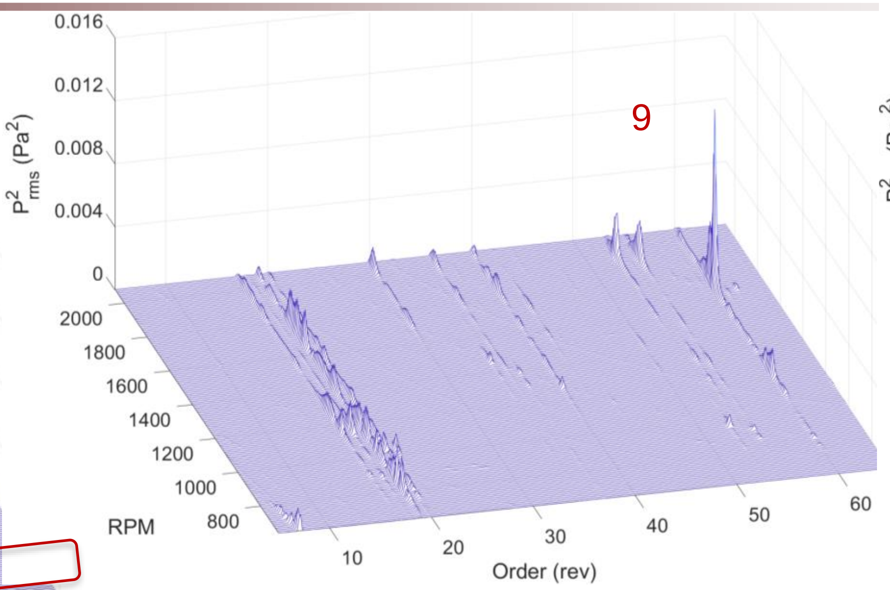


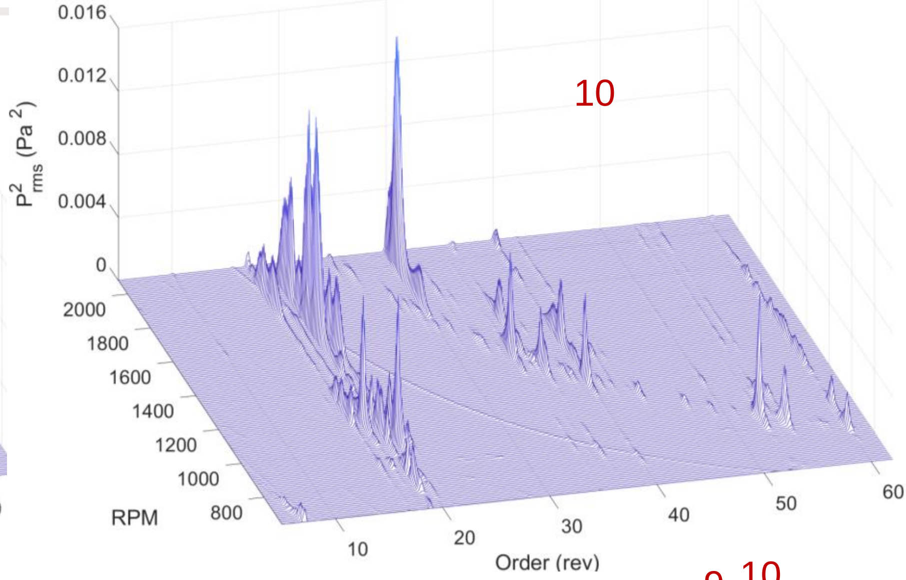


SureFly Motor (EMRAX)

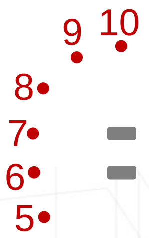


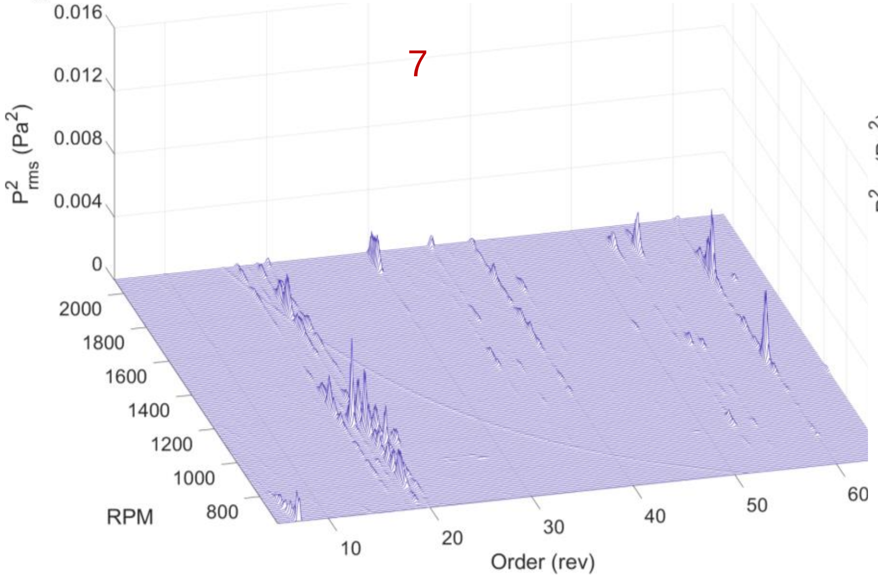
45-55% Throttle

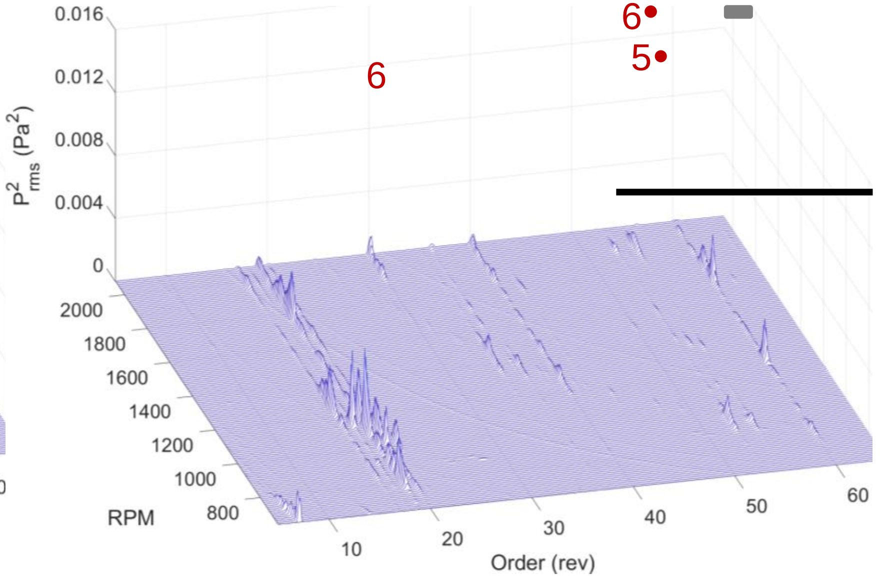




Significant Orders	17	18	19	20	21	30	35	36	37	40	53	55	60

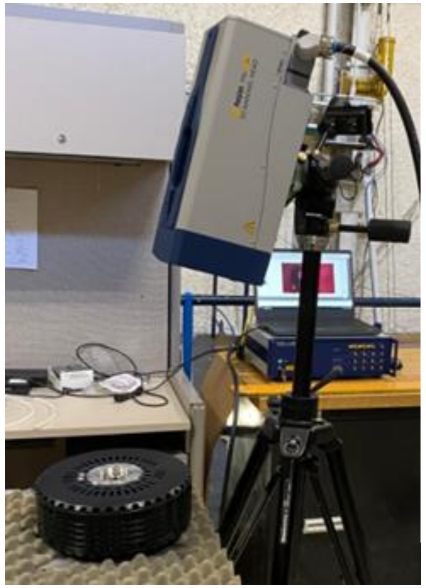




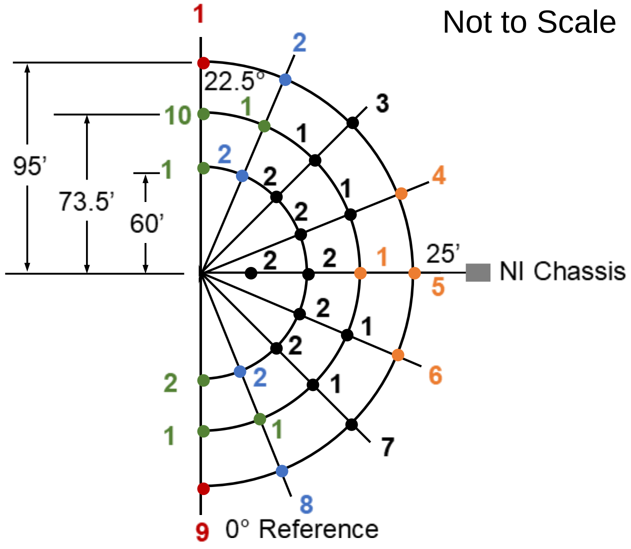


Future Work

- EMRAX motor
  - Experimental modal analysis using scanning laser vibrometer
  - Finite element modal analysis
- Moog/Surefly Hover Acoustic Measurement
  - Limited measurements planned for April 2022
    - 15ft hover
    - Yaw (possible station keeping issues)
  - Locate far field more accurately
  - Initial directivity assessment



EMRAX Motor



Hover Test Setup

- Complete acoustic modal analysis data processing
- Start programming motor rotor acoustic radiation model
  - Infinite vibrating cylinder
  - Finite vibrating cylinder
  - Rotating finite vibrating cylinder

1 – 4kW Motor Near-Field Array