Electric Motor Noise Research Status

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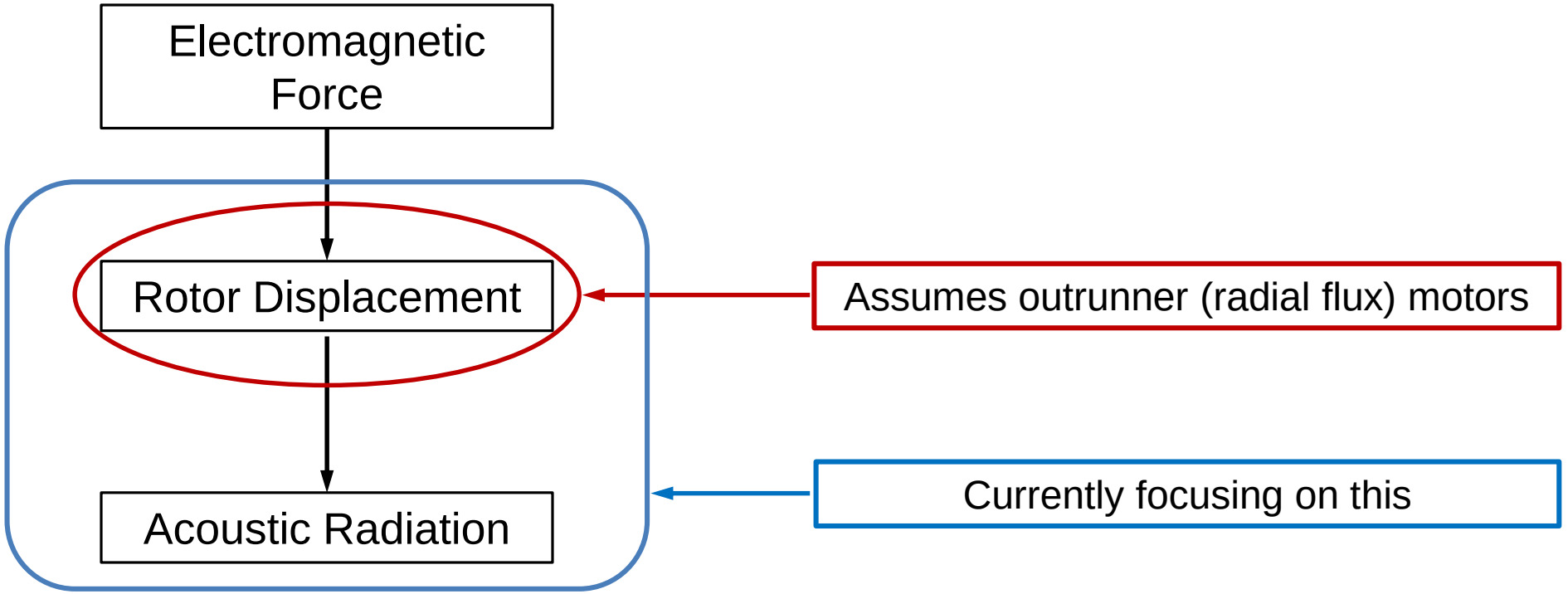
NASA Acoustics Technical Working Group

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RVLT Project Milestones for Electric Motor Noise

Milestone ID	Milestone Title	Level	Exit Criteria	Due Date	Status/POC	Org
RVLT.23.21.L496	Initial Acoustic Model for Outrunning kW Class Electric Motors	4	Complete validation of model against electric motor noise database	10/30/2021	1/Henderson	GRC: LTVO

Electric Motor Noise Prediction Plan



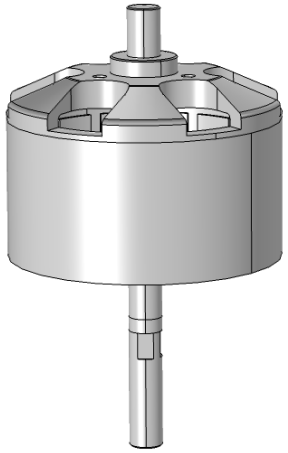
Intent is to develop a tool for system type studies

Vibration Calculations

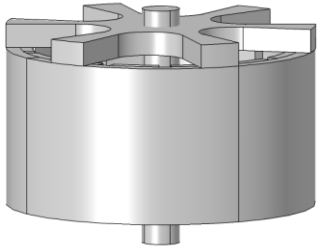
Parameterized FEA Model



Scorpion SII-420



High Fidelity Rotor Model



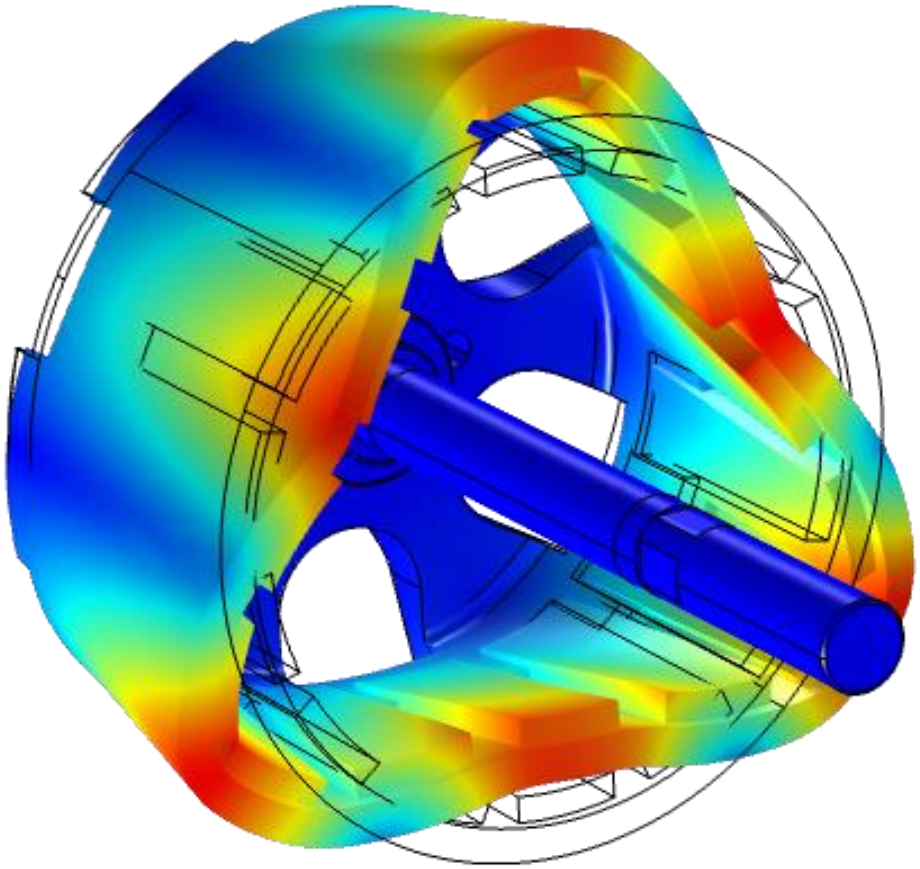
Simplified Parameterized Rotor Model



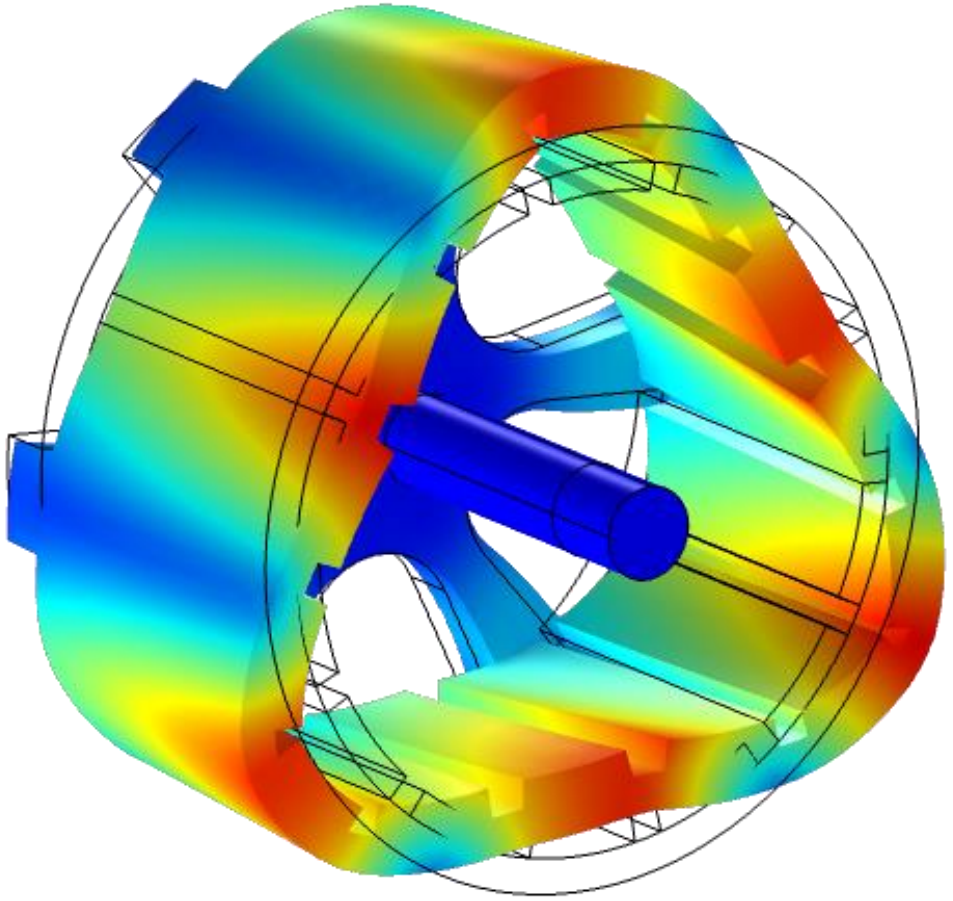
T-Motor U13

- We need (at least) the resonance frequencies for the acoustic radiation calculation
- The modes and displacements would be nice
- Multiple analytical models have accurately predicted the resonant frequencies
- Finite element models can produce reliable results but are difficult to use in a system type study
- We have moved to a parametric model for the FEA calculations
  - Defined by 8 characteristic values
    - Diameter/Height
    - Number of Spokes
    - Number of Magnets
    - Etc.
  - Comparing to high-fidelity model to determine relevant parameters
  - Validating against our experimental data
  - Being used to evaluate importance of rotation speed and other factors
    - No significant impact of rotation on resonant frequencies
  - May ultimately be used to create a database for the prediction tool
- Previous efforts have shown some differences in COMSOL and SolidWorks results so we continue to compare results from both packages to quantify differences

Comparison of Results from the High Fidelity and Parametric Model for (3,1 Mode)



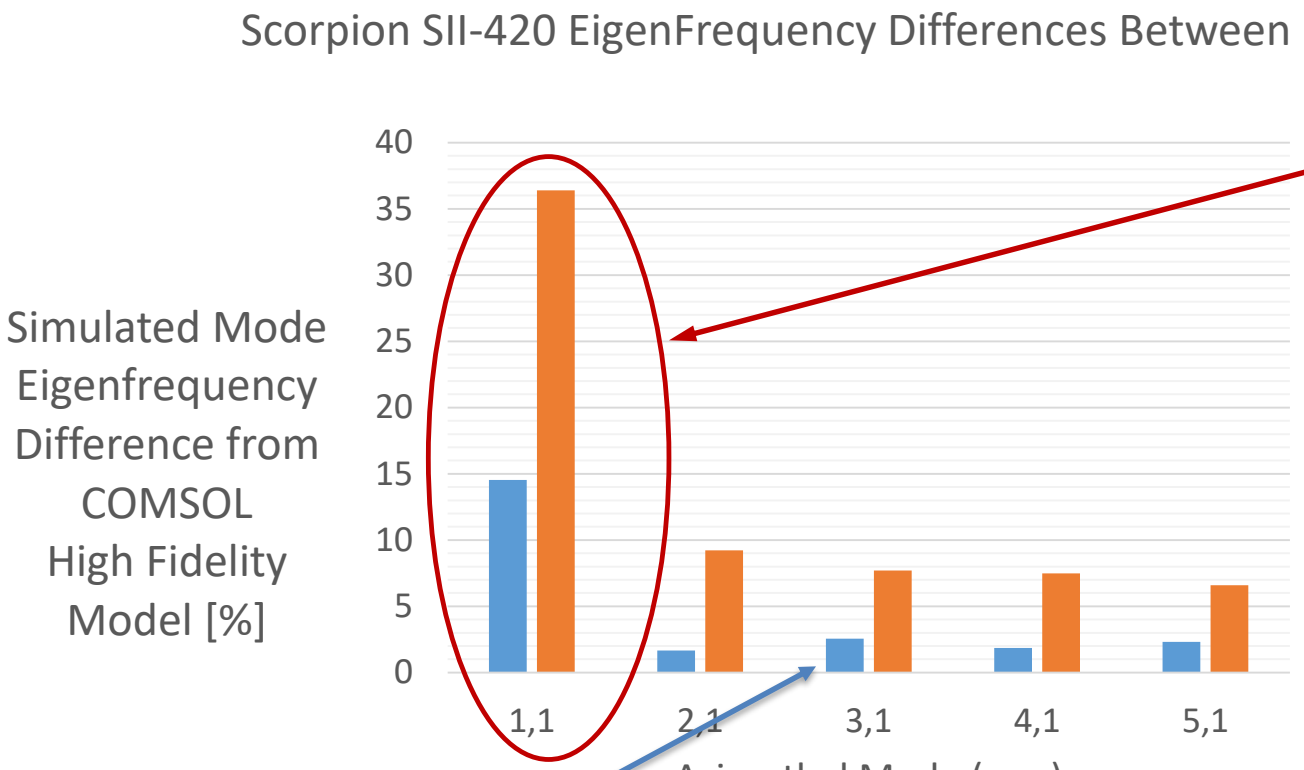
High Fidelity Model



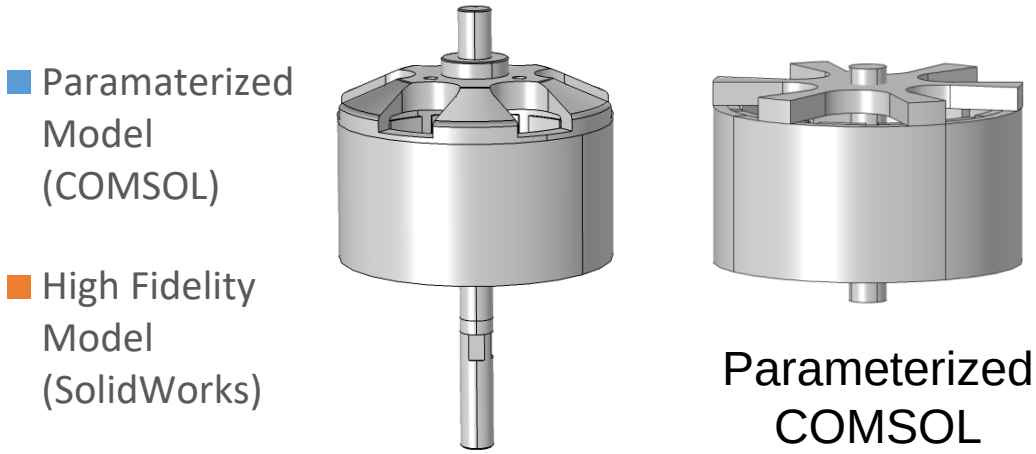
Parameterized Model

Scorpion Motor

Predicted Eigen Frequency Differences Between Model Versions

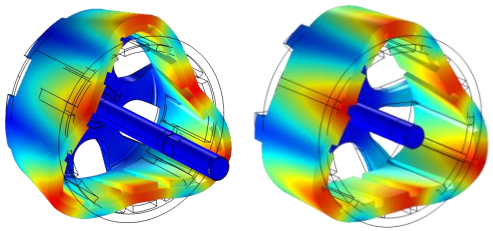


Mode (1,1) is generally not dominant but need to understand differences



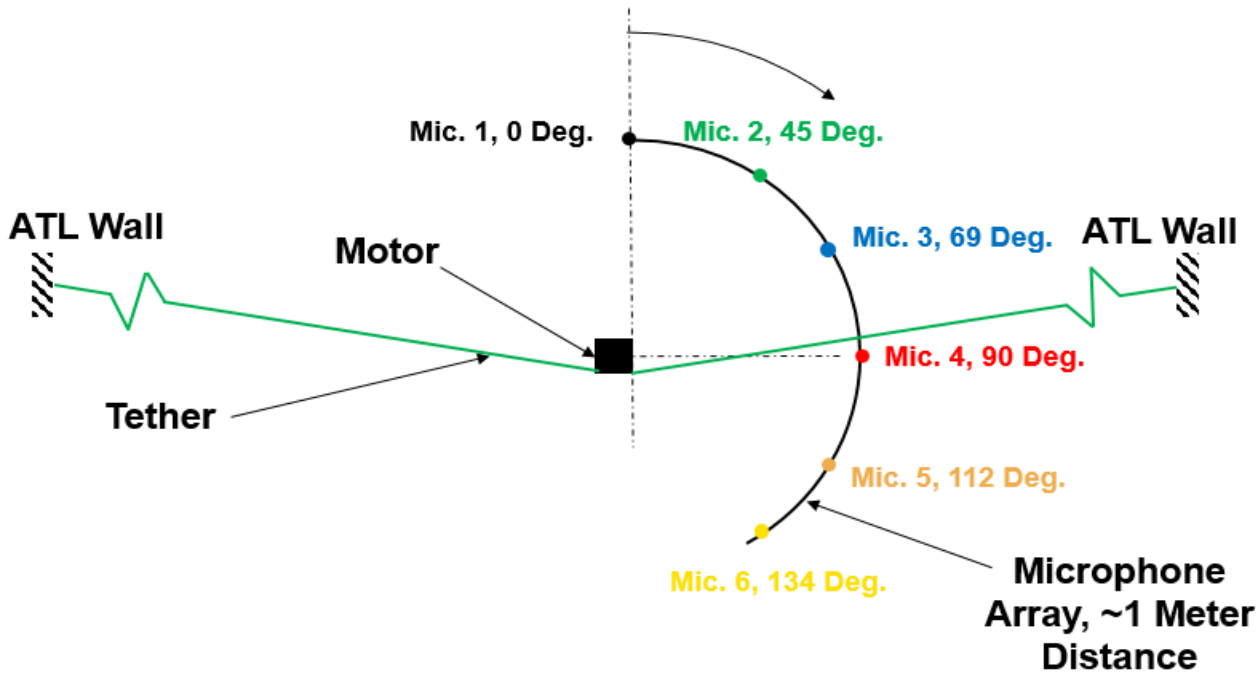
High Fidelity COMSOL SolidWorks

Parameterized COMSOL

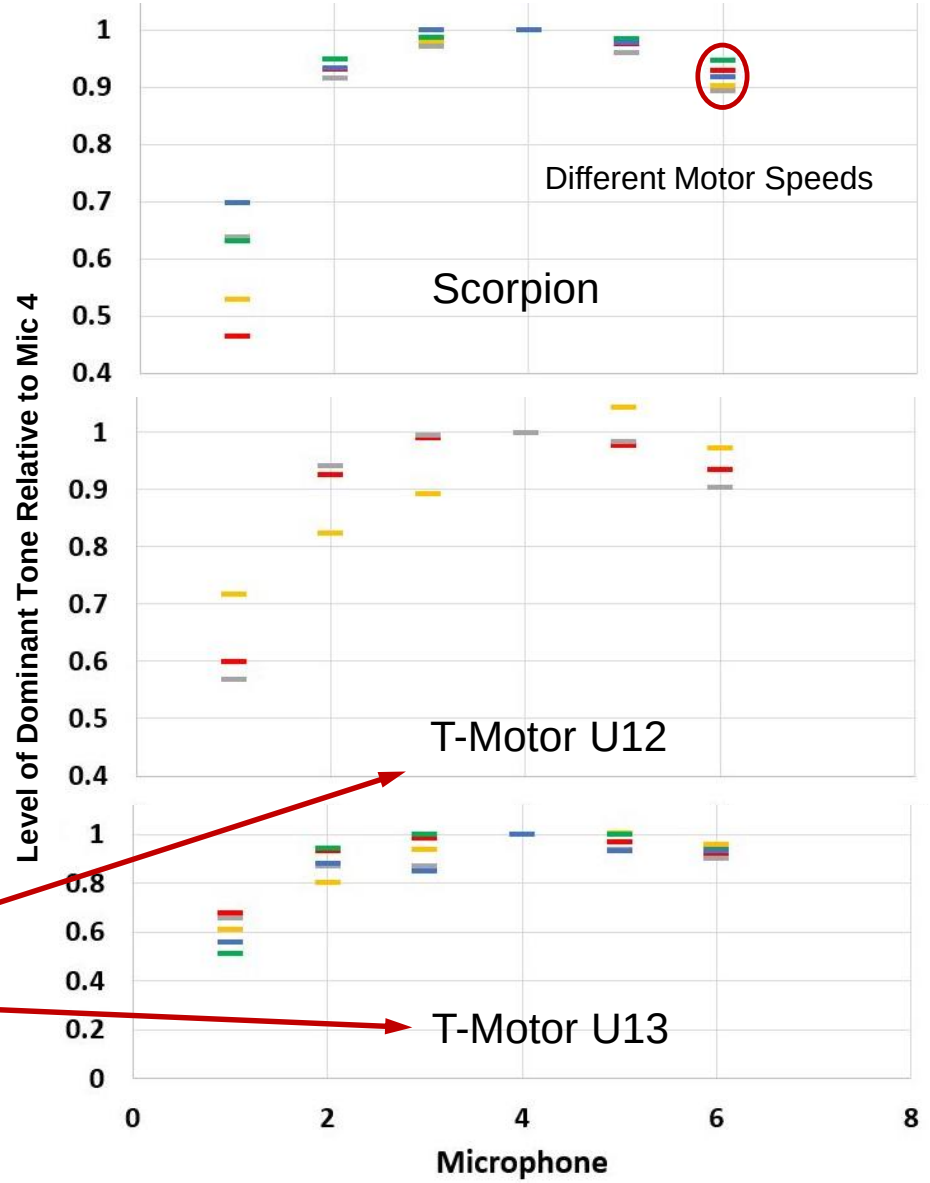


Acoustic Calculations

Directivity Calculations



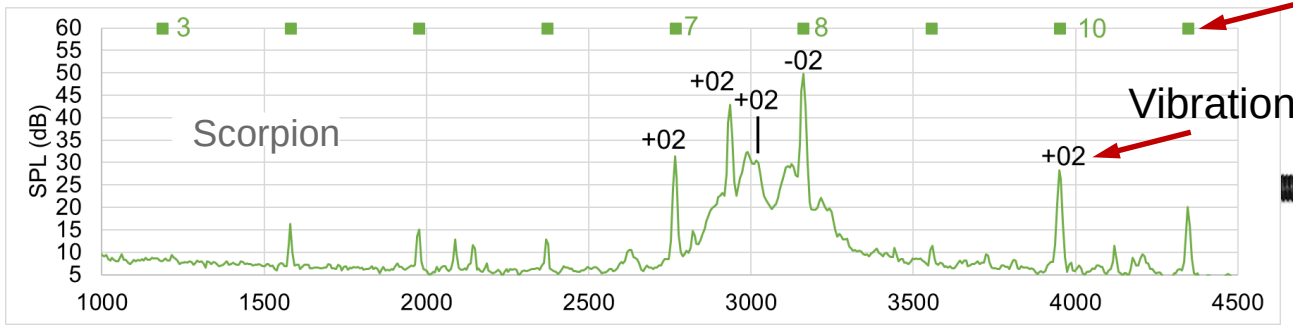
Experimental Setup



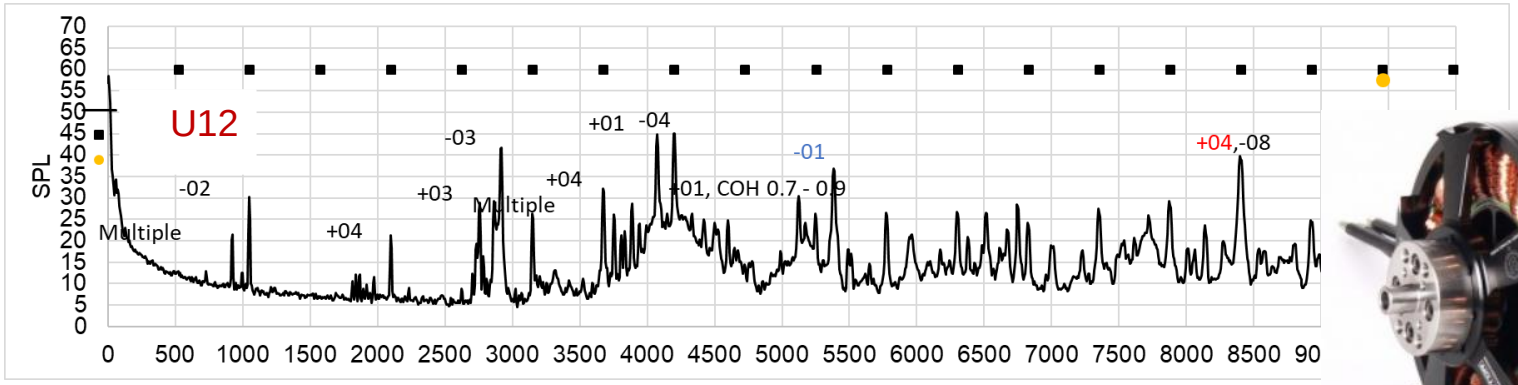
Some Dependency on Mode

Modal Decomposition

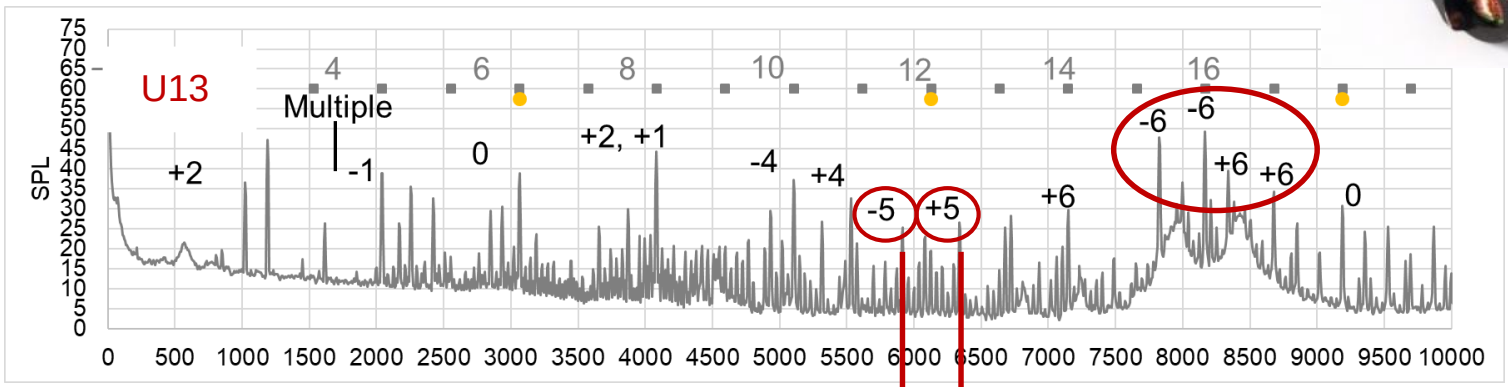








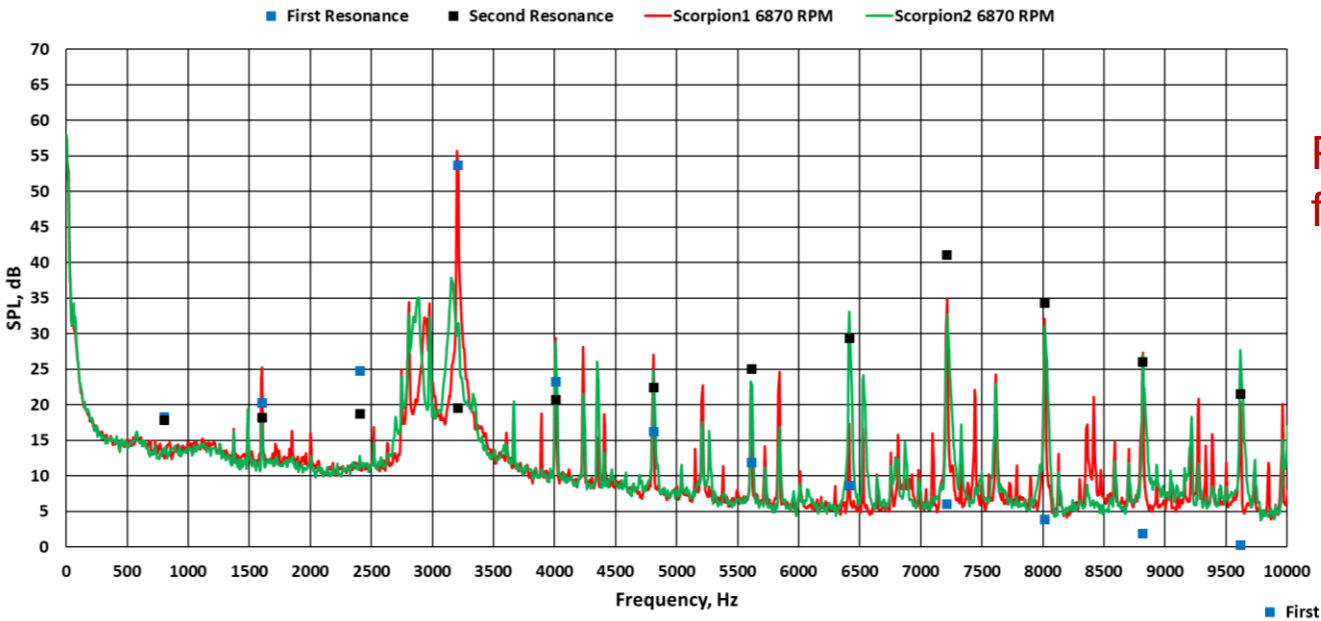




Amplitude Calculations

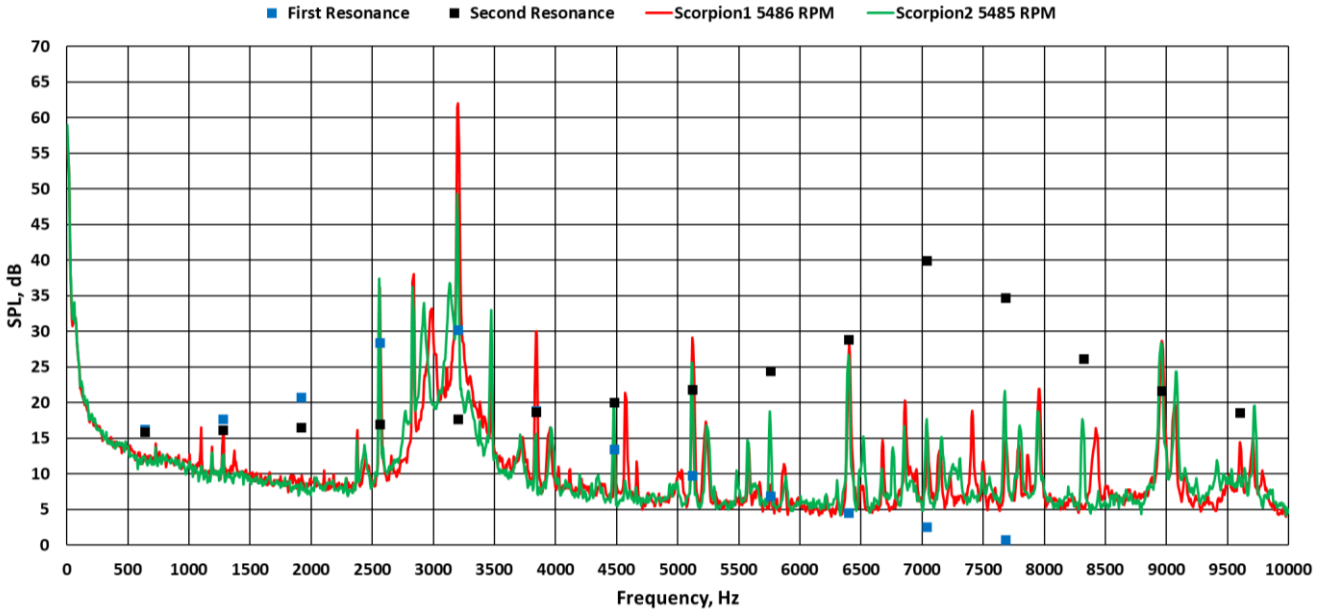
- P. L. Alger, *Induction Machines*, Gordon Breach: New York, 1970
  - Simplified analysis appropriate for system level prediction
- Computes displacements using simple beam theory
  - Computes amplitudes for each electrical line frequency harmonic
  - Can use for resonance frequency
  - Calculation for resonance frequency
    - 20% off of measured value for Scorpion Mode 2
    - Significantly off for T-Motors
- Need to know resonance frequency of rotor
- Using the surface amplitude calculation, it is straight forward to calculate acoustic radiation at 90˚
- Use experimental directivity for angles other than 90˚

Scorpion Results

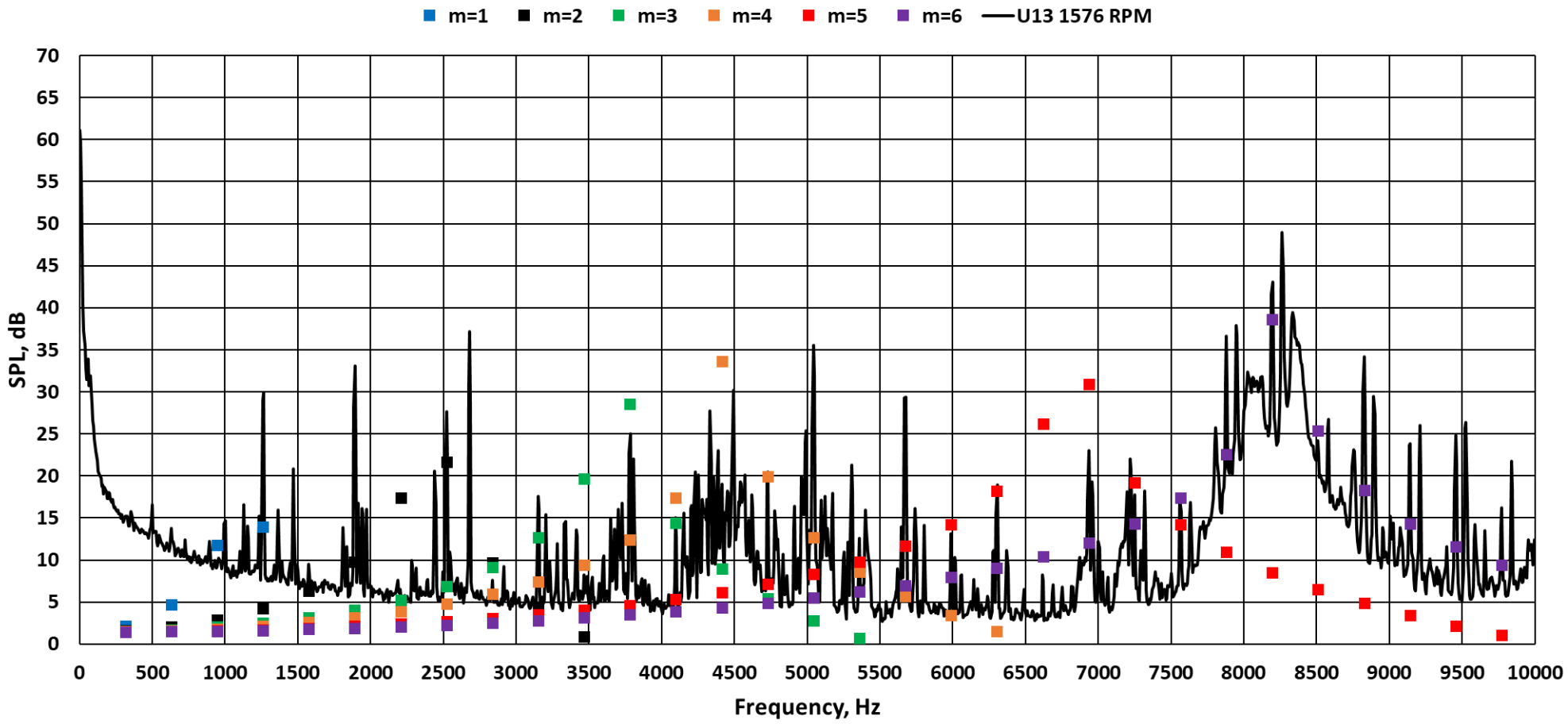


Reasonable agreement of resonant frequency and roll off

Improvements required for some speeds



U13 Results


m=1
m=2
m=3
m=4
m=5
m=6
U13 1576 RPM
SPL, dB
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
9500
10000
Frequency, Hz

Future Plans

Future Plans

- Acquire acoustic data for additional kW class motors (outrunner, radial flux)
  - Motors exist, need access to the laboratory to conduct tests
  - Use peak hold technique to locate resonance
  - Acquire spectra at resonance speed as well as other speeds
- Conduct modal analysis for each motor to understand spectral content and enhance models
- Acquire directivity for each motor
- Compare results of parametric FEA model to test results
- Modify Alger method for acoustic computation using resonance frequencies from FEA and modal analysis information for “pancake” type motors