Acoustic Characterization of the NASA Langley 14- by 22-Foot Subsonic Tunnel Using a Phased Array

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Outline

- Motivation
- Experimental Setup
  - Facility
  - Noise Sources
  - Phased Array
- Beamforming
- Results
  - Static Runs
  - Flow-on
  - Deconvolution
- Conclusion

Motivation

- Characterize acoustic treatment of large wind tunnel
- Past acoustic testing
  - High frequency (airframe noise and propulsion-airframe aeroacoustics)
  - Periodic impulsive (large rotor)
- Sound from scale-model UAM/AAM vehicles may blend into tunnel background noise
- Need to capture signal in low signal-to-noise (SNR) environments


Source: NASA


Source: NASA

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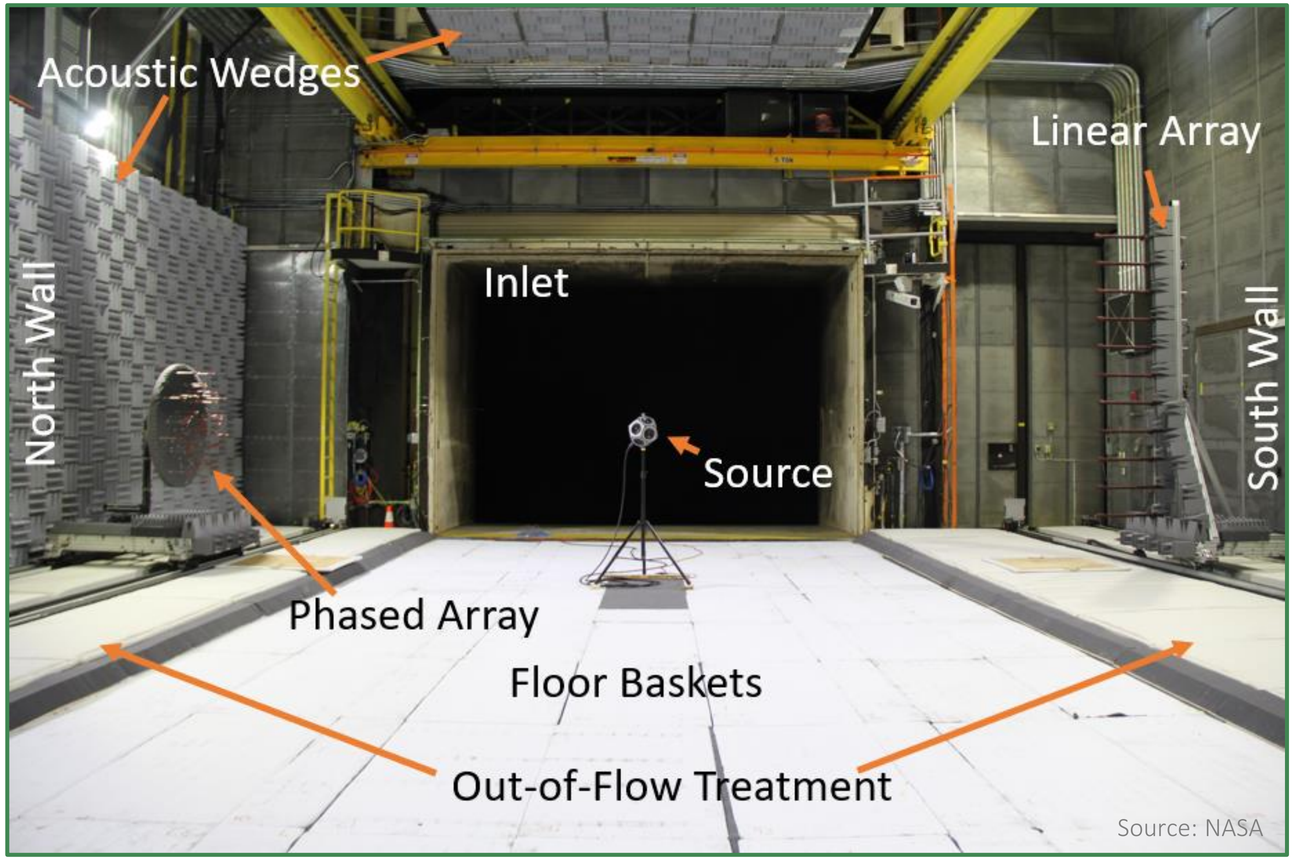
Experimental Setup - Facility

- NASA Langley 14- by 22-Foot Subsonic Tunnel (14x22)
  - Closed circuit, atmospheric
  - Up to Mach 0.12 in this analysis
  - Run in open-jet configuration
- Acoustic treatment of tunnel
  - Walls of open-jet have some permanent treatment
  - Acoustic wedges on north wall and ceiling
  - Walls and ceiling out of flow
  - Floor in flow
  - Floor treated with acoustic floor baskets



Discussion of linear array results in Stutz et al. 2024

Discussion of floor baskets in Zawodny et al. 2024

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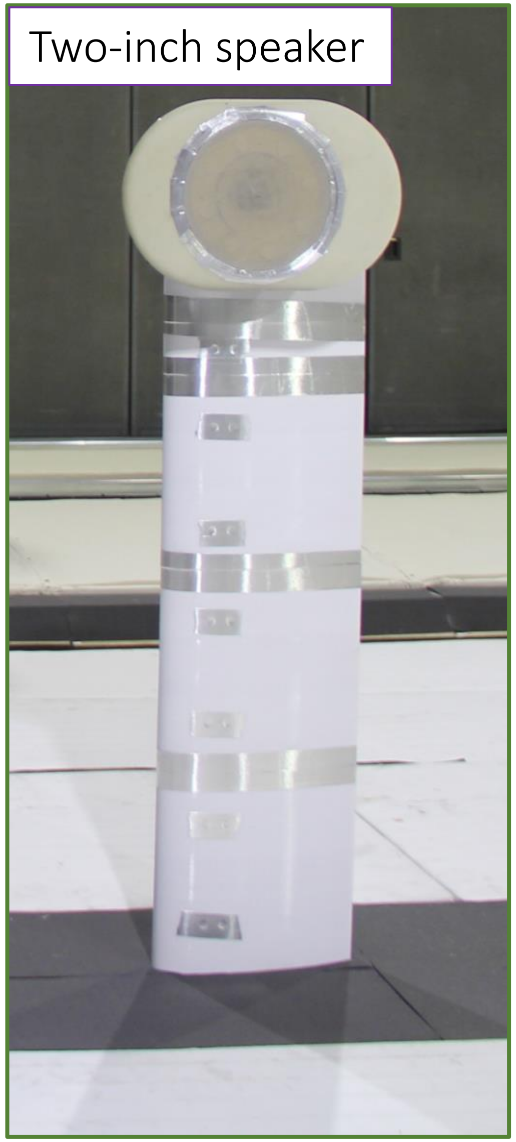
Experimental Setup – Noise Source

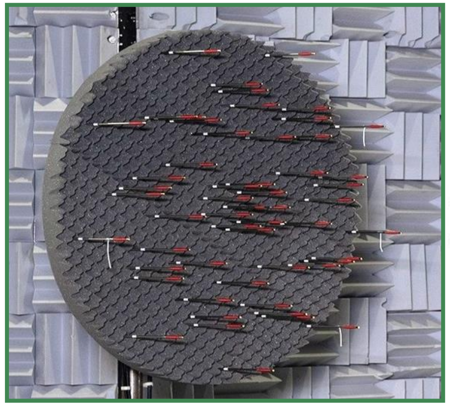
- Source located halfway across test section and 60 in above floor, 16 ft downstream from inlet
- Two static (no-flow) noise sources
  - **Cabinet speaker (directional)**
  - Dodecahedron speaker (omnidirectional)
- Two inflow noise sources
  - **Two-inch speaker (directional)**
  - Air source (high frequency stochastic)
  - Both embedded in aerodynamic fairing

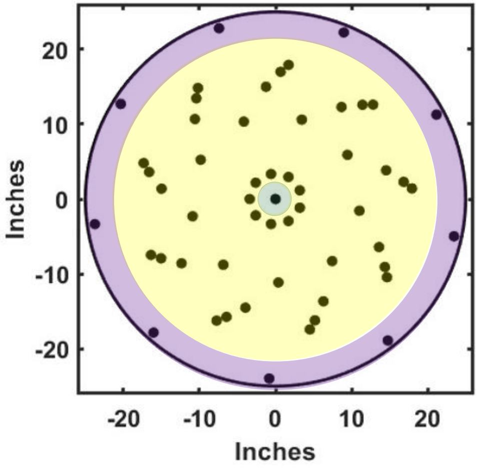


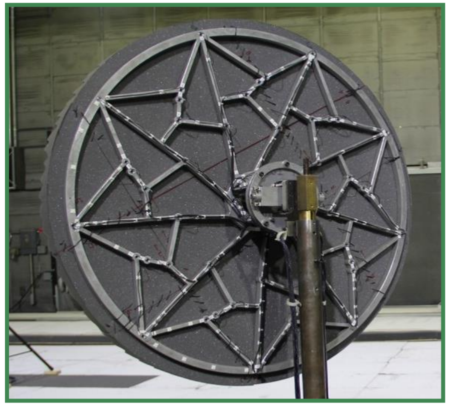
Source: NASA

Experimental Setup – Phased Array

- 54 elements
- ¼-in microphones
- Inner array
  - 45 elements in reverse-log distribution
  - 36-in diameter
- Outer ring
  - Nine elements
  - 48-in diameter
  - Improves low frequency resolution
- Single reference microphone
- Microphone diaphragms 187 in away from noise source in lateral direction







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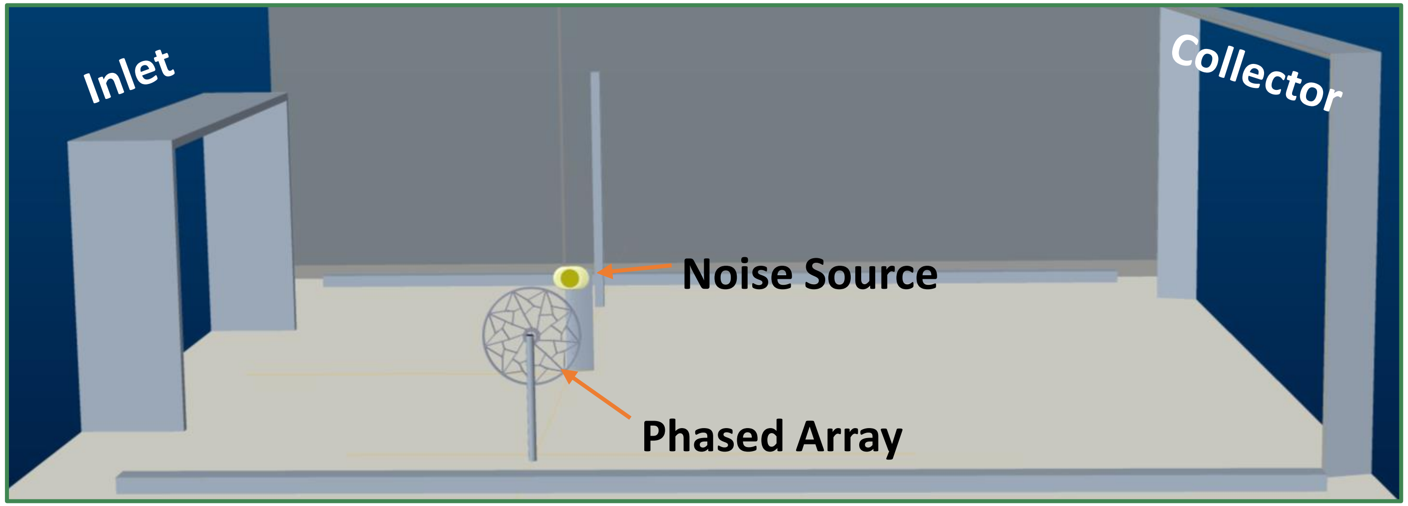
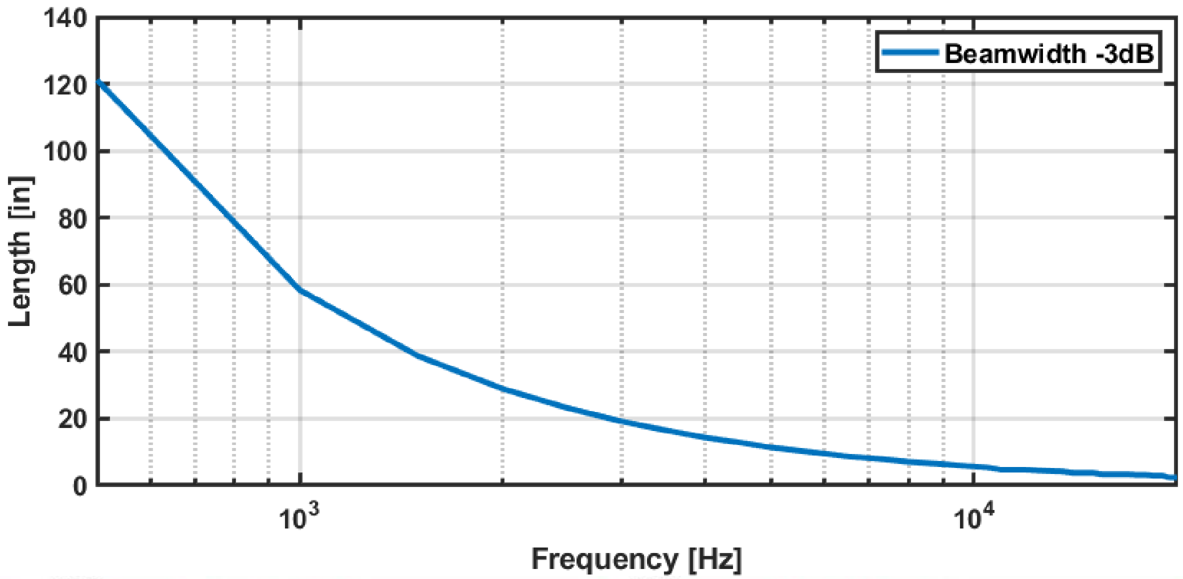
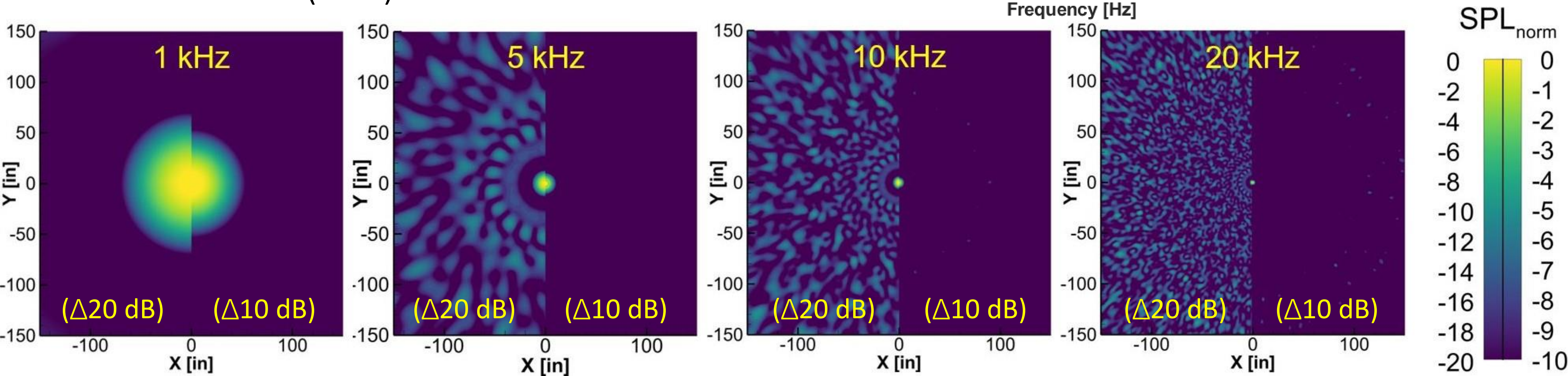


Experimental Setup - Phased Array Response

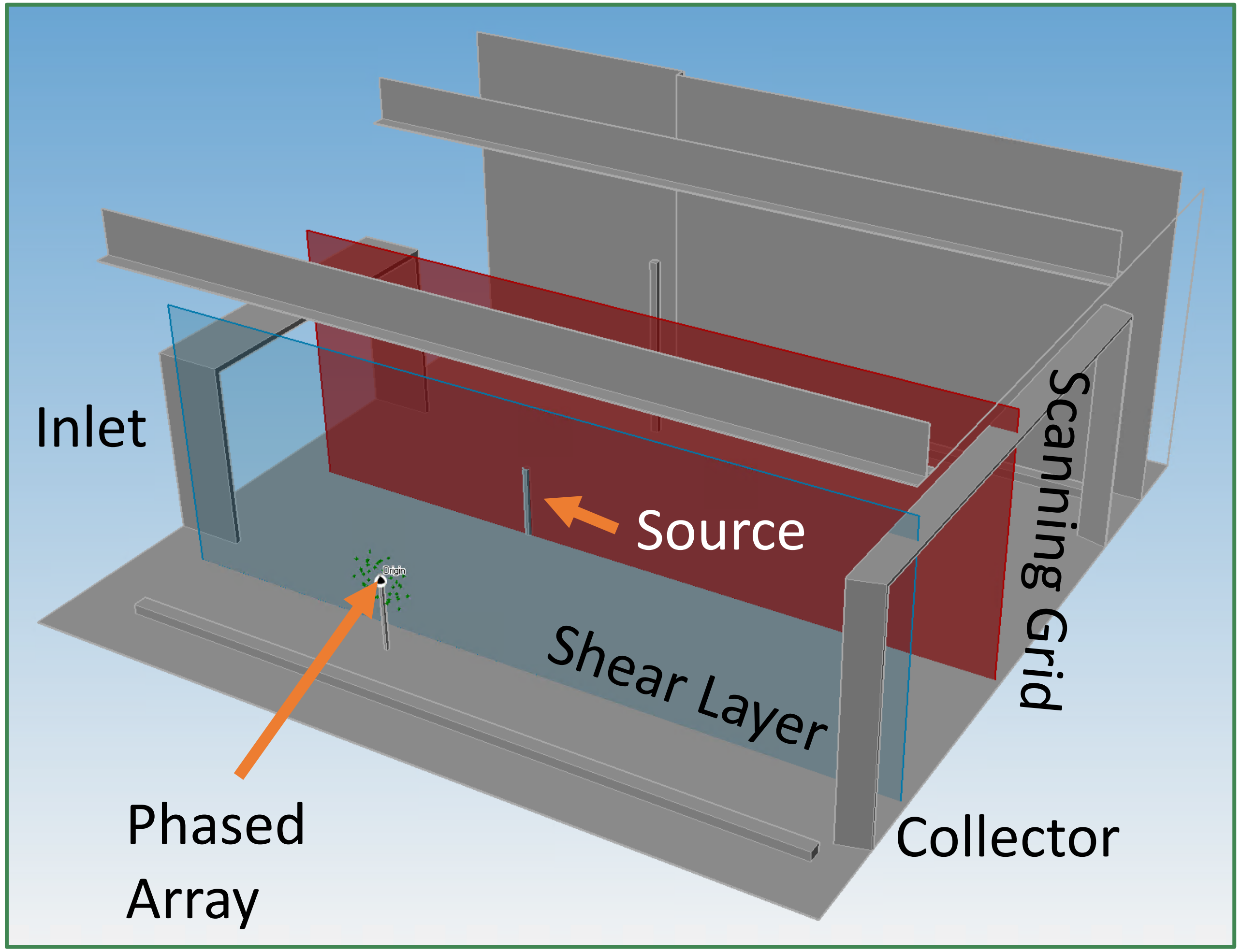
- Minimizes 3-dB beamwidth
- Sidelobes more than 10 dB below main lobe from 1 to 16 kHz
- Simulated Point Spread Functions (PSF)





Beamforming

- Conventional frequency-domain beamforming (CFDBF)
- CLEAN deconvolution
- Static runs to identify reflection
- Flow-on runs to identify noise sources
- Integration for background noise rejection
- Correction for flow convection and shear layer refraction



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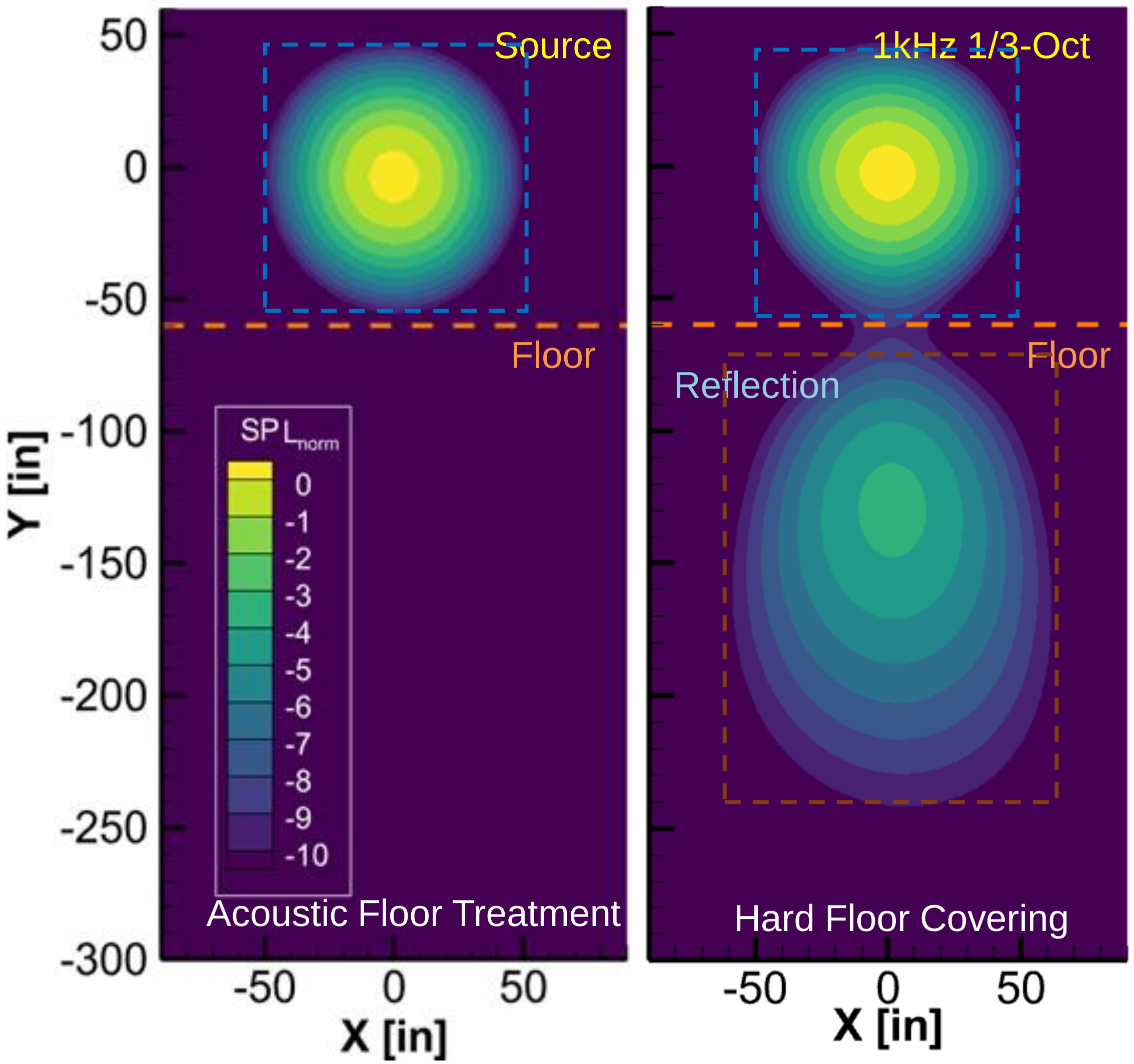
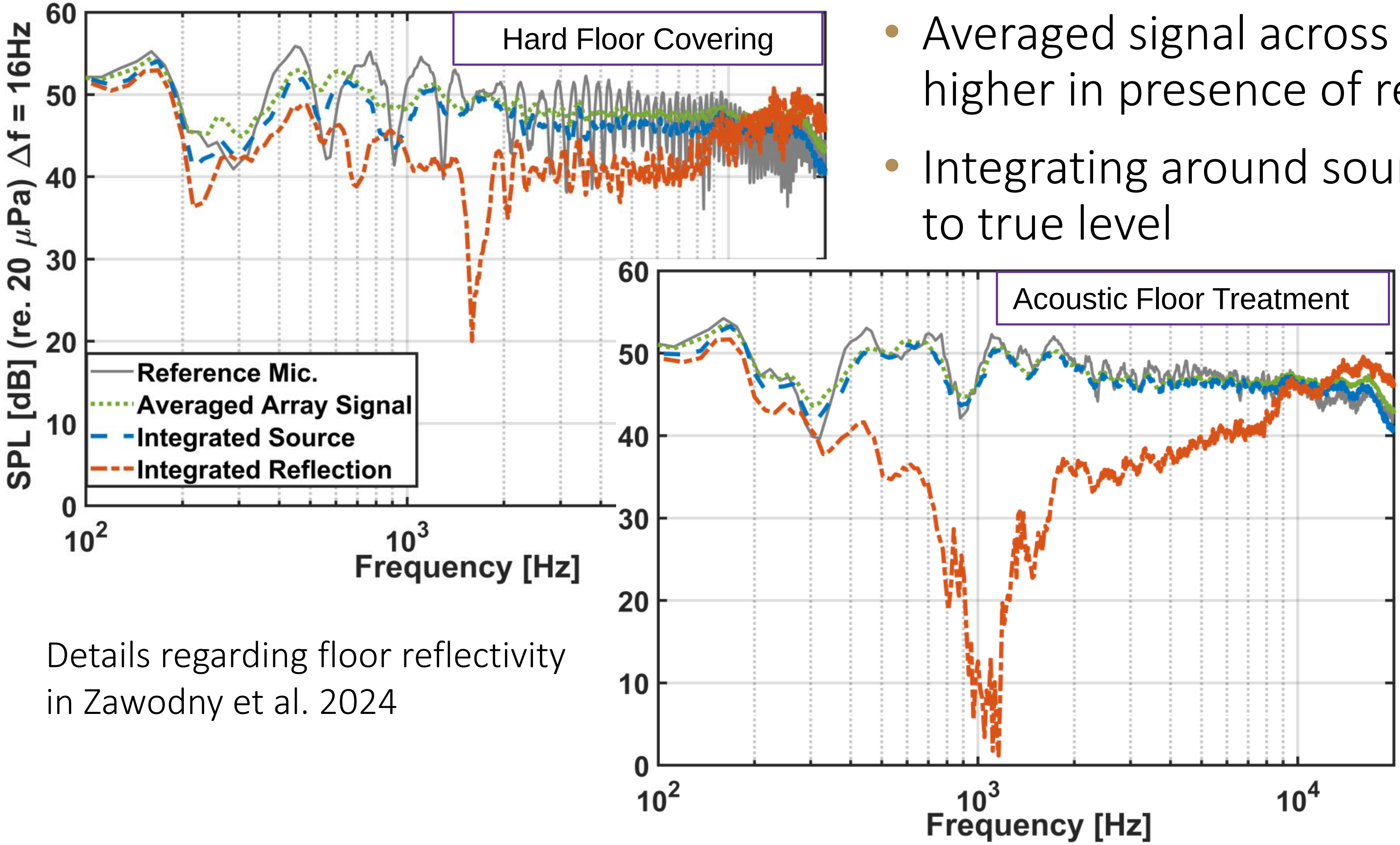
Results – Static (No-Flow)

- Demonstrate lower reflectivity of acoustic floor treatments
- Able to identify source reflected off hard floor covering
- Reflection captured as "image source" below floor
- Could not identify other sources of reflection
- Extract spectra by integrating around source/ reflection



Results – Static (No Flow)

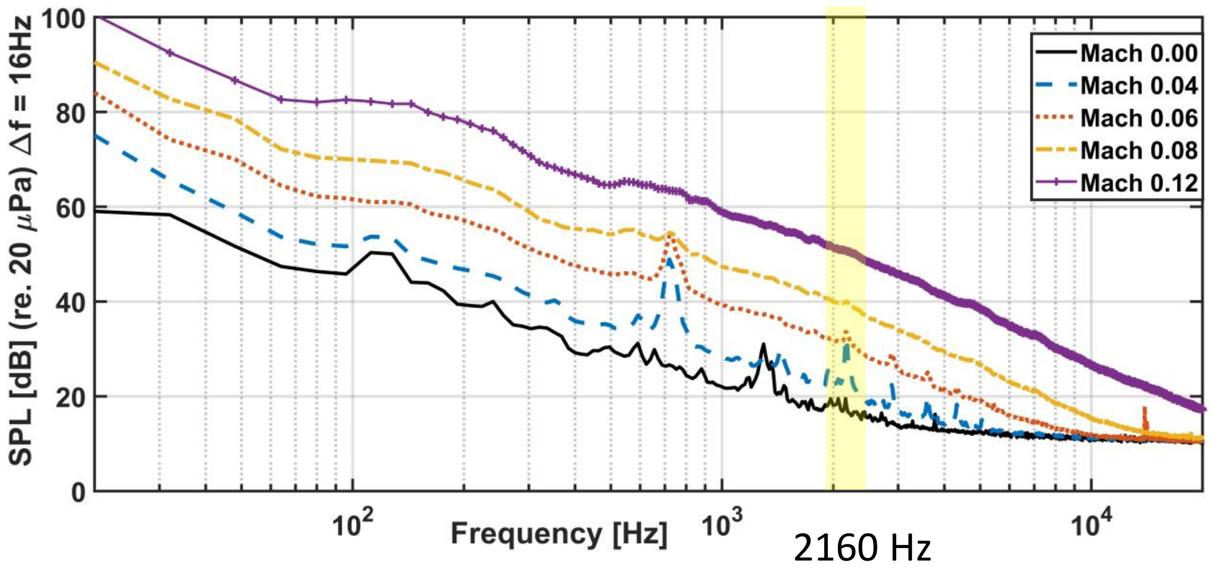


Details regarding floor reflectivity in Zawodny et al. 2024

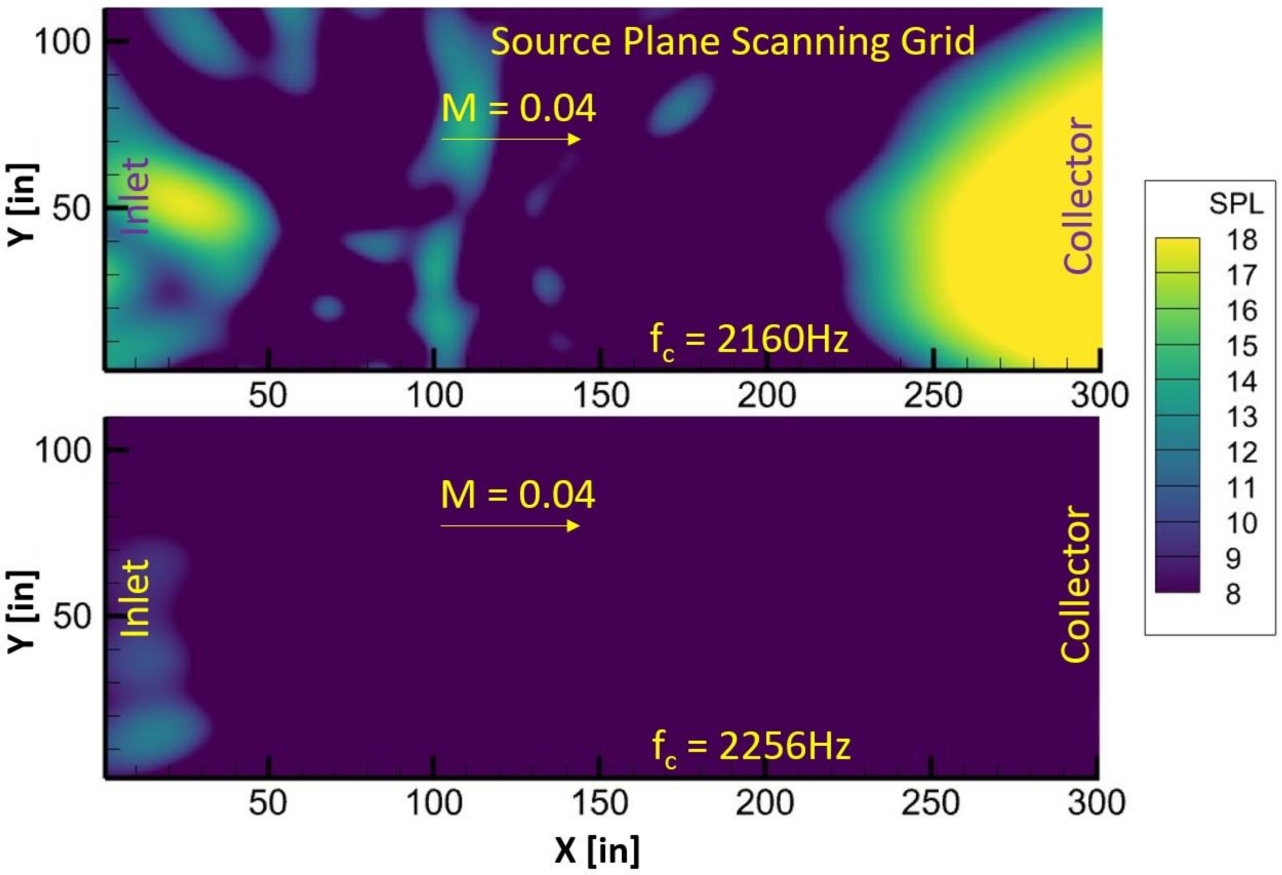
- Averaged signal across all array microphones higher in presence of reflection
- Integrating around source brings level closer to true level
- Averaged signal same as integrated signal with acoustic floor treatment
- Reflected data impacted by source directivity
- Reflected data above 10 kHz likely incorrect

Results – Flow-On

- Background noise source identification
  - Identified direction of 2160 Hz peak in Mach 0.04 data
  - 720 Hz peak in spectra too low for array to resolve clearly
  - Both peaks likely harmonics of fan cooling unit

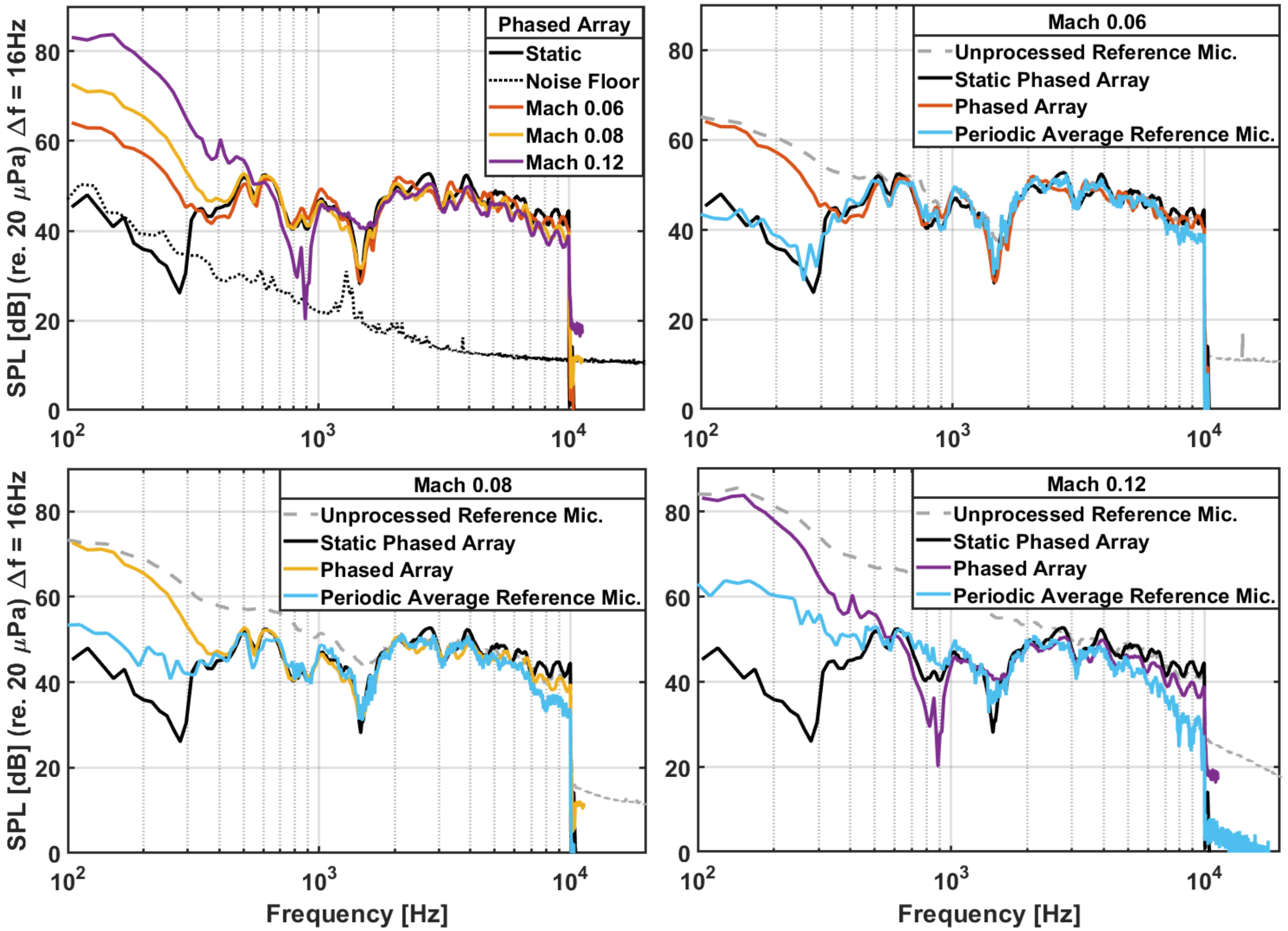


2160 Hz



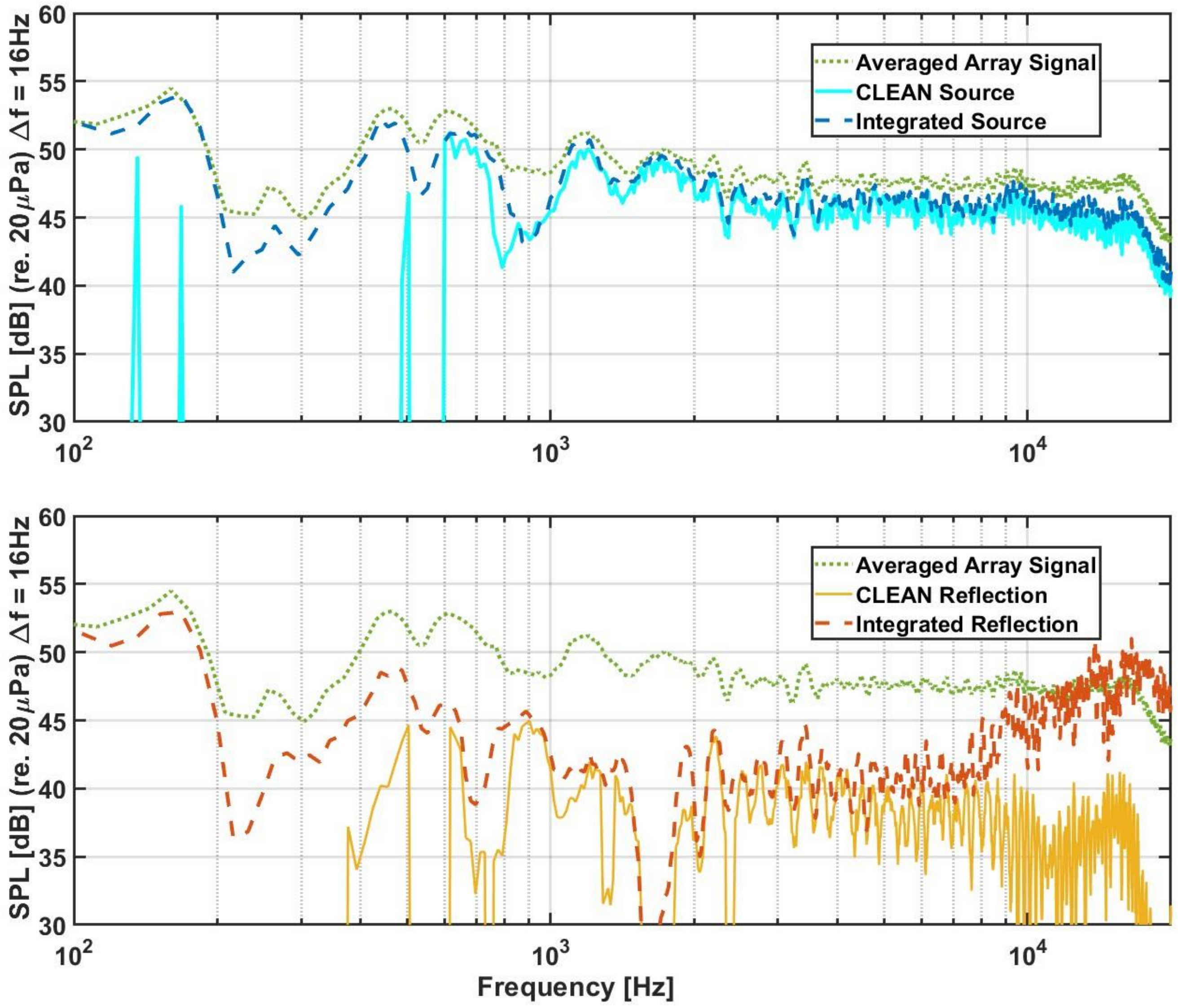
Results – Flow-On

- Background noise rejection
- Captures high frequency better than periodic averaging of single microphone
- Does not require periodic signal
- Periodic averaging better at low frequency where the array response is poor



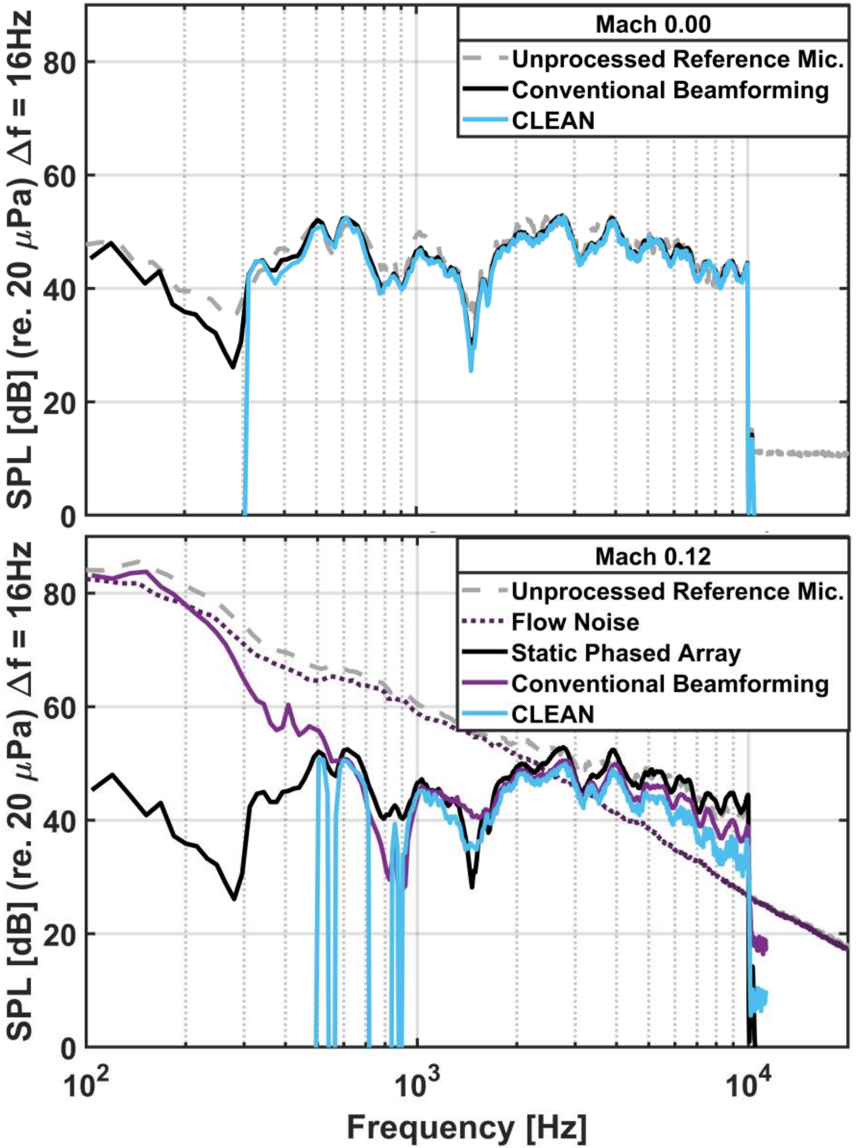
Results – Deconvolution (Static)

- CLEAN deconvolution removes effects of scanning grid
- Struggles at frequencies below array design level (*f* = 1 kHz)
- Further reduces integrated source below averaged signal level
- Applicable to reflection because it is sufficiently separated from main source
- Reduces amplitude of reflected spectra for *f* > 10 kHz
- Difficult to measure true level of reflected signal



Results – Deconvolution (Flow-on)

- SPL dropouts at low frequency
- Impaired high frequency response through shear layer
- Sensitive to decorrelation through turbulent shear layer



Conclusions

- Testing with known acoustic sources will allow better interpretation of results from unknown sources
- Single microphone measurements overestimate source strength when reflective floor is present
- Integrating around source in beammap rejects contributions from reflections
- Conventional Frequency Domain Beamforming (CFDBF)
  - Reflection from acoustically treated floor not observed in beammap
  - Able to determine direction of 2160 Hz peak present at certain flow speeds
  - Captures high frequency content passing through the shear layer better than periodically averaged single microphone
- CLEAN
  - Deconvolution impairs high frequency capture through shear layer
  - CLEAN deconvolution may improve low frequency response below designed limits but also exhibits frequency dropouts

Acknowledgments

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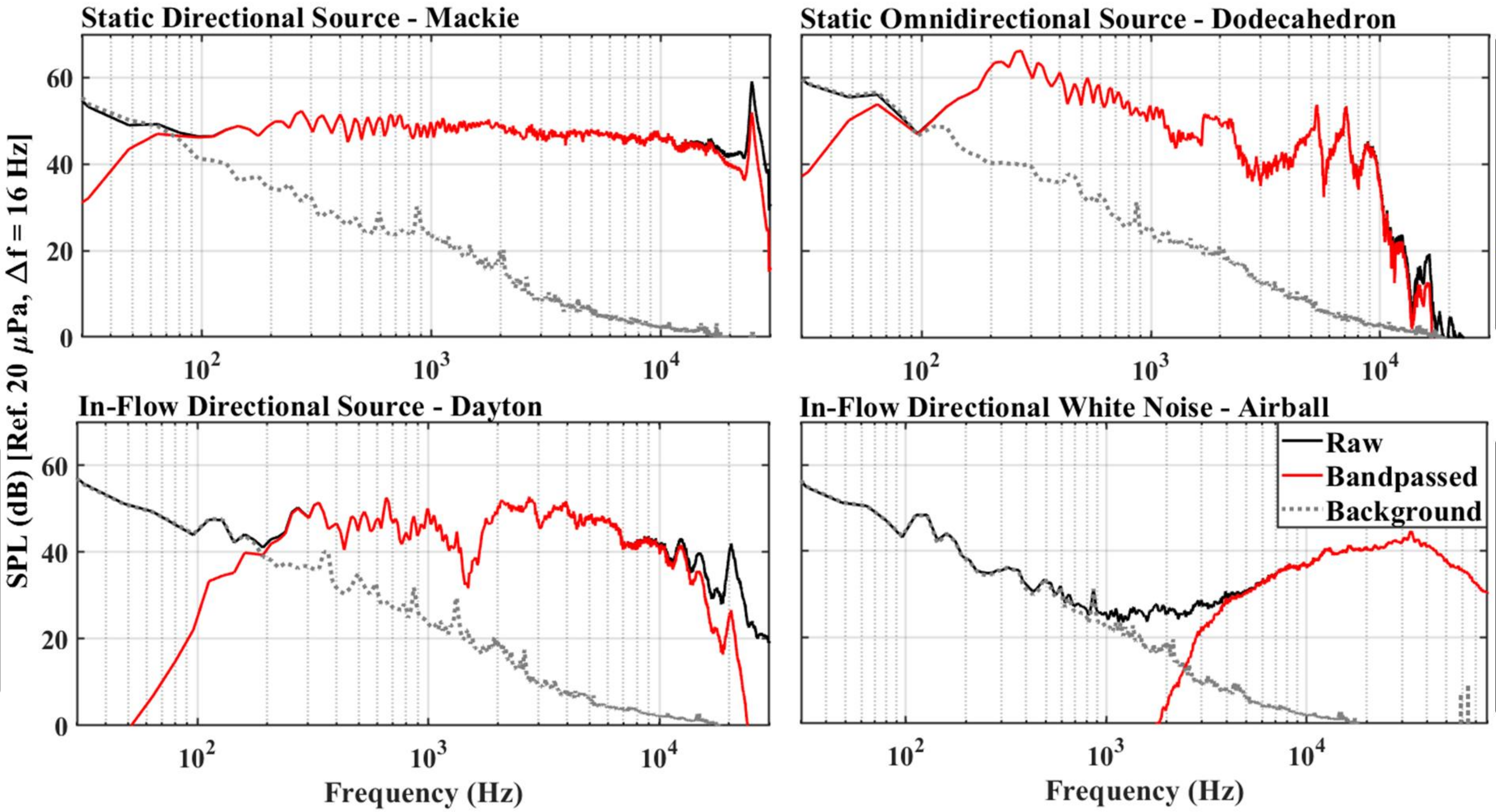
Broadband Output of Sources

Source: NASA



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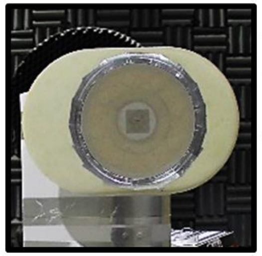

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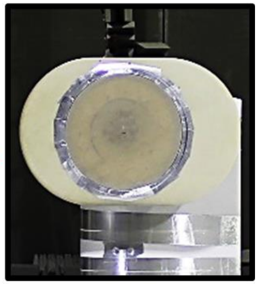

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