



Phased Array Measurements of Scaled Propellers through a Wind Tunnel Shear Layer

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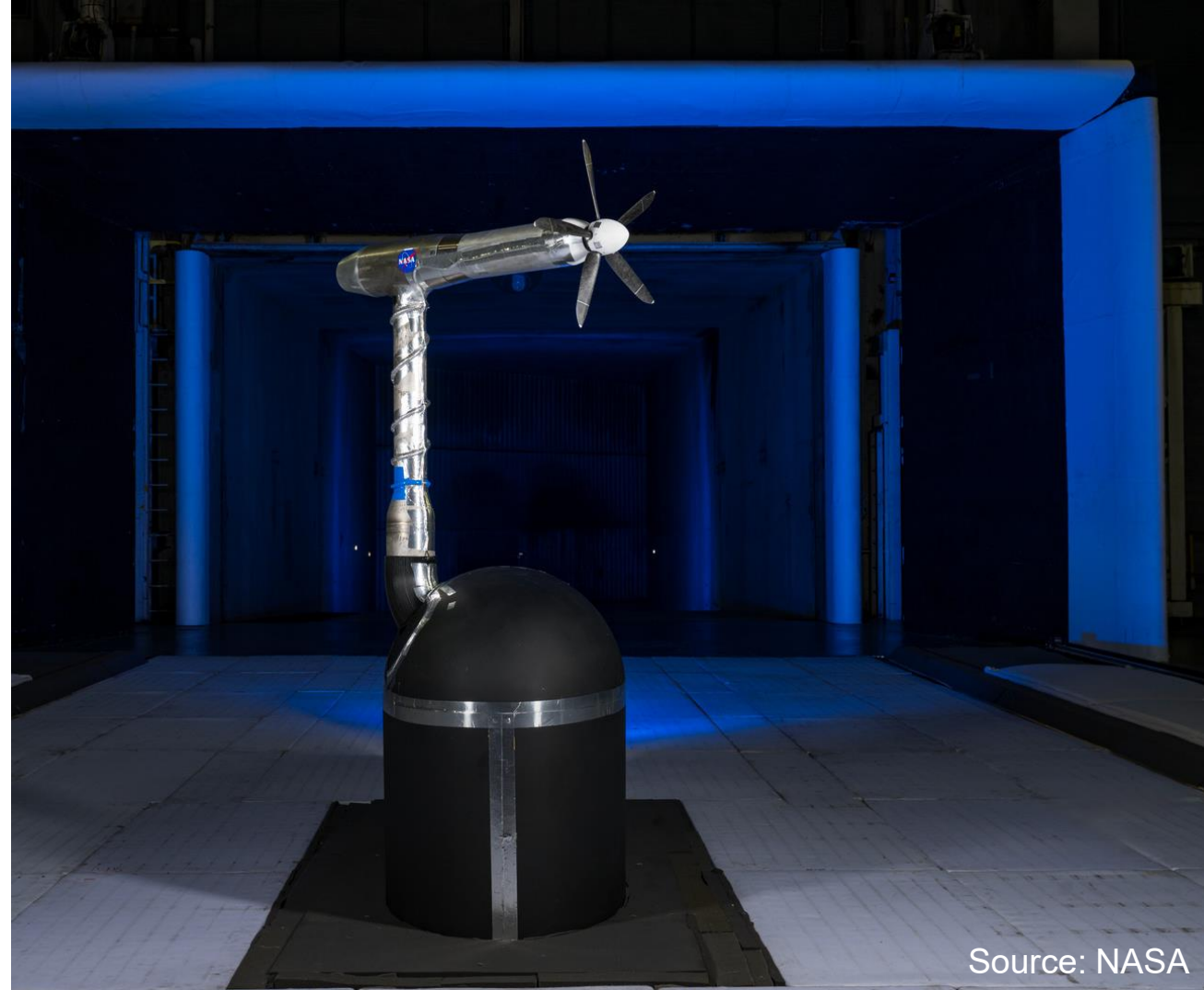
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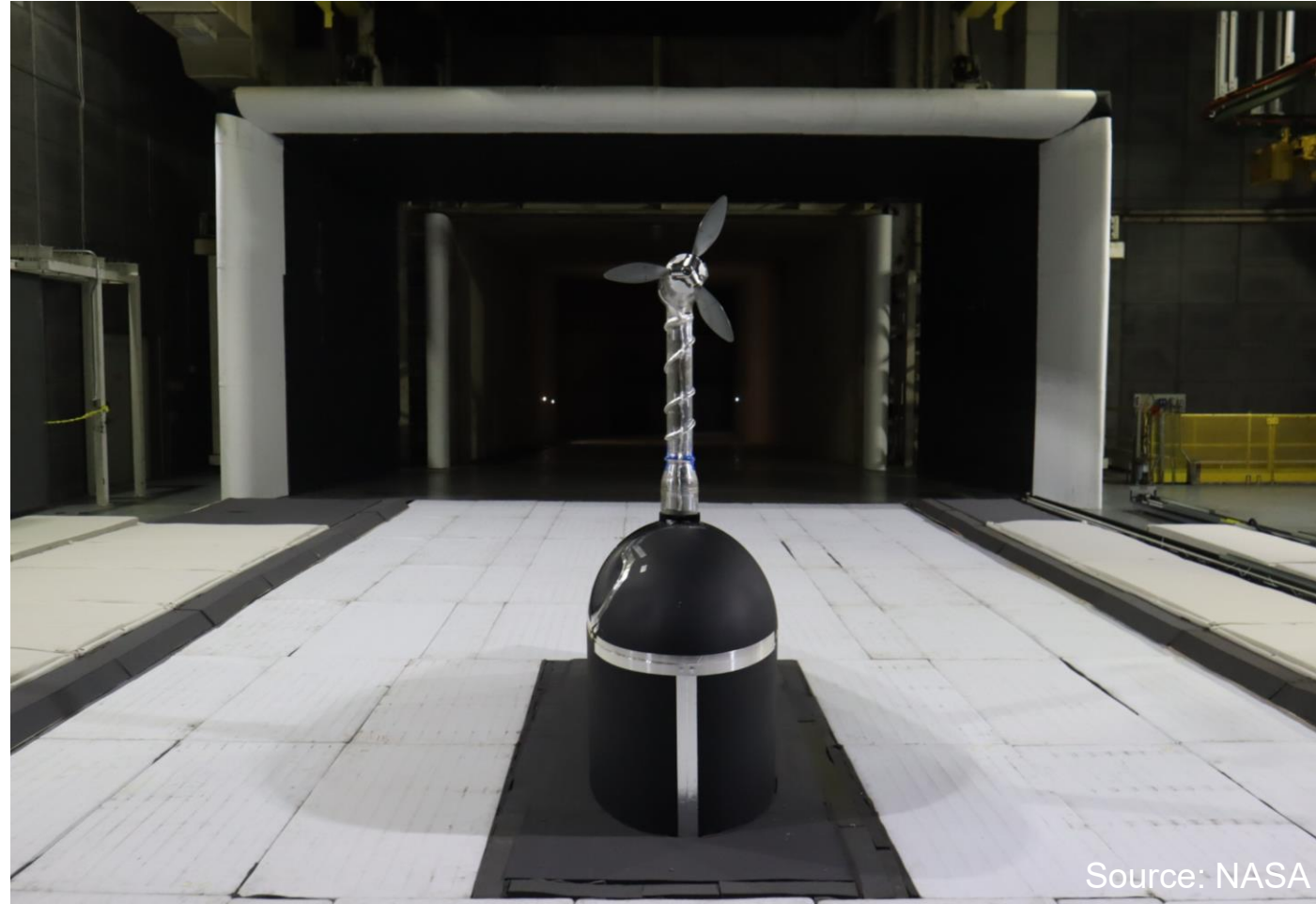


Source: NASA

Outline



- Experimental overview
- Objectives of beamforming
- Processing methods with representative results
 - Conventional Frequency Domain BeamForming (CFDBF)
 - ROtating Source Identifier (ROSI)
 - Shear Layer Correction
 - Segmented ROSI
- Summary of findings



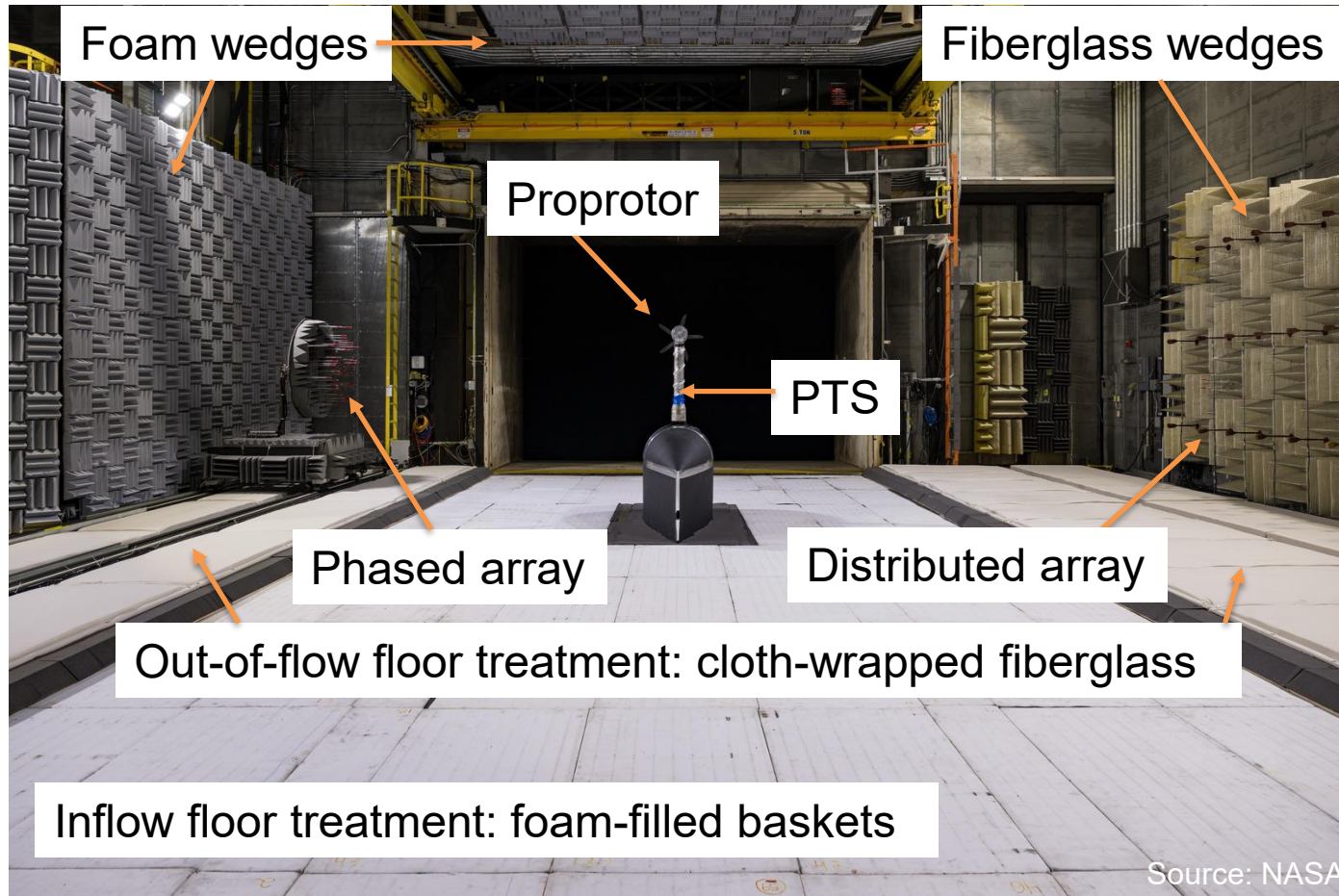
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Experimental Overview

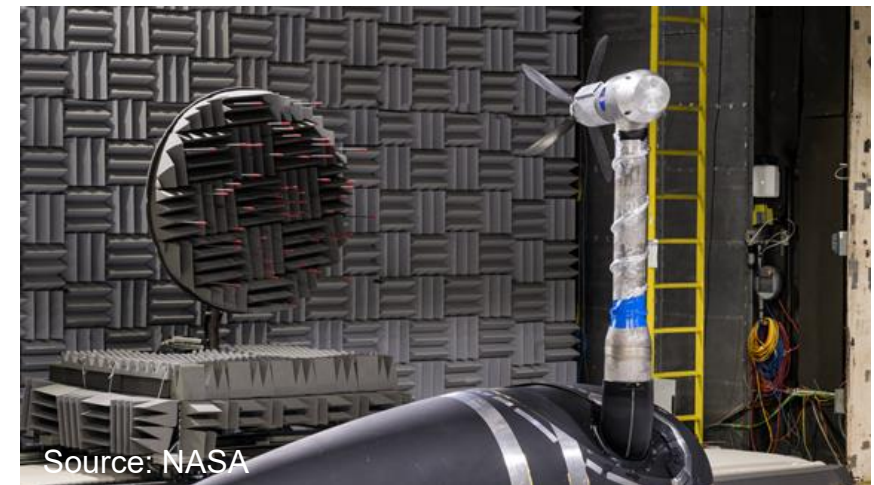


- Extensive proprotor acoustic test in the NASA Langley 14- by 22-Foot Subsonic Tunnel, July – December 2025
- Blade geometries chosen to represent those used in the emerging Future Vertical Lift (FVL) and Urban Air Mobility (UAM) industries
- Performance and acoustic measurements taken for
 - Edgewise flight configuration
 - **Partially transitioned configuration**
 - Simulated descent conditions
 - Dynamic pitching maneuvers intended to emulate portions of a tilting rotor's transition envelope

Test Cell Configuration



- Test section in semi-open jet configuration
- Acoustic treatment on walls, ceiling and floor
- Phased array (54 channel)
- Distributed array (30 channel)
- Proprotor blades mounted on Propeller Test Stand (PTS)
 - 6-axis load cell
 - 1 per rev. tachometer
 - Yaw up to 90 deg

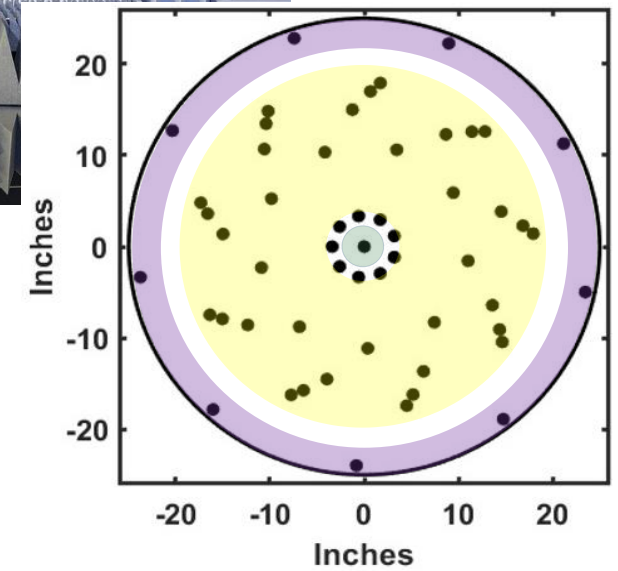
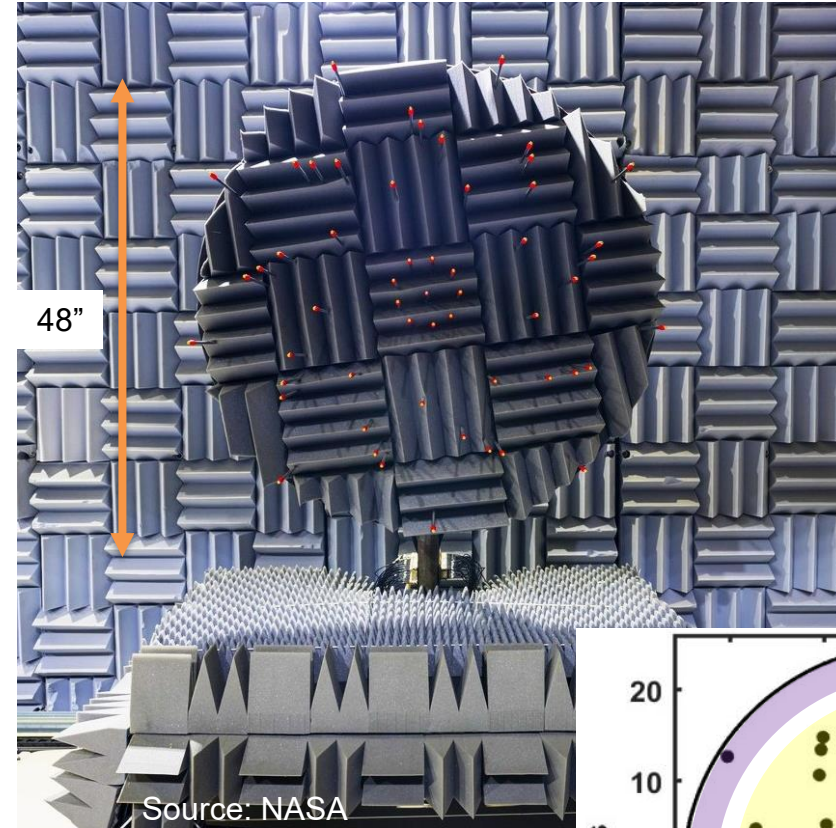


Acoustic Instrumentation



54-microphone phased array

- 48" aperture
- Reverse-logarithmic distribution
- 9 arms of five microphones + outer ring
- Reference microphone in center
- Operate between 1 – 16 kHz
- Minimize main lobe 3 dB beamwidth
- Sidelobes 10 dB below main lobe

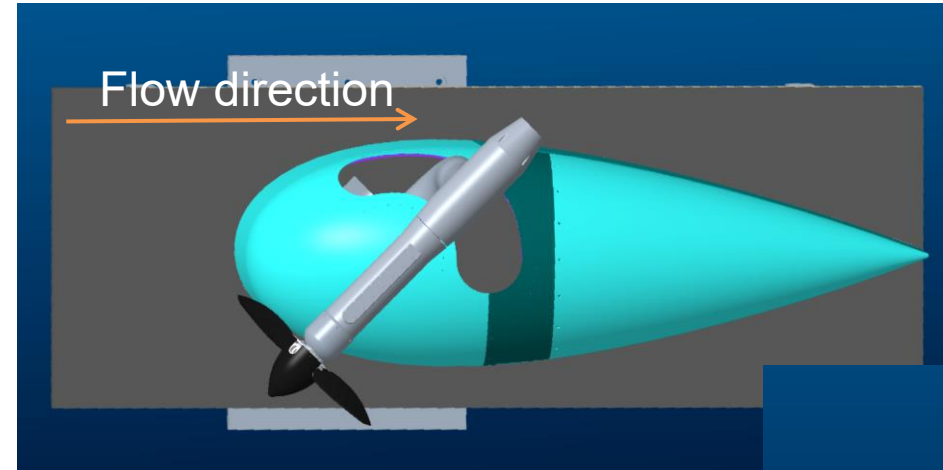


Cases Considered

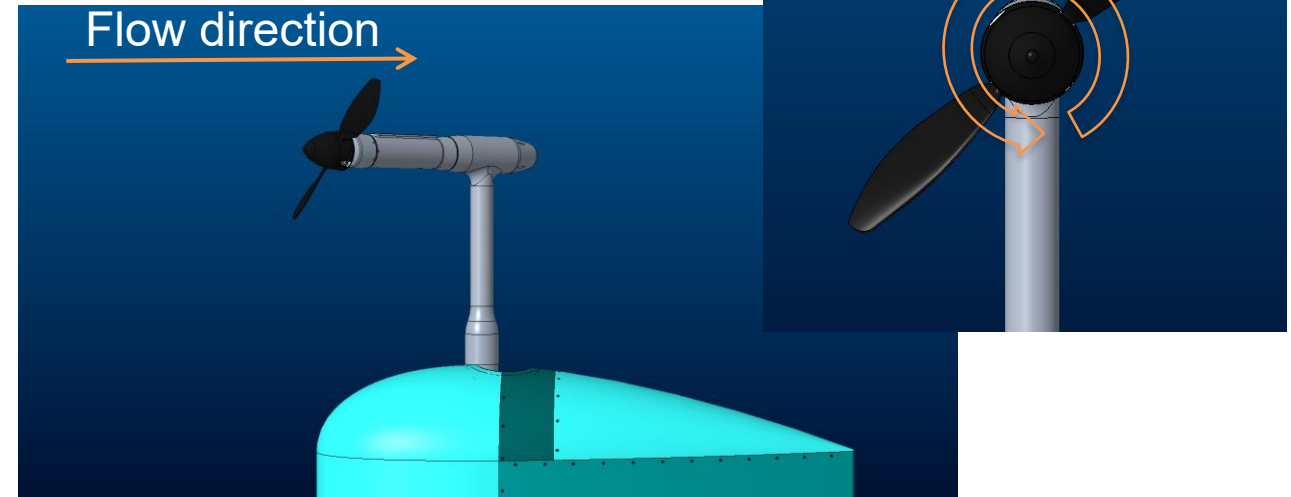


Two cases examined (out of 4000+)

- Tunnel Speeds: Static, Mach 0.06
- 36-inch, 2-bladed prop rotor
- NASA's COPR geometry
- Yaw angle 45 degrees
- 2704 RPM (45 revs/s)



Source: NASA



Overview of Beamforming Techniques



Technique	Objective
Conventional Frequency Domain Beam Forming (CFDBF)	Locate noise source spatially in region “viewed” by microphone array
Rotating Source Identifier (ROSI)	Remove motion smear from rotating source
Segmented ROSI (S-ROSI)	Recover some acoustic directivity of rotating source otherwise lost by the ROSI algorithm

Conventional Frequency Domain Beamforming

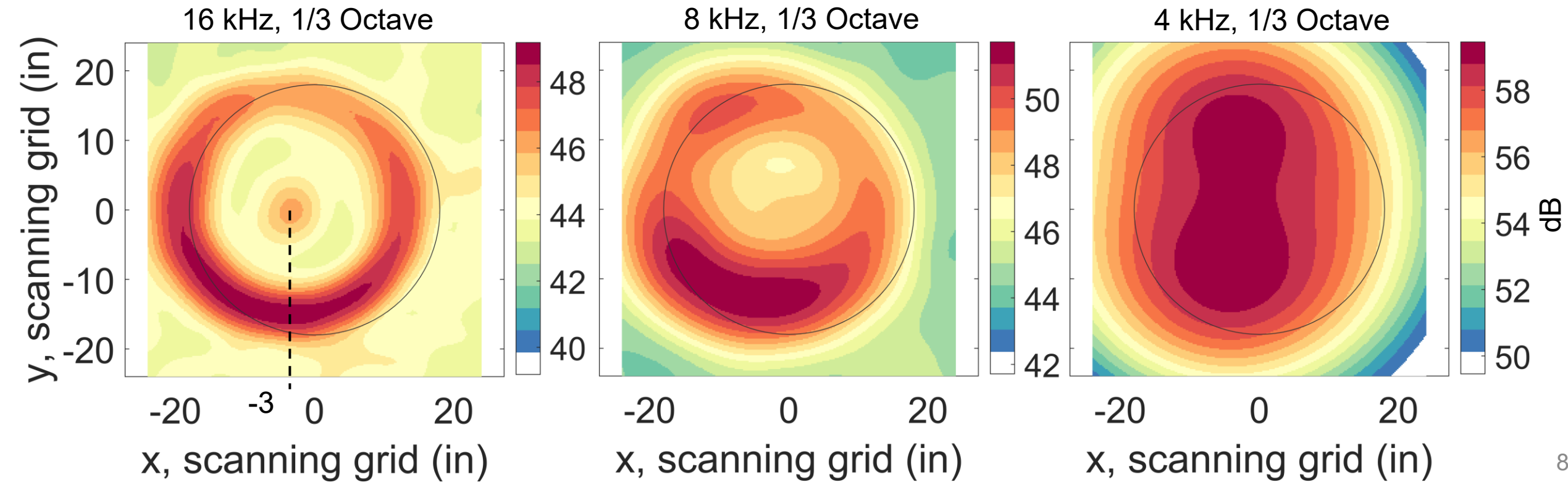


- Performed on both static and Mach 0.06 flow cases
- Captures azimuthal directivity but smears beam map
- Shear layer refraction correction applied as needed
- Poor resolution at lower frequencies
- Very fast to complete!

Zero tunnel flow results shown

Black circle: expected tip-path

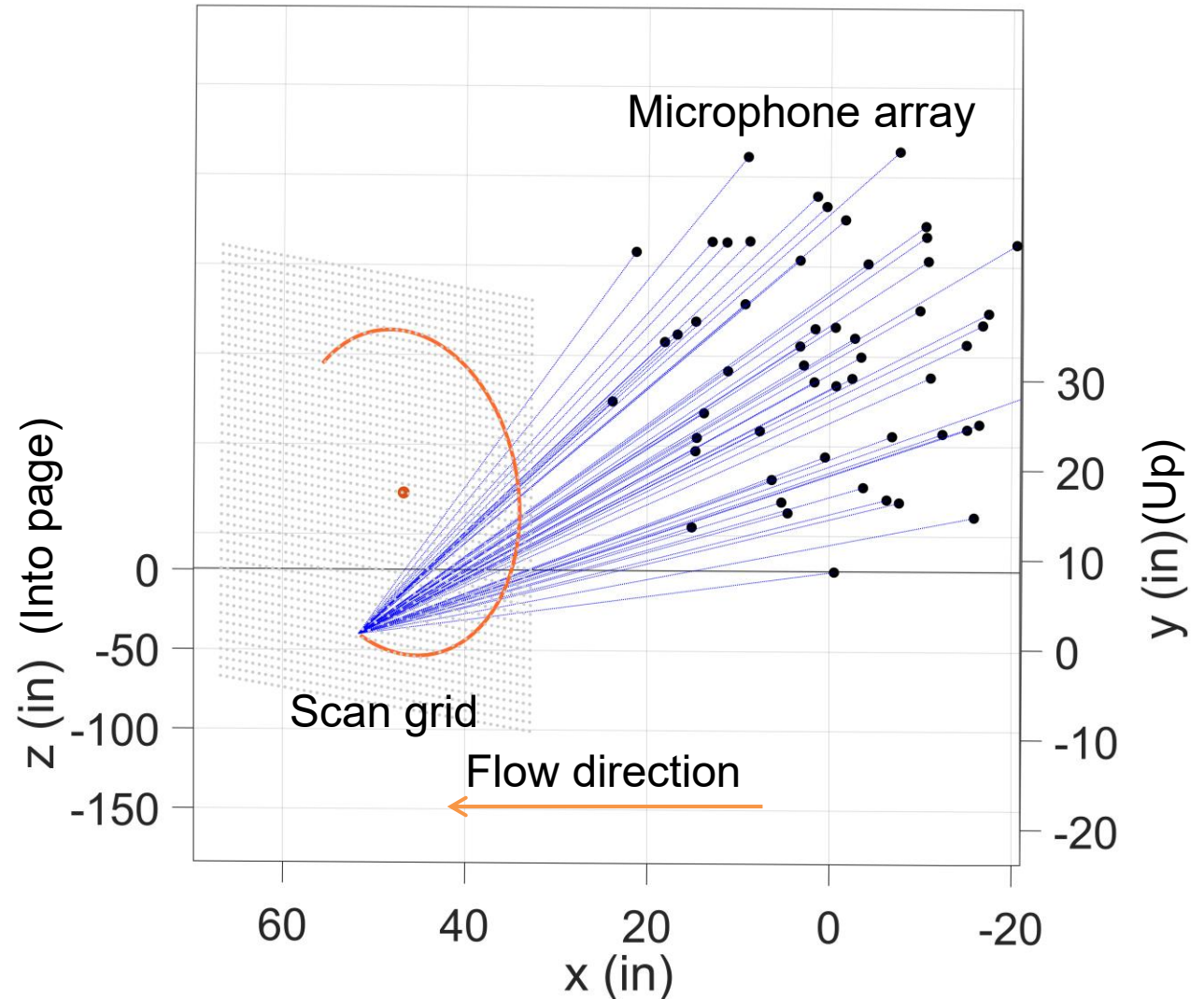
3 inches off center!



Rotating Source Identifier (ROSI)



- Performed on both static and Mach 0.06 flow cases
- Virtually rotates scanning grid with the propeller
 - Effectively isolates non-deterministic sources located on rotor
 - Rejects non-rotating noise sources and blade harmonic noise
 - Azimuthally averages beammap - loses directivity
 - **Need to know center of rotation**
- Beamforming performed in **time domain**
 - Poor spatial resolution at lower frequencies
 - No established post-processing method to improve resolution



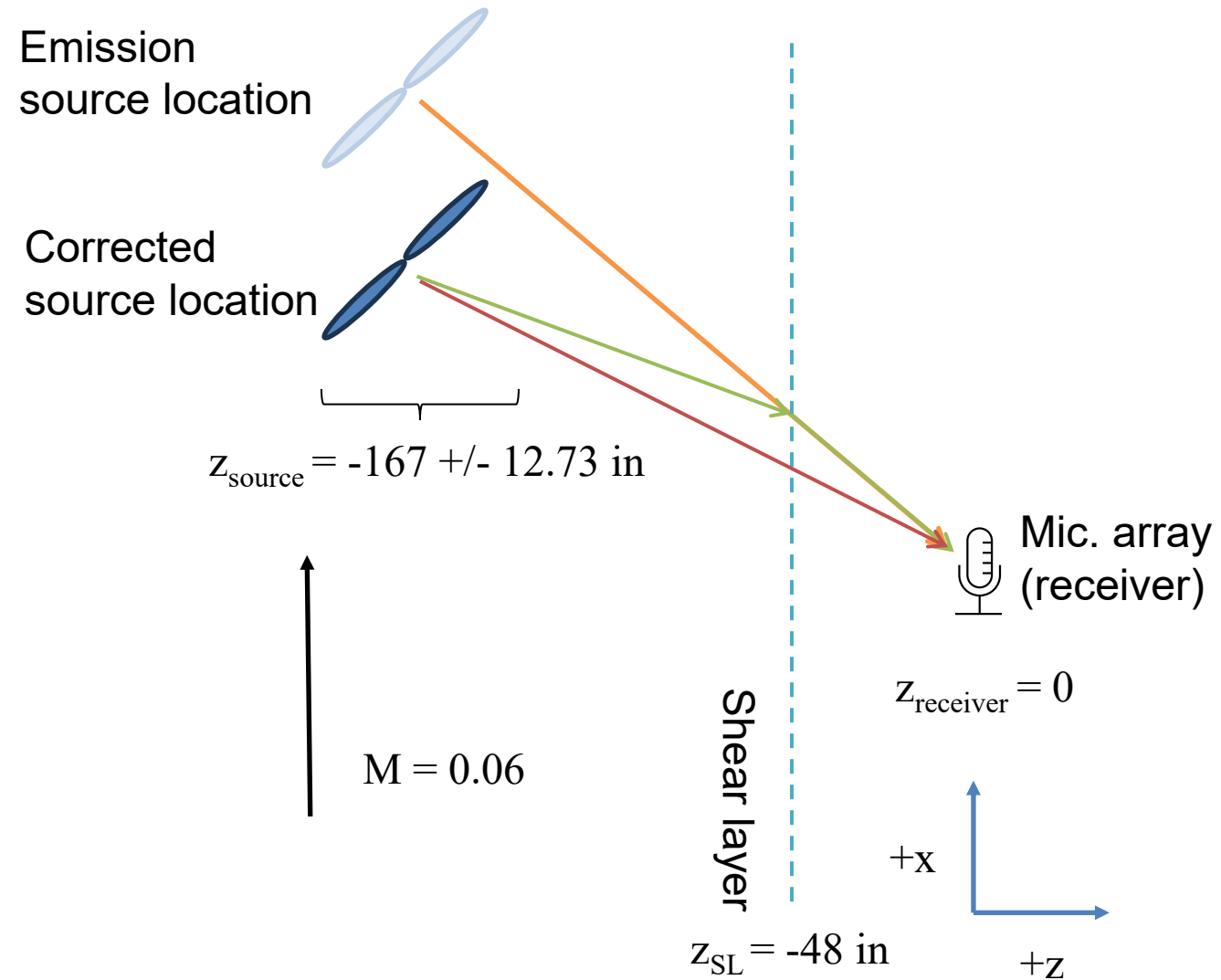


Shear Layer Correction



- Relative motion of source/grid make true shear layer correction prohibitive
- Simple correction applied to calculated time delays of moving source
- More accurately a convection correction
 - Valid from flow speeds and source-receiver angle present
 - Speed of sound in direction of flow modified by the average Mach number between source and receiver

$$correction = 1 + M \frac{(z_{source} - z_{SL})}{(z_{source} - z_{receiver})}$$



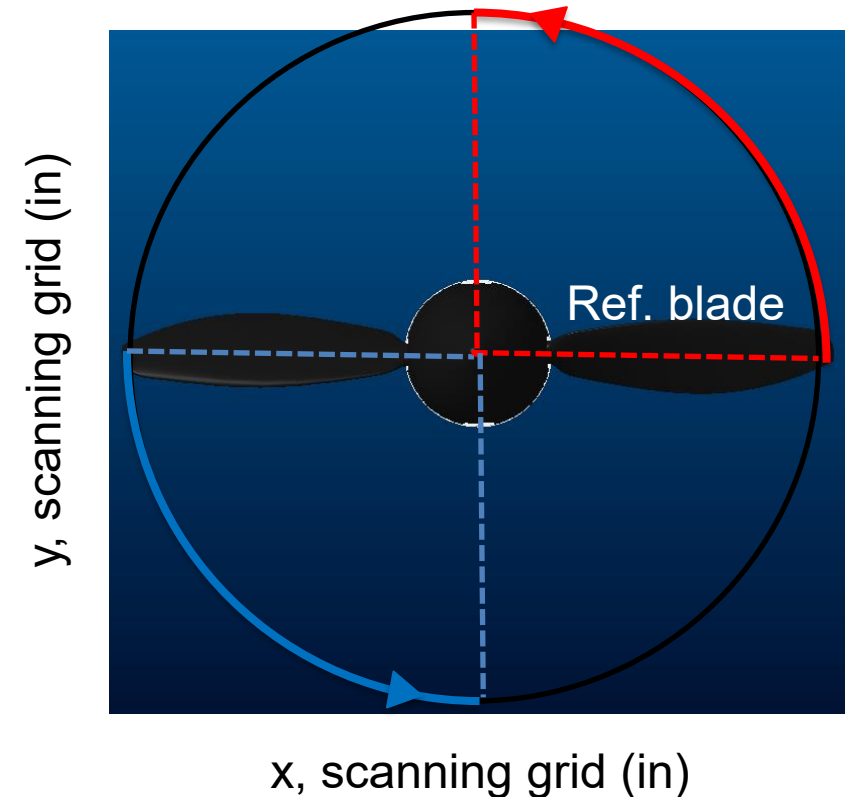


Segmented ROSI



Division made in the time domain

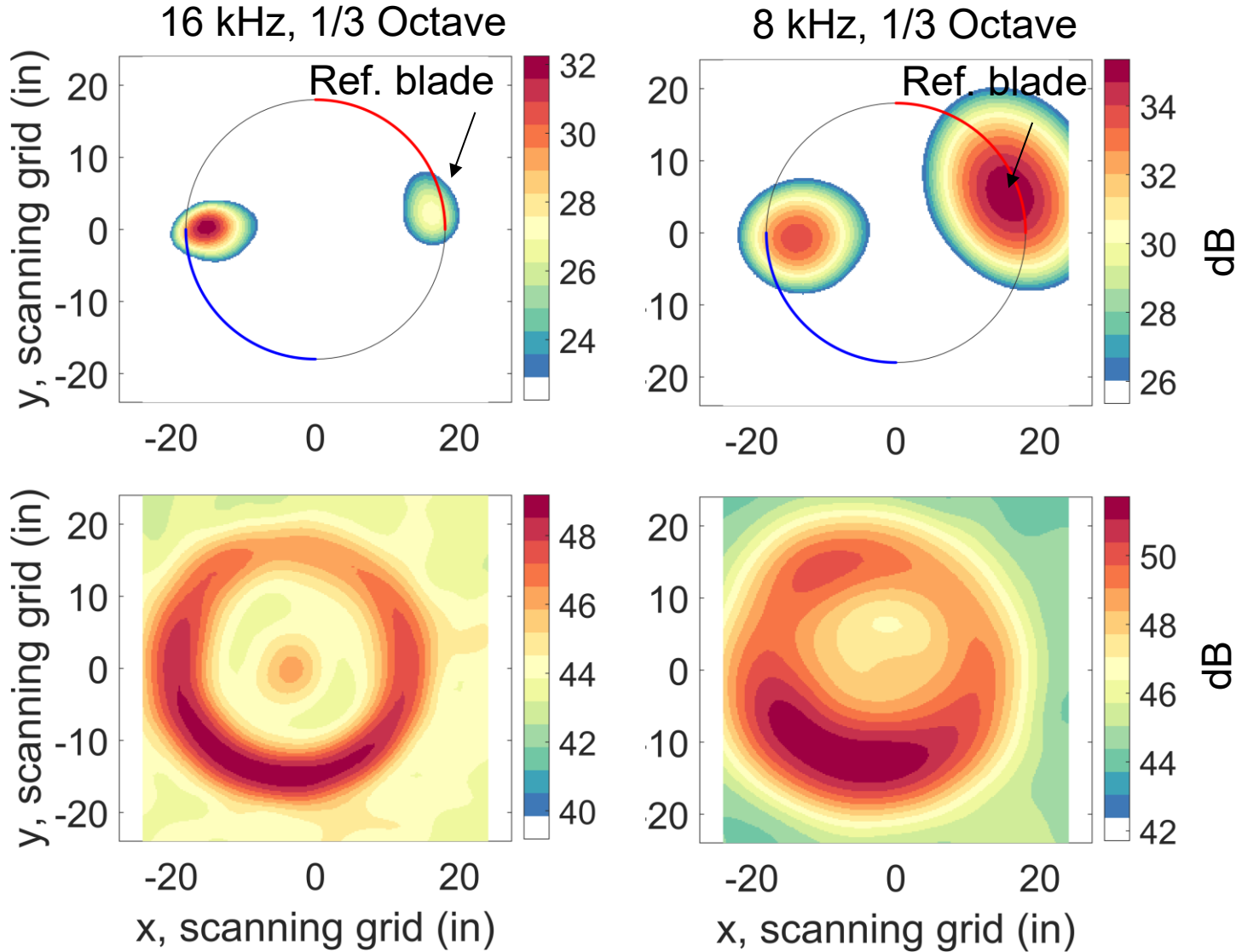
- Reference blade and position are identified
- Tachometer data provide time-varying rotation rate
- Each point in pressure signal associated with an azimuthal location of reference blade
- Each revolution is broken into segments based on azimuth
- FFT applied on per-segment basis, then averaged over revolutions
- Result: Beam map retains crude directivity



Segmented ROSI



S-ROSI
CFDBF (for reference)



- Static tunnel condition shown for simplicity
- Marked asymmetry present
- Can support same shear layer correction as ROSI
- Faces same resolution limitations as ROSI
- Reduced duration of continuous time segments results in reduced frequency resolution
- Results difficult to interpret
- **Note: Beam map always shows blades in reference position**

Summary of Findings



Conventional beamforming

- Quickly returns source maps and captures azimuthal directivity of a rotating source
- Exhibits poor spatial resolution and smears the location of the rotating source
- Supports deconvolution methods to improve spatial resolution
- Easy implementation of refractive shear later correction

ROSI

- Isolates rotating blades and rejects non-rotating acoustic contributions
- Azimuthally averages noise sources
- Spatial resolution equivalent to conventional beamforming, but no deconvolution methods are currently supported
- Full shear layer correction computationally prohibitive, but simple correction adequate

S-ROSI

- Partially restores azimuthal directivity in ROSI
- Reduces available frequency resolution

Future Work!

- Research methods to improve spatial resolution applicable to ROSI/ S-ROSI
- Use integrated spectra to verify azimuthal directivity of S-ROSI

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Technology (RVLT) projects



References for Covered Topics



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