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Holographic Visualization of a Subsonic Jet

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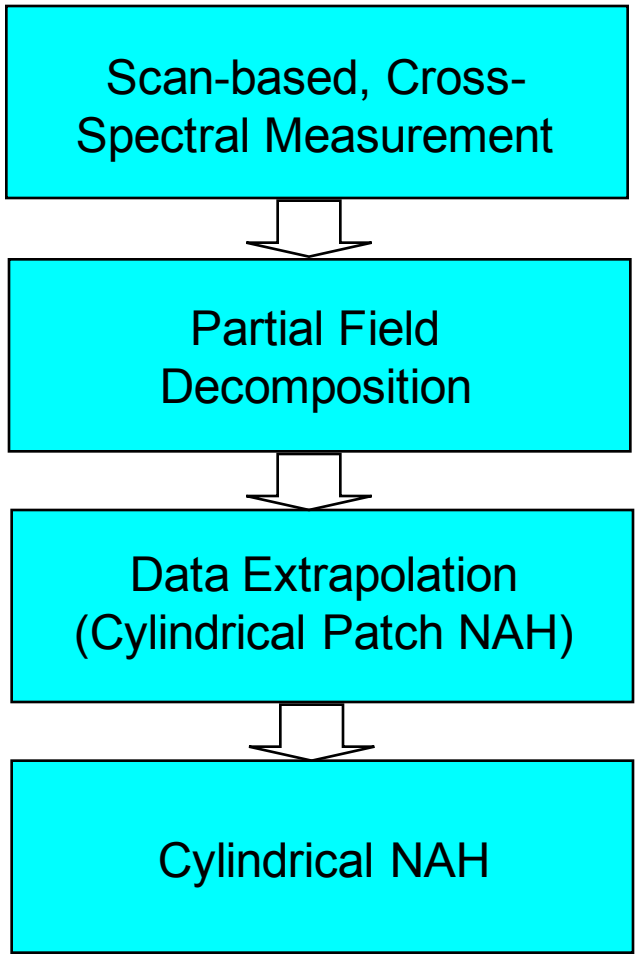
Background

- Array-based measurements for jet noise source localization
  - One-dimensional array: acoustic mirror, acoustic telescope, polar correlation technique
  - Two-dimensional array based on beamforming theory

  ⇨ Farfield measurement and oversimplification of the problem
- NAH can visualize the sound field with high spatial resolution
- Objective
  - Develop NAH procedure for aeroacoustic sources
  - Identify source distribution and radiation pattern of a subsonic jet
  - Predict farfield radiation based on nearfield measurements

Procedure



- The use of a large number of references to minimize noise effects
- Careful design of a reference array

- Based on the use of the acoustic transfer matrix in conjunction with a proper regularization by using TSVD to compensate for source nonstationarity

- Extension of the data measured in a finite region by iterative method

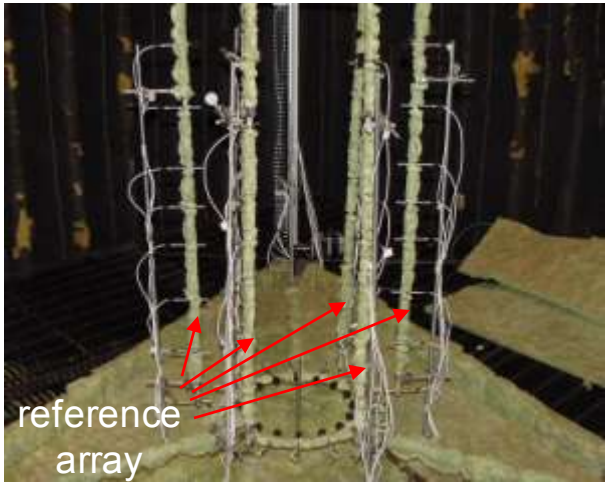
- Regularization: Tikhonov regularization used in conjunction with Mozorov discrepancy principle
- Pressure, particle velocity, acoustic intensity

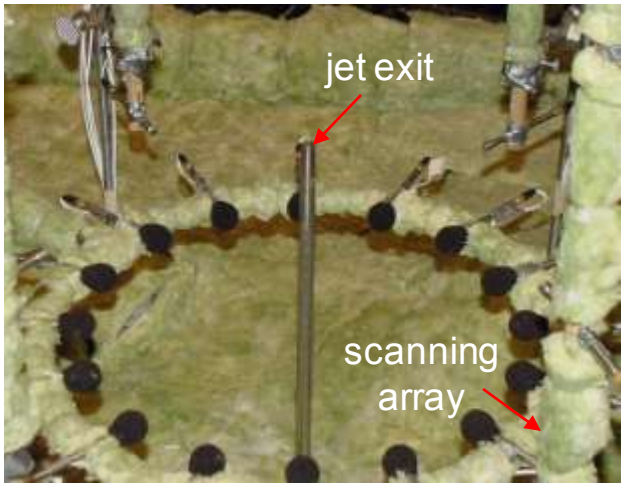
Strategy for Reference Array Design

- The references should be positioned in the region outside the flow
- The position of the field microphones is not strictly restricted in the same way as long as the field microphones are not positioned too close to the references
- From the results of preliminary measurements (at NASA Glenn AAPL)
  - A large number of references are required
  - The references should cover the whole circumference and extend axially beyond all possible source regions

Experimental Setup

- *Ma* = 0.26 turbulent cold jet from a 0.8 cm diameter burner nozzle
- The number of references: 48 (6 linear arrays)
- Hologram radius: 30 cm
- The number of measurement points: 16 (circum.) by 36 (axial)
- Increment in the axial direction: 3 cm

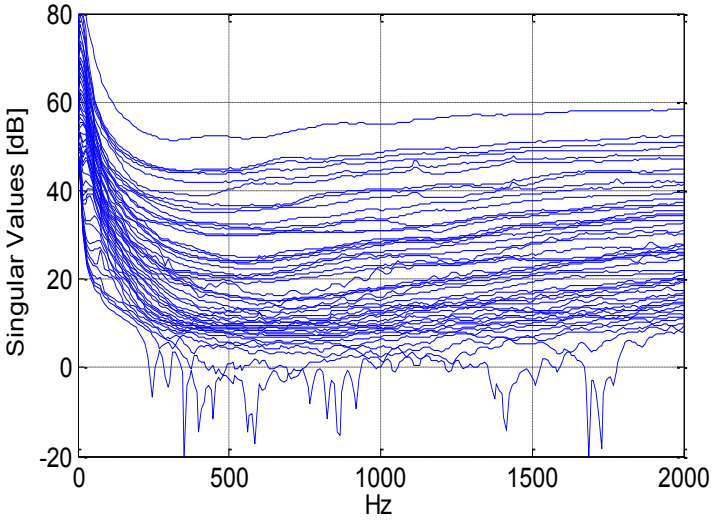




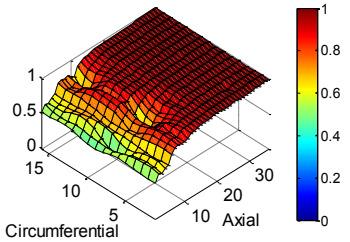
SVD and Virtual Coherence Function

- check whether the configuration of measurement arrays is appropriate
- Determine to the number of singular values that should be discarded in the partial field calculation

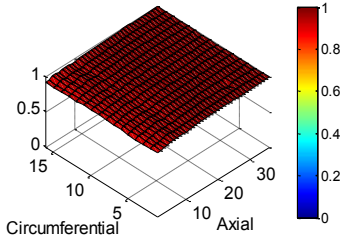
< Singular values >



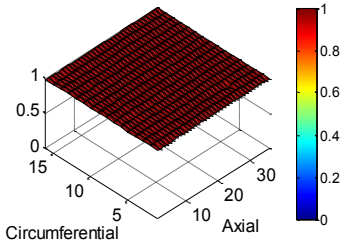
< Sum of the virtual coherence at 1 kHz >



5 partial fields

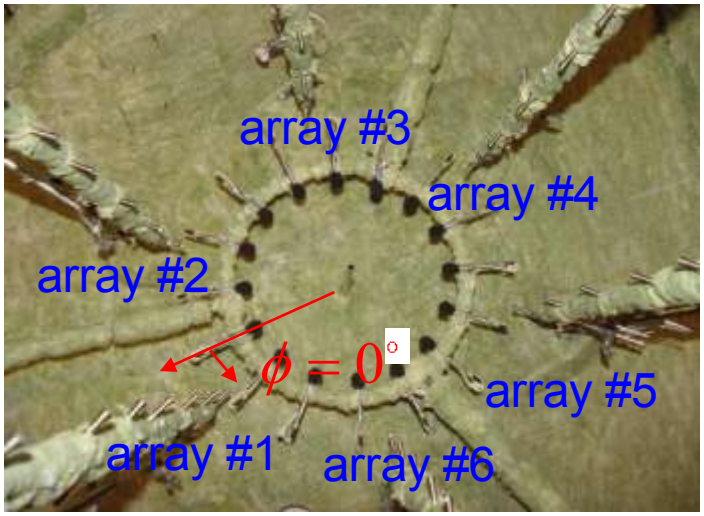


11 partial fields



20 partial fields

Effect of the Number of References (1)

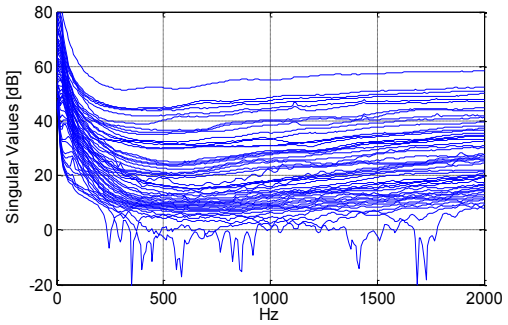


Three array configuration

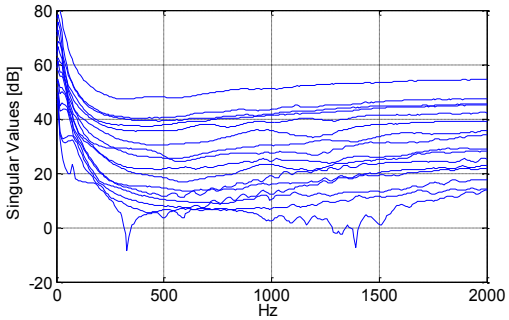
- Case 1: use 48 references
- Case 2: use 16 references (array #1 and #2)
- Case 3: use 18 references (3 references from each array)

Effect of the Number of References (2)

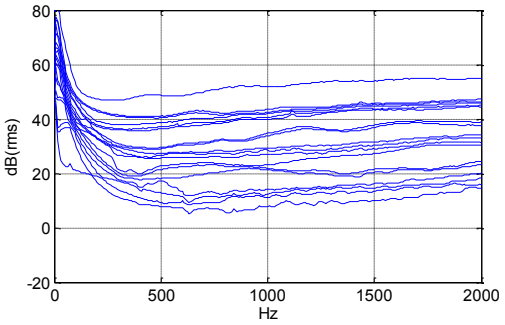
< Singular values >



Case 1

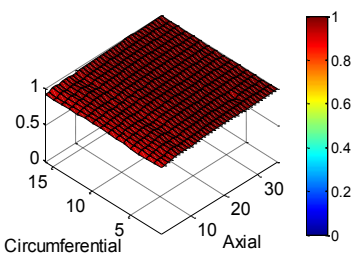


Case 2

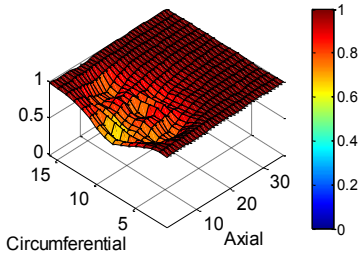


Case 3

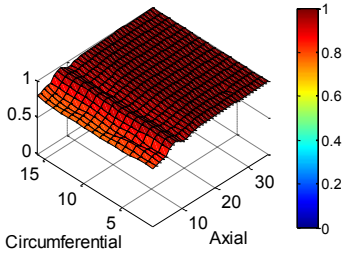
< Sum of the virtual coherence at 1 kHz >



Case 1
11 partial fields



Case 2
16 partial fields

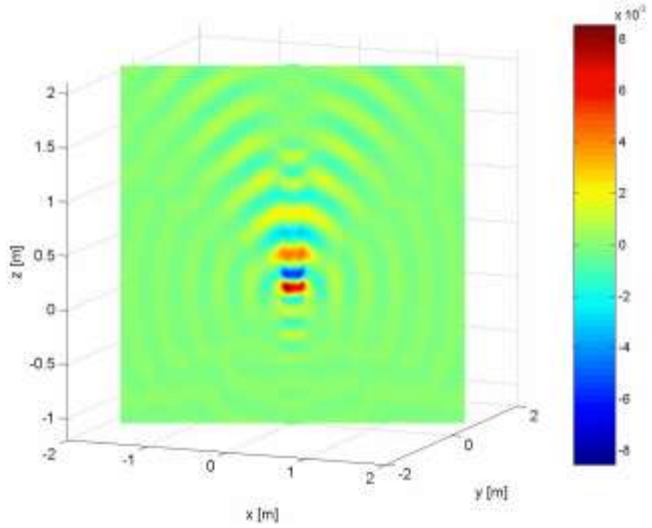


Case 3
18 partial fields

Partial Field (1)

- Dipole-like component (the 1st and 9th partial field)

The 1st partial field at 1kHz



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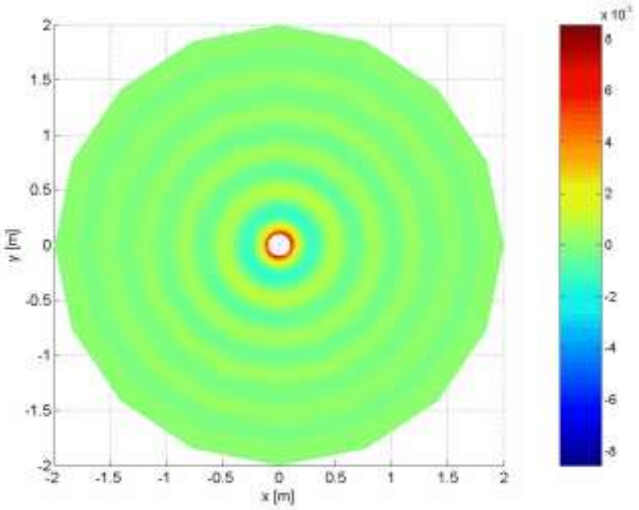
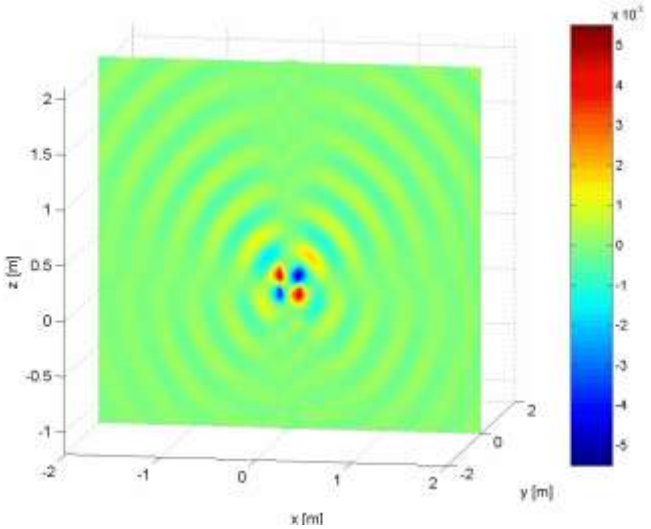


< top view >

Partial Field (2)

- Quadrupole-like component (the 2nd and 3rd partial field)

The 3rd partial field at 1kHz



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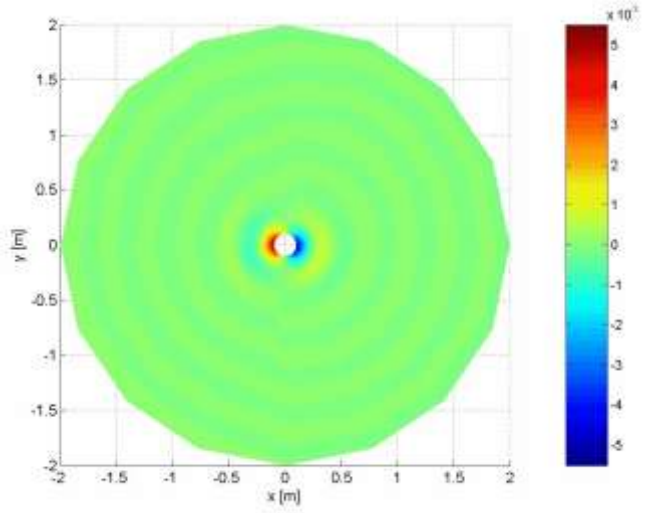
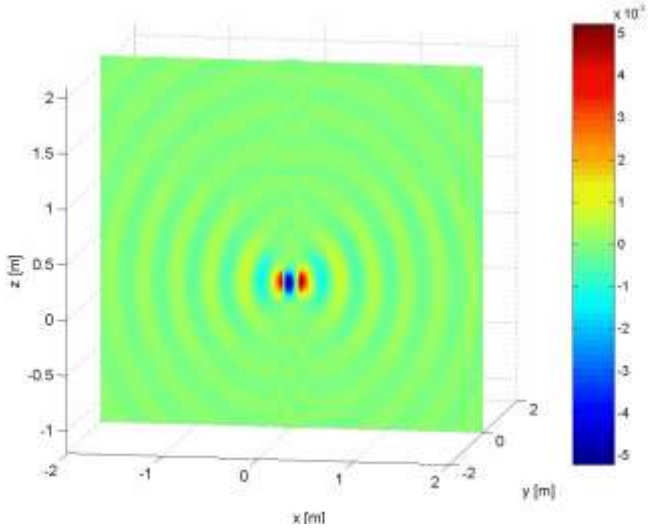


< top view >

Partial Field (3)

- Quadrupole-like component (the 4th and 5th partial field)

The 4th partial field at 1kHz



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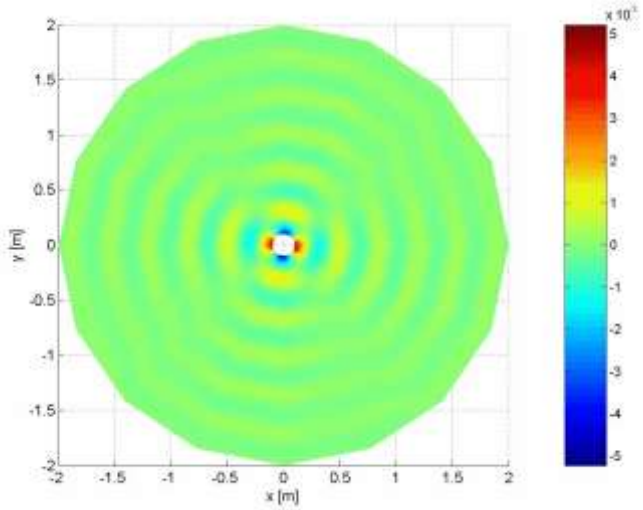
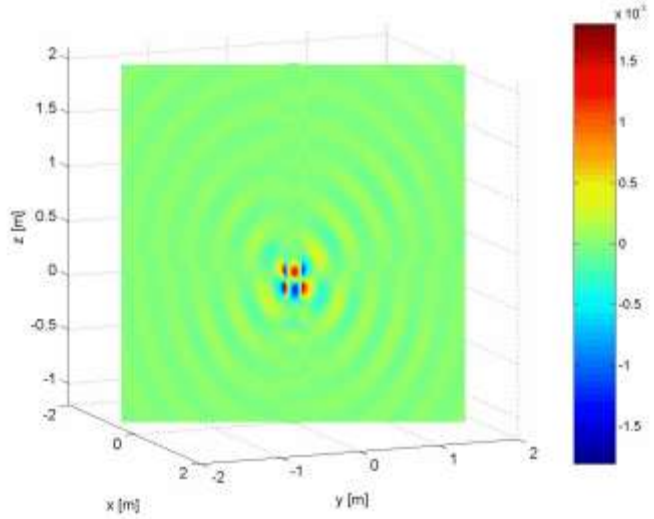


< top view >

Partial Field (4)

- Octupole-like component (the 10th and 11th partial field)

The 10th partial field at 1kHz



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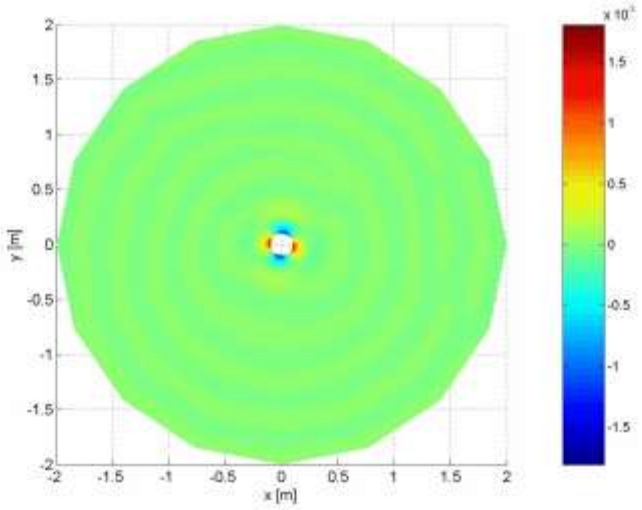

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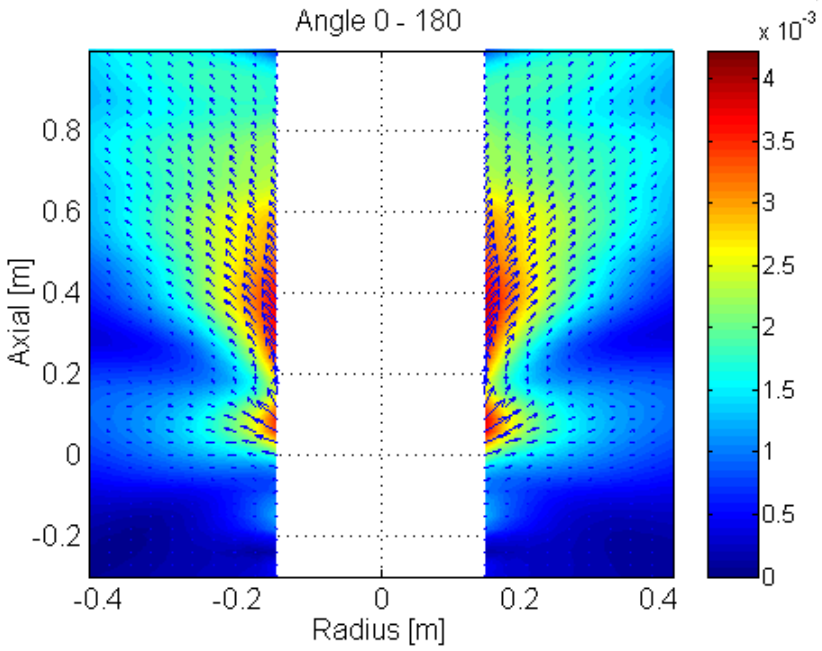
Acoustic Intensity (1)

- Dipole-like component (the 1st partial field)



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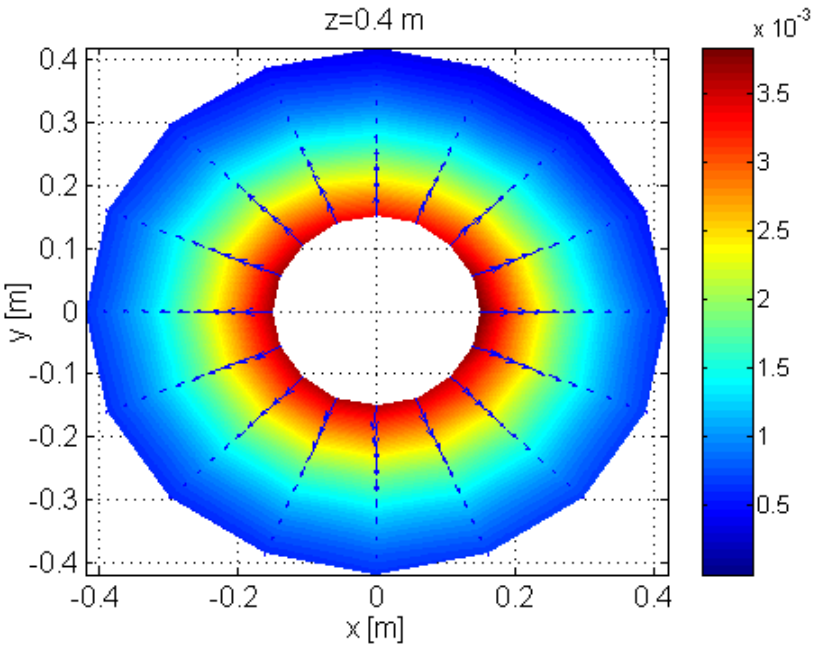

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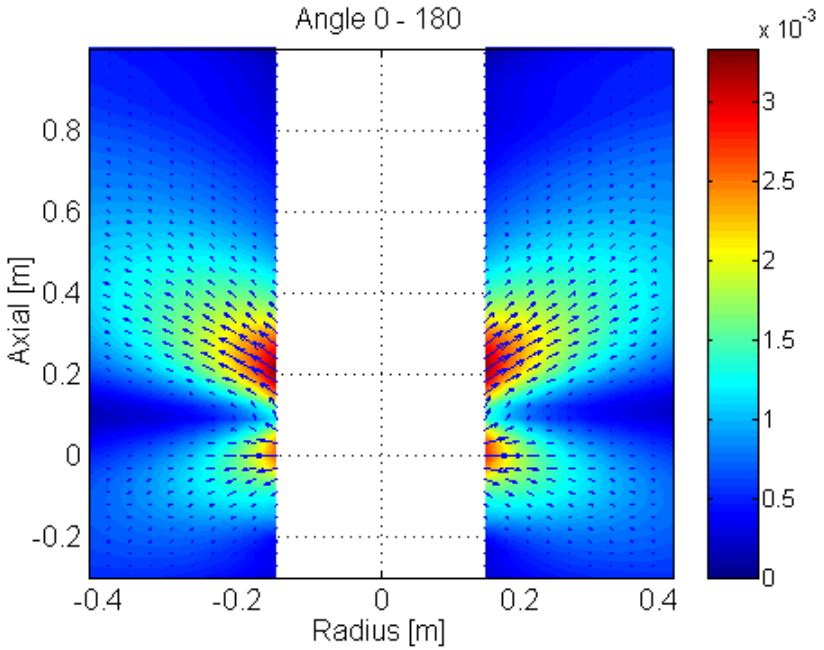
Acoustic Intensity (2)

- Quadrupole-like component (the 2nd partial field)



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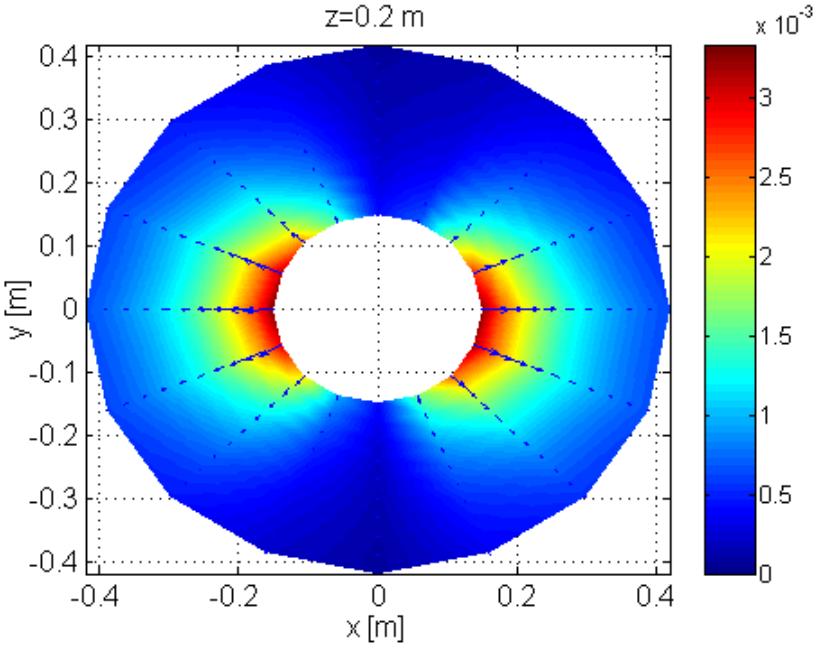
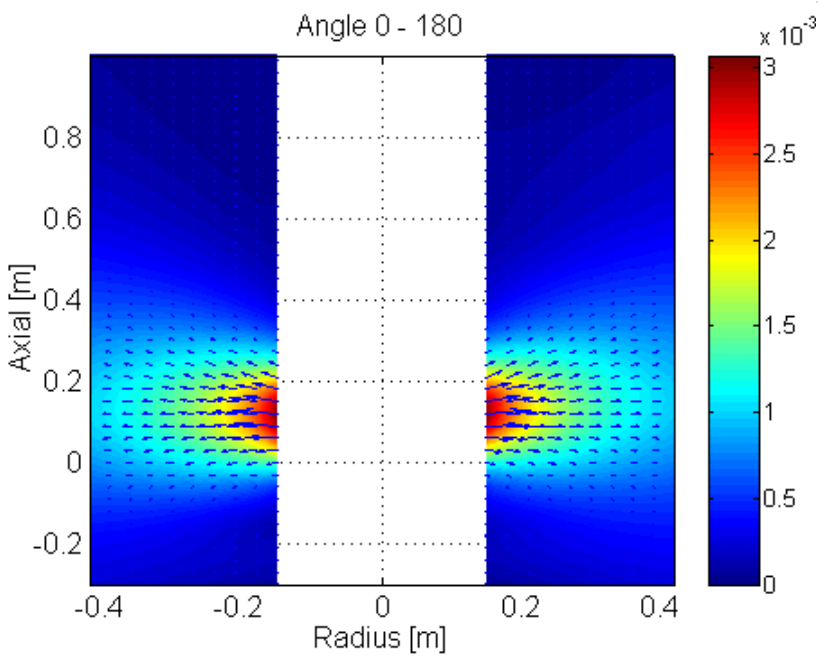


< top view >

Acoustic Intensity (3)

- Quadrupole-like component (the 4th partial field)



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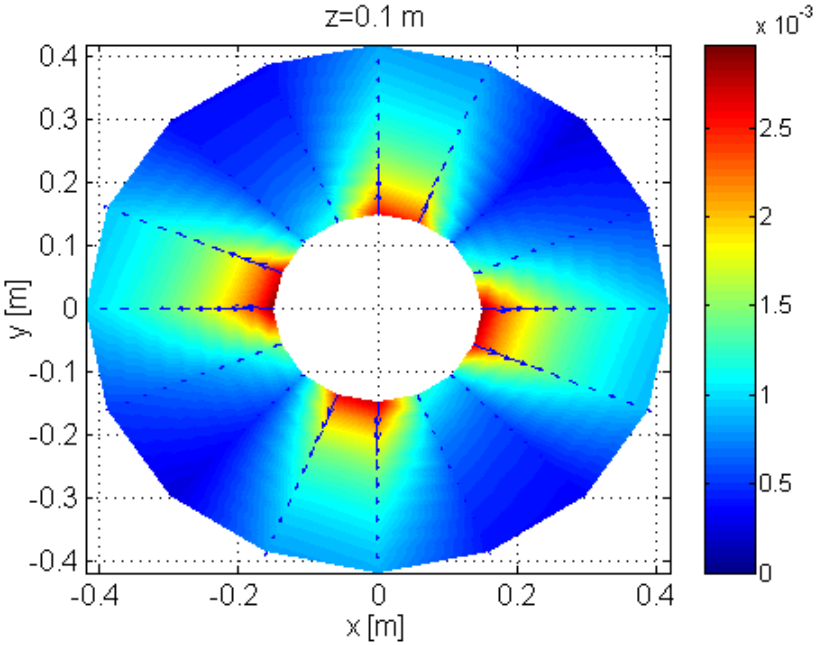
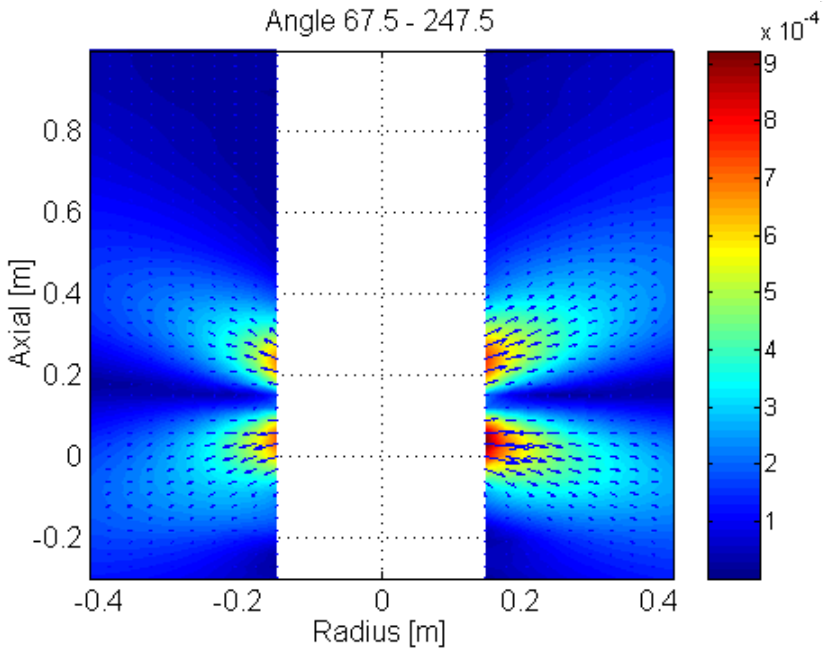


< top view >

Acoustic Intensity (4)

- Octupole-like component (the 10th partial field)



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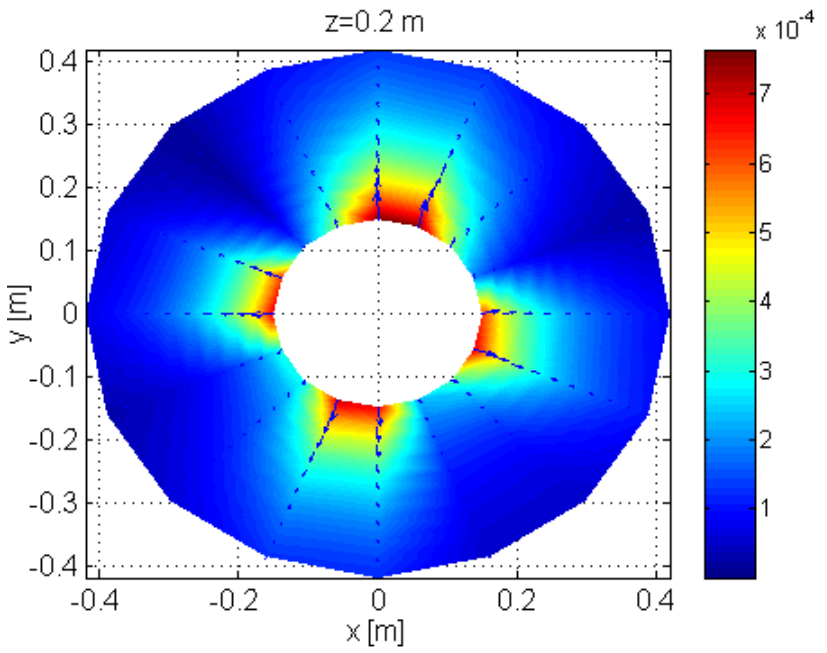
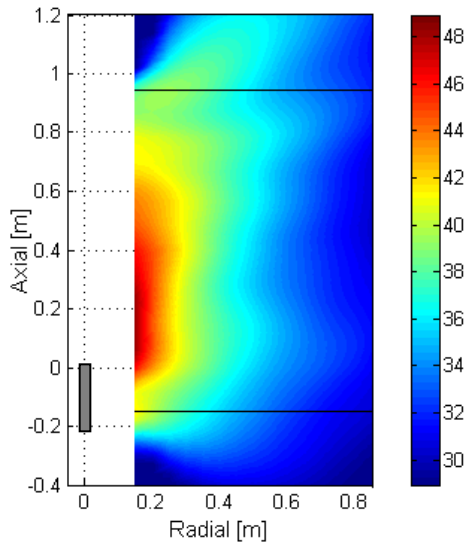


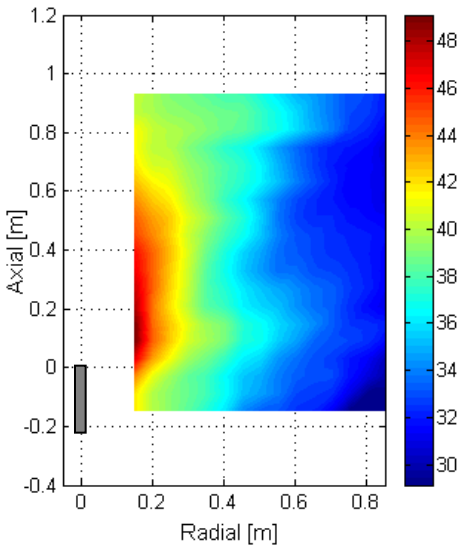
< top view >

Total Sound Field

- The sound field was constructed by using 11 partial fields obtained when 48 references were used
- The comparison with the directly measured sound field was made on the plane defined by $\phi = 225^{\circ}$



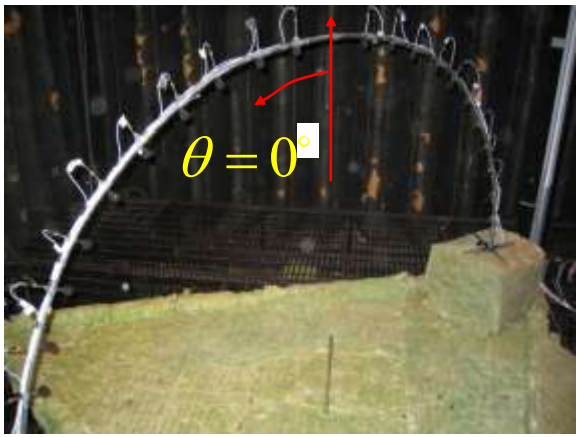
< reconstructed by NAH >



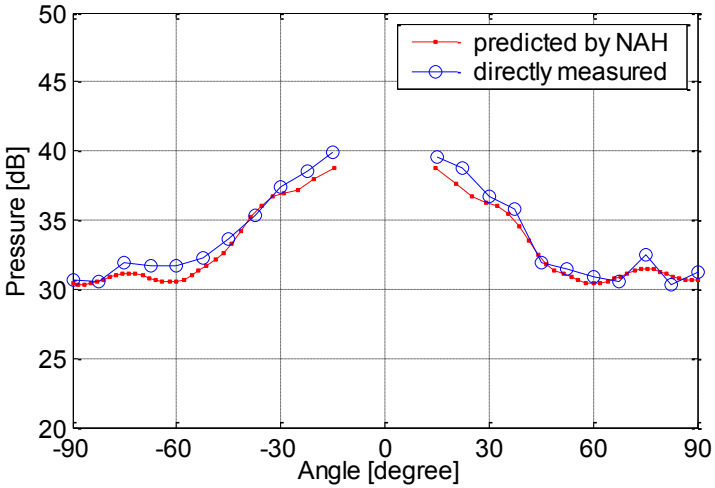
< directly measured >

Farfield Directivity

- The comparison with the directly measured directivity was made on an arc 96 cm from the jet exit



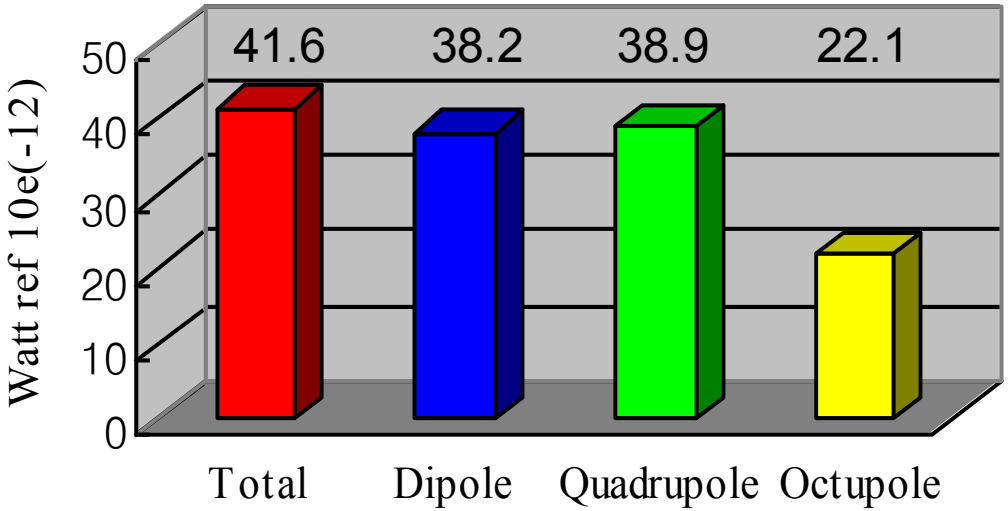
< measurement array >



< pressure at r = 96 cm >

Sound Power

- Dipole-like: the 1st and 9th partial fields
- Quadrupole-like: partial fields from the 2nd to 8th
- Octupole-like: the 10th and 11th



Dipole- and quadrupole-like components are the main contributors to the sound radiation

Summary and Conclusion

- Cylindrical NAH procedure was applied to the visualization of the sound field radiated by a subsonic jet
- Results reconstructed by using NAH were compared with directly measured results, and good agreement was found
- Strategy for reference array was described and its effect was demonstrated
- It was found that the sound field generated by the turbulent jet was naturally decomposed into dipole-, quadrupole-, and octupole-like components
- Future works
  - Establish whether the partial fields correspond to physically meaningful source mechanisms
  - A large scale implementation is scheduled at NASA Langley