Holographic Visualization of a Subsonic Jet

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Holographic Visualization of a Subsonic Jet

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April 23 2004
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
Scan-based, Cross-Spectral Measurement

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

Partial Field Decomposition

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

Data Extrapolation (Cylindrical Patch NAH)

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

Cylindrical NAH

- 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
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
11 partial fields

Case 2
16 partial fields

Case 3
18 partial fields

< Sum of the virtual coherence at 1 kHz >
Partial Field (1)

- Dipole-like component (the 1\textsuperscript{st} and 9\textsuperscript{th} partial field)

The 1\textsuperscript{st} partial field at 1kHz

< side view >

< top view >
Partial Field (2)

- Quadrupole-like component (the 2\textsuperscript{nd} and 3\textsuperscript{rd} partial field)

The 3\textsuperscript{rd} partial field at 1kHz
Partial Field (3)

- Quadrupole-like component (the 4\textsuperscript{th} and 5\textsuperscript{th} partial field)

The 4\textsuperscript{th} partial field at 1kHz

< side view >  < top view >
Partial Field (4)

• Octupole-like component (the 10\textsuperscript{th} and 11\textsuperscript{th} partial field)

The 10\textsuperscript{th} partial field at 1kHz
**Acoustic Intensity (1)**

- Dipole-like component (the 1\textsuperscript{st} partial field)
**Acoustic Intensity (2)**

- Quadrupole-like component (the 2\textsuperscript{nd} partial field)
Acoustic Intensity (3)

• Quadrupole-like component (the 4th partial field)
Acoustic Intensity (4)

- Octupole-like component (the 10\textsuperscript{th} partial 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 $\phi = 225^\circ$. 

![Total Sound Field](image)
The comparison with the directly measured directivity was made on an arc 96 cm from the jet exit.
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.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Dipole</th>
<th>Quadrupole</th>
<th>Octupole</th>
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</thead>
<tbody>
<tr>
<td>Watt ref 10e(-12)</td>
<td>41.6</td>
<td>38.2</td>
<td>38.9</td>
<td>22.1</td>
</tr>
</tbody>
</table>
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