Background Acoustics Levels in the 9x15 Wind Tunnel and Linear Array Testing

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Funded by NASA projects: Environmentally Responsible Aviation and Subsonic Fixed Wing
Comparison with 2005 Data

Roll-off due to Filter

Electronic Noise

Empty Tunnel M=0.10

Empty Tunnel M=0.20

2005

2011
Comparison of Background Noise

M=0.10

M=0.20

Empty Tunnel (2011)
ORPR Tare (2009)
ORPR Windmill Approach (2010)
Aerodynamic Microphone Forebody

Bullet Nose Tests, M=0.20

Frequency, Hz
PSD, dB

B&K
G.R.A.S
F.I.T.E
Phased Array Measurements:
Noise from upstream of test section
Conclusions on 9x15 Noise Level

• Levels very similar to 1995
• M=0.20 about 15 dB higher than M=0.10
• High frequency tone due to AMF being investigated
• Phased array results suggest upstream noise sources
- 16 Locations at Equal Angles from Sound Source
- 20x Acoustic Test Efficiency
- Simultaneous Sampling
- Fixed Locations
### Linear Array Modification

<table>
<thead>
<tr>
<th>Problem:</th>
<th>Solution:</th>
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<tbody>
<tr>
<td>The flush mounted microphones are unable to distinguish between unsteady hydrodynamic pressures (casually referred to as “flow noise”) and the acoustic pressures of interest.</td>
<td>Recess the microphone slightly and install a fine wire mesh over the sensing area to reduce the influence of the external flow while largely transmitting the acoustics.</td>
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The cross-correlation technique helps, but the signal to noise ratio in the current experiment is quite low at some frequencies.

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**Diagram**

- **M = 0.2 Flow**
- **Noise generating experiment**
- **Acoustic Pressure**
- **Hydrodynamic Pressure**
- **Thin wire mesh**
- **Solid mounting plate**
- **Flush Mounted Microphone**
- **Recessed Microphone**
Additional Calibrations Required

- Additional calibrations are required due to surface reflections, impedance changes due to cavity opening, attenuation due to screen, and reflections inside the cavity.

- The incoming sound wave (want to measure) interacts with the conical cavity, generating reflections and changes in impedance.

- Reflections due to the cavity opening and the screen contribute to the overall signal attenuation and distortion.
Tunnel On, Source Off

- Screen attenuates hydrodynamic pressure on microphone by 5-15 dB between 1k and 50k Hz
Improvement in Coherence
Max Speaker Level

![Graphs showing Mean Squared Coherence for Flush Mount and Recessed Mount with different values of Mean Squared Coherence (M). The graphs compare the coherence levels at various frequencies, with logarithmic scales for both axes.]
Signal Processing Methods

• To reject signal that is incoherent between microphones:
  – Coherent spectra technique
    \[ G_{11} \frac{\gamma_{12} \gamma_{13}}{\gamma_{23}} \]
  – Auto-spectra of spatial average
    \[ G_{\langle 123 \rangle} \]
  – Magnitude of Cross-Spectra
    \[ \frac{|G_{12}| + |G_{13}| + |G_{23}|}{3} \]

• Speaker Noise was found to be dependent on Tunnel Speed
Result should scale as $V_{rms}^2$
M=0.10, Flush Mount

![Graph showing PSD vs Frequency for Flow Noise at M=0.10, Flush Mount]

- **PSD**
- **Frequency, Hz**
- **Flow Noise**
M=0.10, Flush Mount

![Graph showing PSD vs Frequency for Flow Noise and Flow Noise + Speaker](image-url)
M=0.10, Flush Mount

![Graph showing PSD vs Frequency for Flow Noise, Flow Noise + Speaker, and Expected Result Based on Louder Source. The graph illustrates the comparison of different noise levels across various frequency ranges.]
M = 0.10, Flush, Signal Processing

PSD

ASD Due to Flow
Raw ASD
Expected Based on Louder Source
Error > 1dB
Good Spectra

Reject 14.3 dB of Flow Noise
M=0.10, Recessed, Signal Processing

Reject 8.1 dB of Flow Noise
M=0.16, Flush, Signal Processing

PSD
ASD Due to Flow
Raw ASD
Expected Based on Louder Source
Error > 1dB
Good Spectra

Frequency, Hz

Log scale graph showing various ASD measurements and expected values.
M=0.16, Recessed, Signal Processing

Reject 7.0 dB of Flow Noise

ASD Due to Flow
Raw ASD
Expected Based on Louder Source
Error > 1dB
Good Spectra

Frequency, Hz

PSD

10
2
10
3
10
4
10
2
10
3
10
4
10
5
10
6
10
7
10
8
Conclusions on Linear Array Modifications

• Huge potential for test efficiency improvements

• Recessed mounting and screen reduces hydrodynamic pressures by 5-15 dB, but adds more calibration complexity

• Signal processing can reject perhaps 10 dB of hydrodynamic pressures
Traversing Microphone, B&K AMF

![Graph showing the relationship between frequency and PSD for B&K AMF with different values of M (0.20, 0.18, 0.15, 0.10). The graph plots frequency in Hz on the x-axis and PSD in dB on the y-axis. Each curve represents a different value of M, with M=0.20 in blue, M=0.18 in green, M=0.15 in red, and M=0.10 in cyan. The graph demonstrates how the PSD changes with varying M values across different frequency ranges.]
Traversing Microphone, FITE AMF

![Graph of FITE AMF with PSD, dB against Frequency, Hz for different values of M: M=0.20, M=0.18, M=0.15, M=0.10]
Traversing Microphone, GRAS AMF

![Graph showing TRAVERSSING MICROPHONE, GRAS AMF with various frequency bands and PSD (Power Spectral Density) values. The graph illustrates the response of different microphone samples across a range of frequencies, with lines indicating different microphone sensitivities (M). The x-axis represents frequency in Hz, and the y-axis represents PSD in dB. The graph shows distinct peaks and trends at various frequencies for different microphone sensitivities.]
The background noise level in the 9x15 foot wind tunnel at NASA Glenn has been documented, and the results compare favorably with historical measurements. A study of recessed microphone mounting techniques was also conducted, and a recessed cavity with a micronic wire mesh screen reduces hydrodynamic noise by around 10 dB. A three-microphone signal processing technique can provide additional benefit, rejecting up to 15 dB of noise contamination at some frequencies. The screen and cavity system offers considerable benefit to test efficiency, although there are additional calibration requirements.