Aeroacoustics of Three-Stream Jets

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Results from acoustic measurements of noise radiated from a heated, three-stream, co-annular exhaust system operated at subsonic conditions are presented. The experiments were conducted for a range of core, bypass, and tertiary stream temperatures and pressures. The nozzle system had a fan-to-core area ratio of 2.92 and a tertiary-to-core area ratio of 0.96. The impact of introducing a third stream on the radiated noise for third-stream velocities below that of the bypass stream was to reduce high frequency noise levels at broadside and peak jet-noise angles. Mid-frequency noise radiation at aft observation angles was impacted by the conditions of the third stream. The core velocity had the greatest impact on peak noise levels and the bypass-to-core mass flow ratio had a slight impact on levels in the peak jet-noise direction. The third-stream jet conditions had no impact on peak noise levels. Introduction of a third jet stream in the presence of a simulated forward-flight stream limits the impact of the third stream on radiated noise. For equivalent ideal thrust conditions, two-stream and three-stream jets can produce similar acoustic spectra although high-frequency noise levels tend to be lower for the three-stream jet.

Fundamental Aeronautics Program

Supersonics Project

Aeroacoustics of Three-Stream Jets

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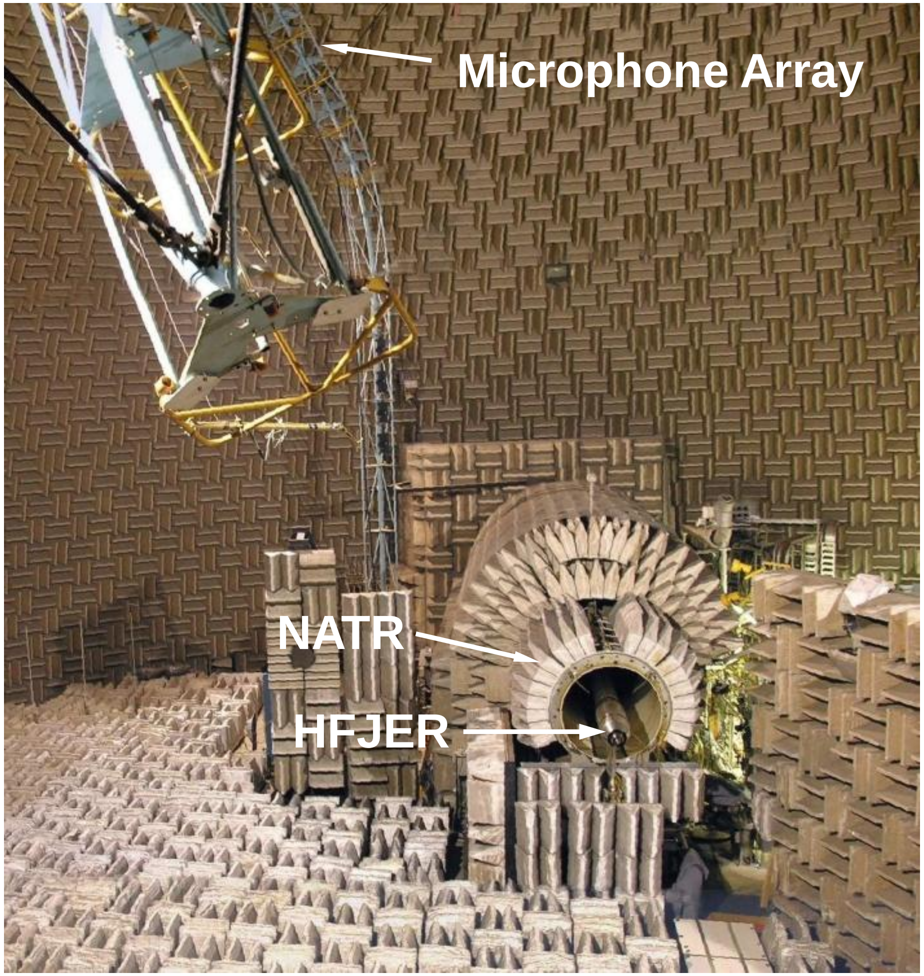
Purpose of Study

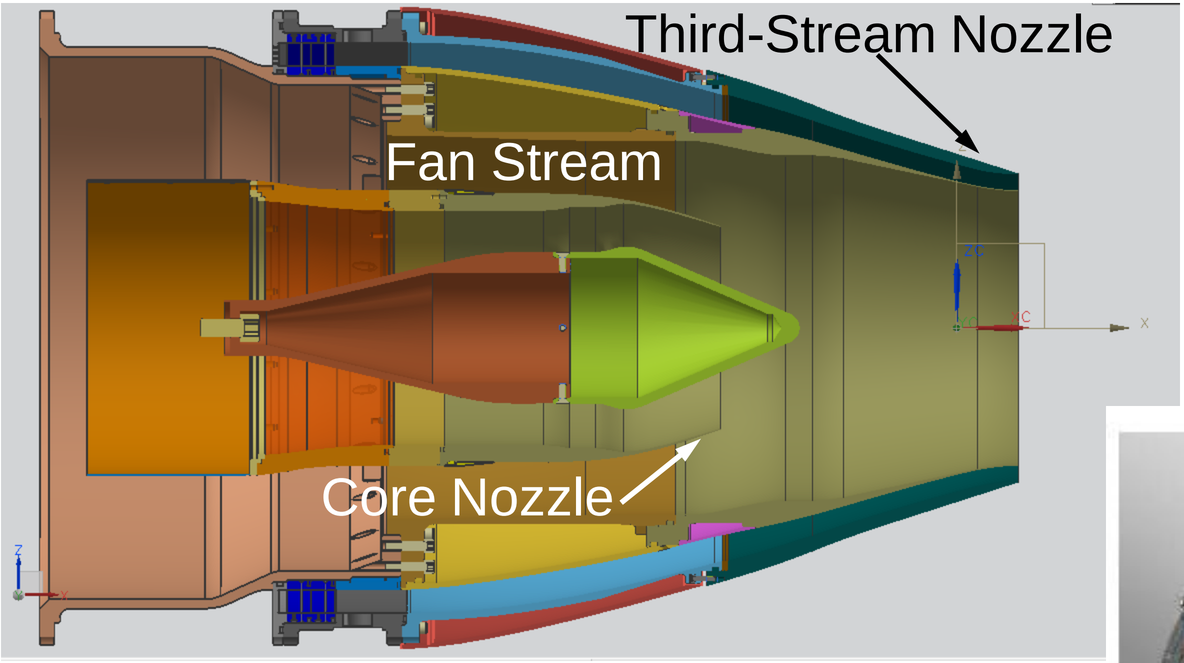
- Understand noise reduction potential of a third stream that may be available in future engine architectures
- Most straight-forward use of third stream is as an additional bypass stream
- Need to predict noise from three-stream jets – current semi-empirical tools address single and dual stream jets
- Results of co-annular studies may guide other three-stream concepts (ejector)

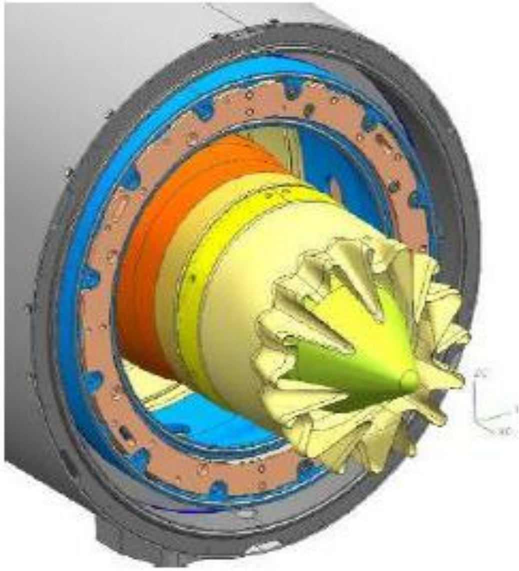
Aero-Acoustic Propulsion Laboratory (AAPL)



- AAPL
  - 66 foot geodesic dome
  - 45 foot microphone arc – 24 elements
- Nozzle Acoustic Test Rig (NATR)
  - 53 inch simulated flight stream
  - Maximum Mach number = 0.35
- High Flow Jet Exit Rig (HFJER)
  - 3-stream capability (3^{rd} stream new)
  - Independent pressure control on all streams
  - Independent temperature control on fan and core streams
  - Fan and third-stream temperatures the same

Model Hardware





- Core stream nozzles
  - Round
  - Lobed mixer
  - 4.8 inch exit diameter
- Fan-to-core area ratio = 2.92 (fixed)
- Tertiary-to-core area ratio = 0.92 (fixed)

Cycle Points

NPR_c	NPR_b	NPR_t	NTR_c	$M_{fj} = 0$	$M_{fj} = 0.2$	$M_{fj} = 0.3$
1.5	1.5	1.0 - 1.5	2.8	✓		
1.6	1.6	1.0 - 1.6	2.8	✓		
1.7	1.7	1.0 - 1.7	2.8	✓		
1.8	1.8	1.0 - 1.8	2.8	✓		
1.5	1.5	1.0 - 1.5	3.2	✓		
1.5	1.4	1.0 - 1.4	3.2	✓		
1.5	1.6	1.0 - 1.6	3.2	✓		
1.6	1.5	1.0 - 1.5	3.2	✓		✓
1.6	1.6	1.0 - 1.6	3.2	✓		✓
1.6	1.7	1.0 - 1.7	3.2	✓		✓
1.7	1.6	1.0 - 1.6	3.2	✓	✓	✓
1.7	1.7	1.0 - 1.7	3.2	✓	✓	✓
1.7	1.8	1.0 - 1.8	3.2	✓	✓	✓
1.8	1.7	1.0 - 1.7	3.2	✓		✓
1.8	1.8	1.0 - 1.8	3.2	✓	✓	✓

$NTR_b = 1.25$

Baseline Experiments

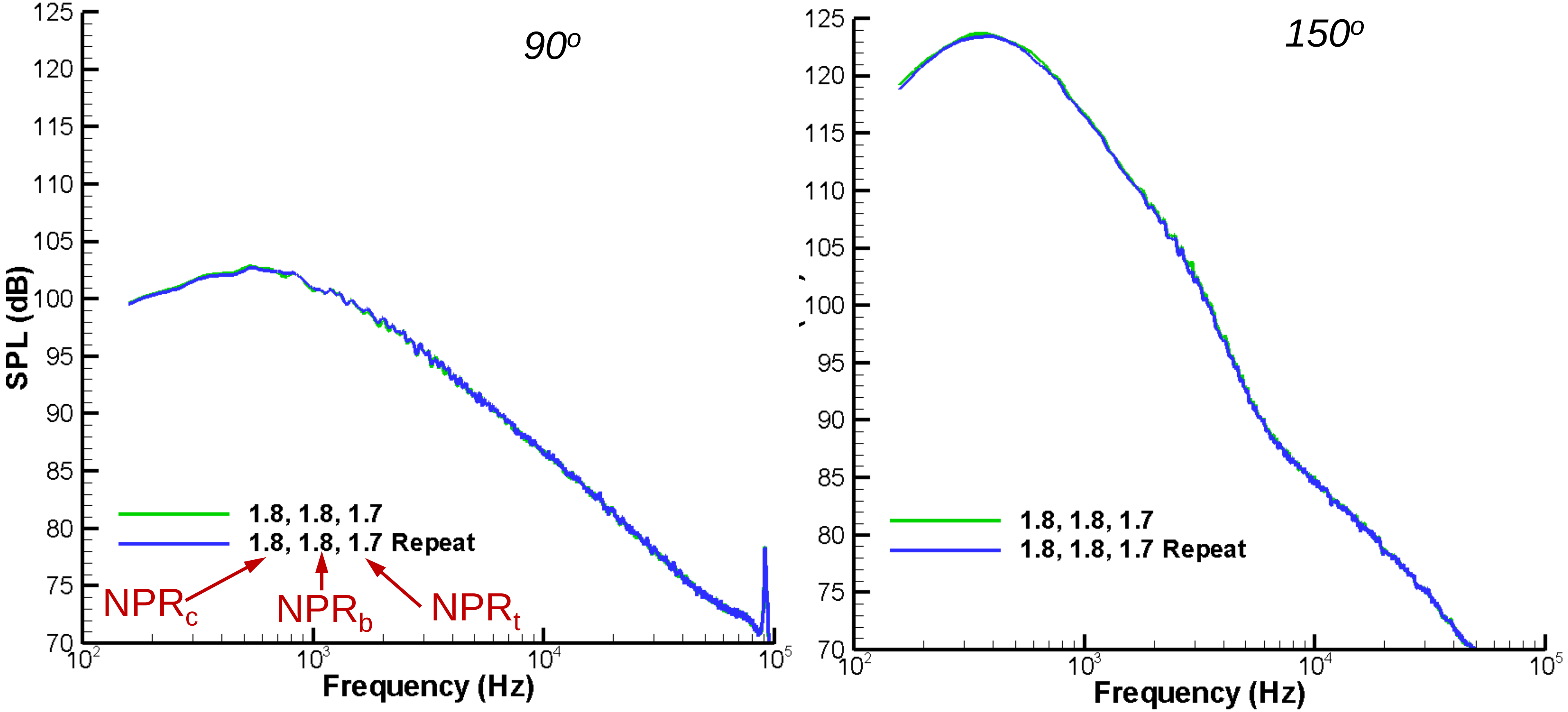
- M_{fj} – free jet (simulated flight stream) Mach number
- NPR – nozzle pressure ratio
- NTR – nozzle temperature ratio

Subsonic Exhausts

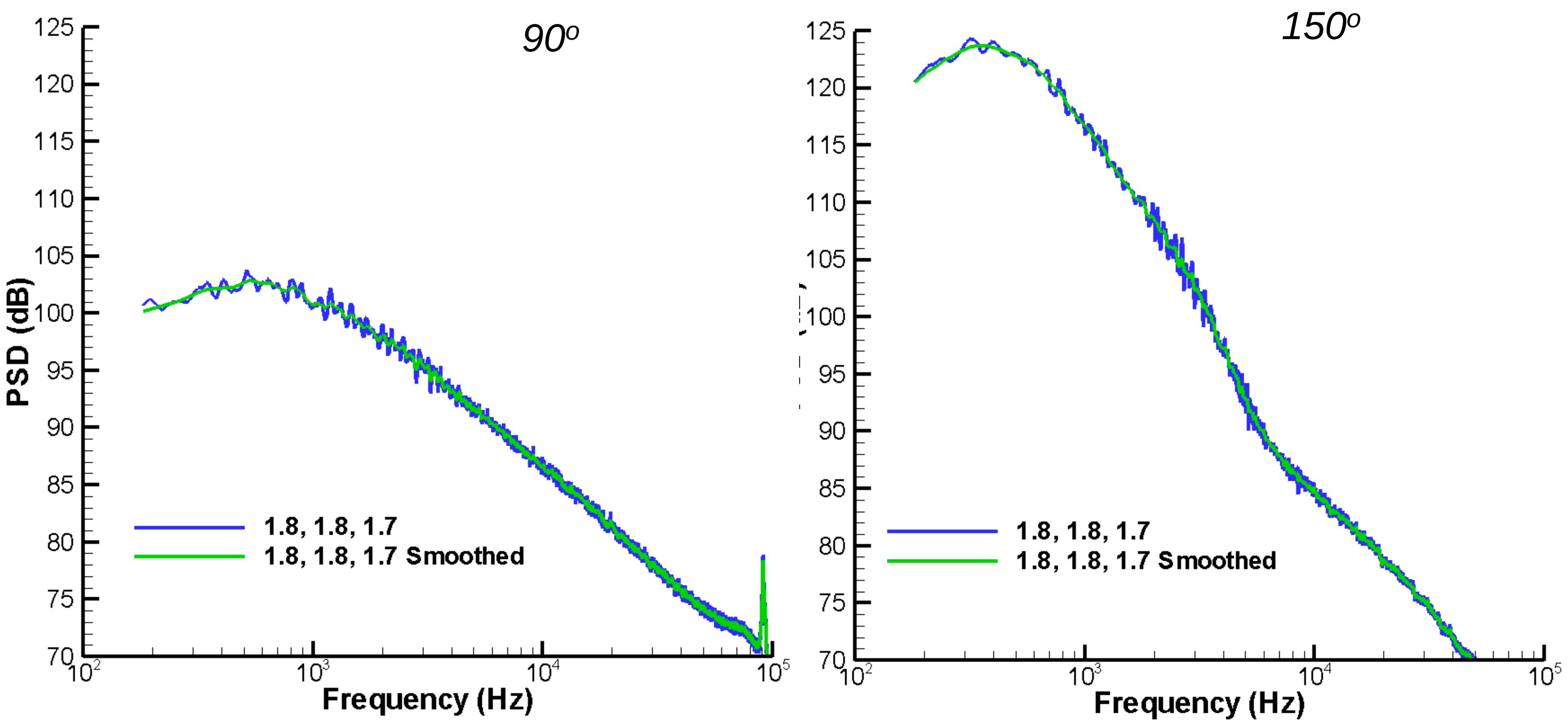
Data Analysis

- Baseline Experiments
  - $NPR_c = NPR_f = 1.8$, $1 \leq NPR_t \leq 1.8$
  - $NTR_c = 3.2$
  - $M_{fj} = 0$
- Reduced velocity of all streams
- Changed velocity ratio (V_b/V_c)
- Impact of velocity and bypass ratio
- Impact of simulated flight stream
- Impact of partially mixed flow
- Comparison on equal thrust basis

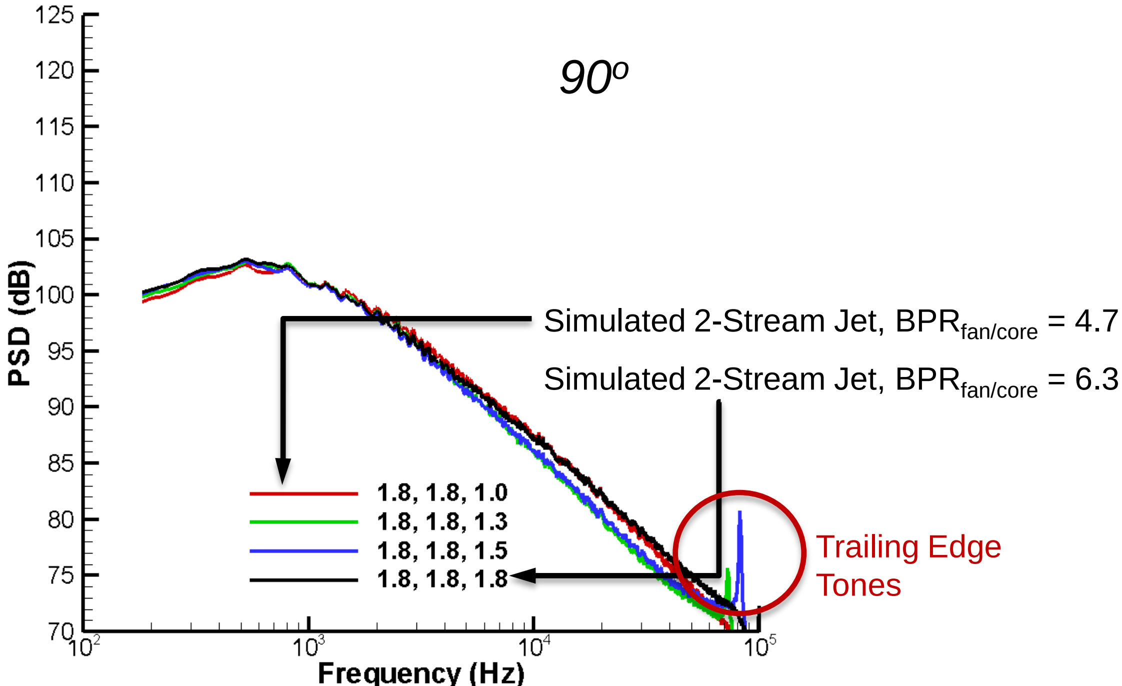
Repeat Acquisitions

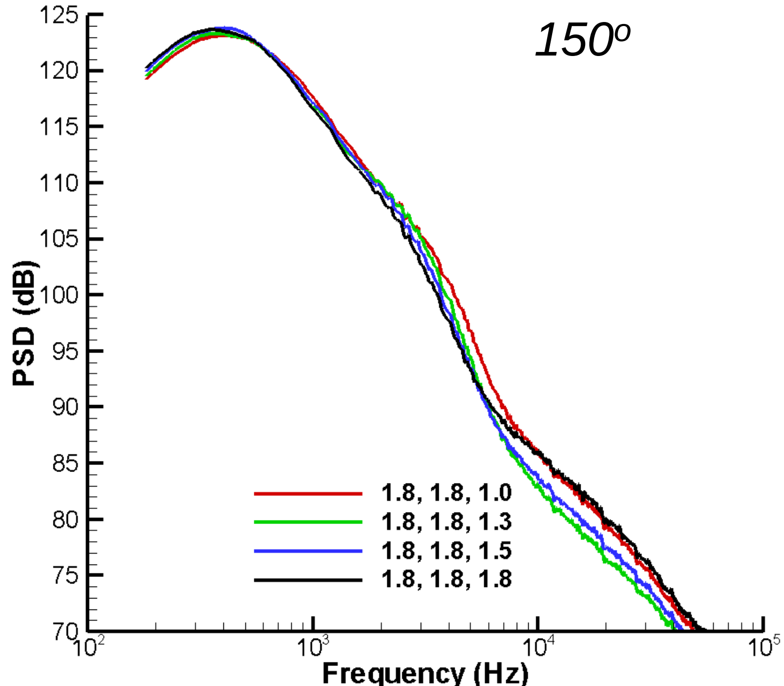


Smoothed Data



Baseline Results

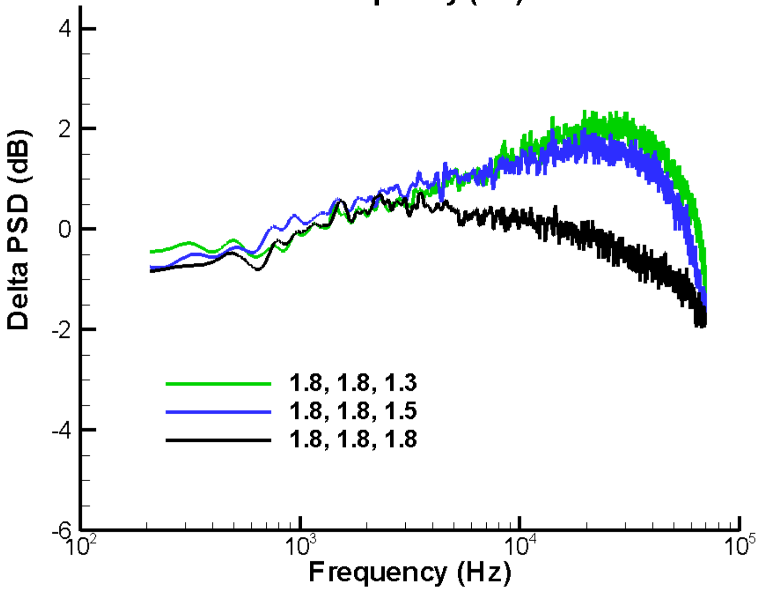


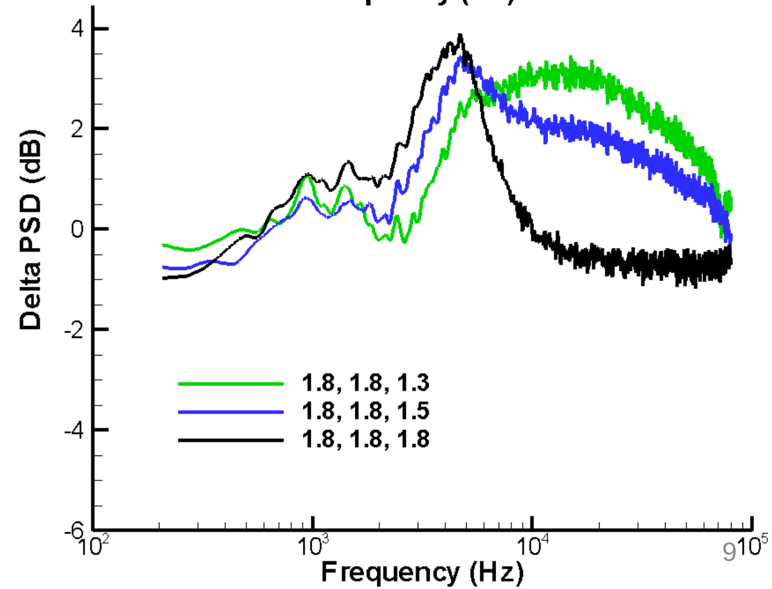


$NTR_c = 3.2$

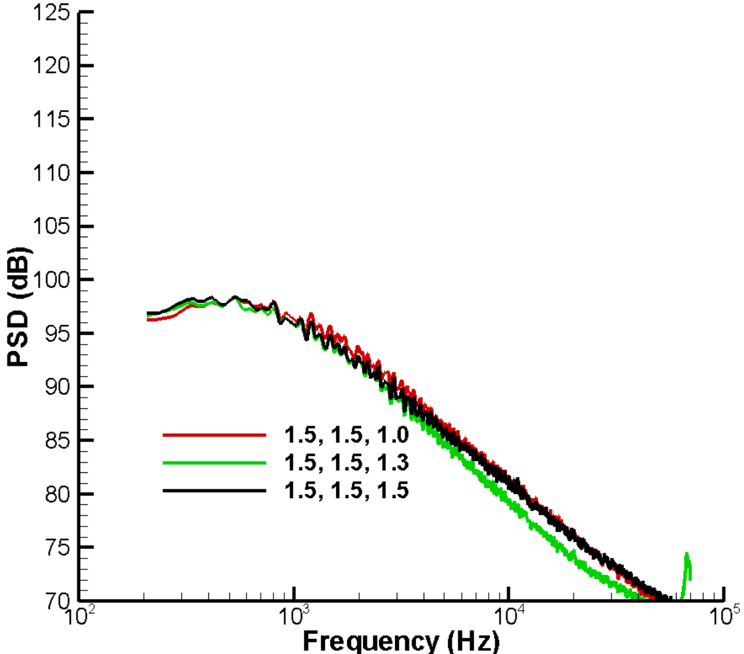
$V_b/V_c = 0.62$

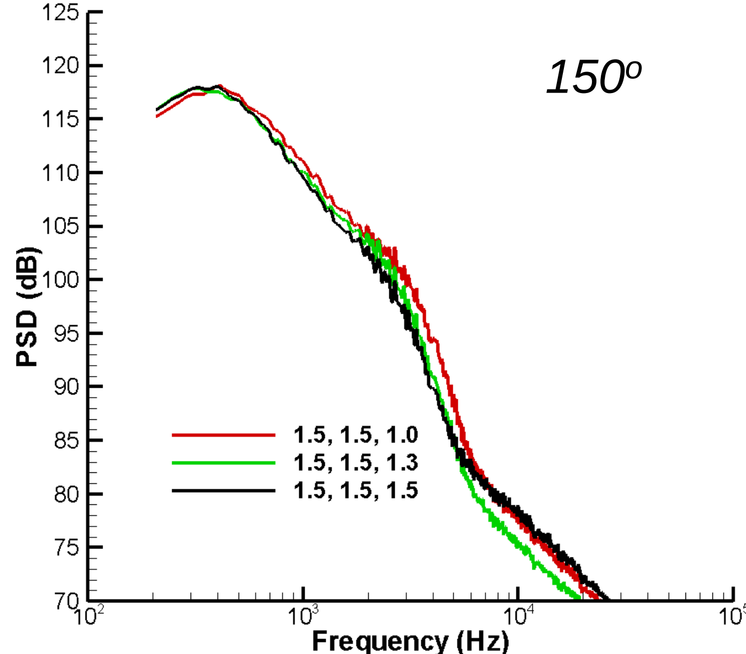
$W_b/W_c = 4.7$





Reduced Pressure/Velocity

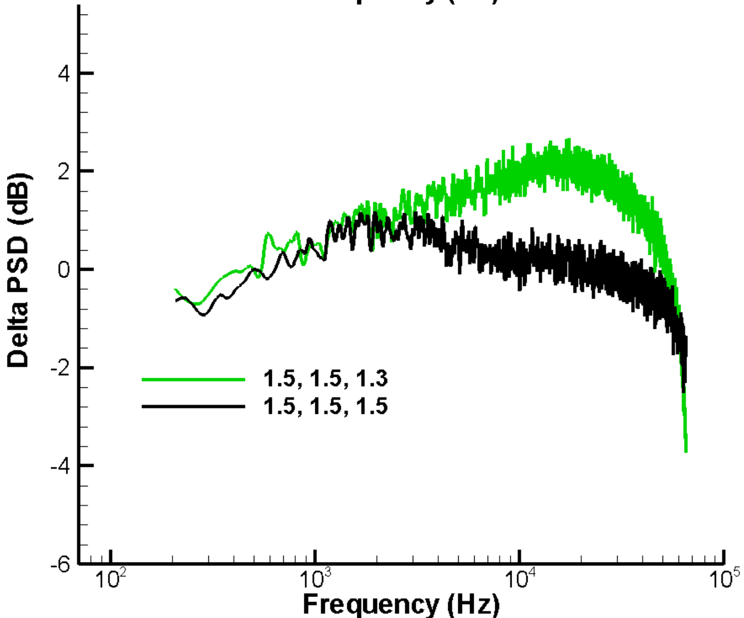


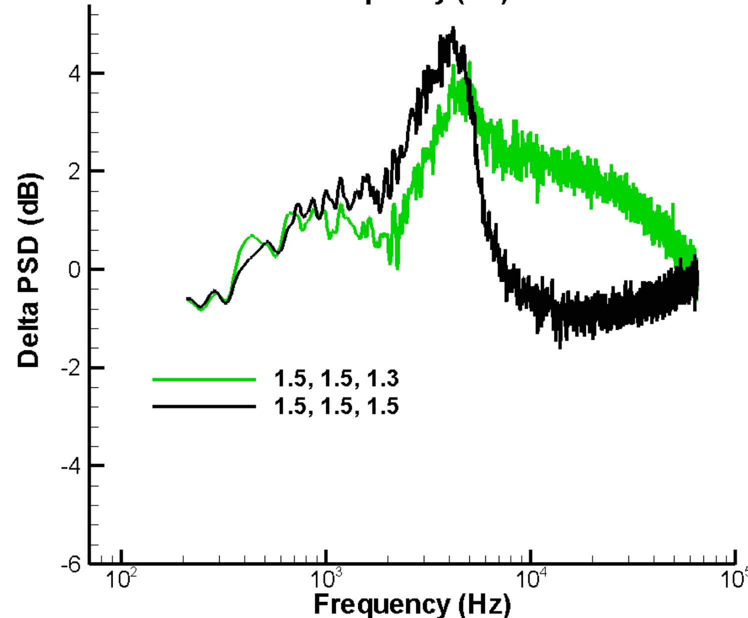


$NTR_c = 3.2$

$V_b/V_c = 0.62$

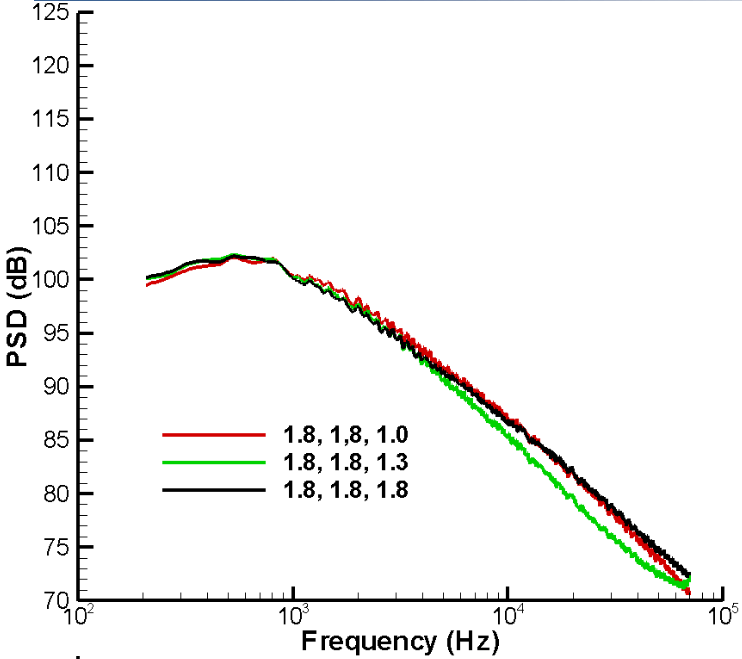
$W_b/W_c = 4.6$

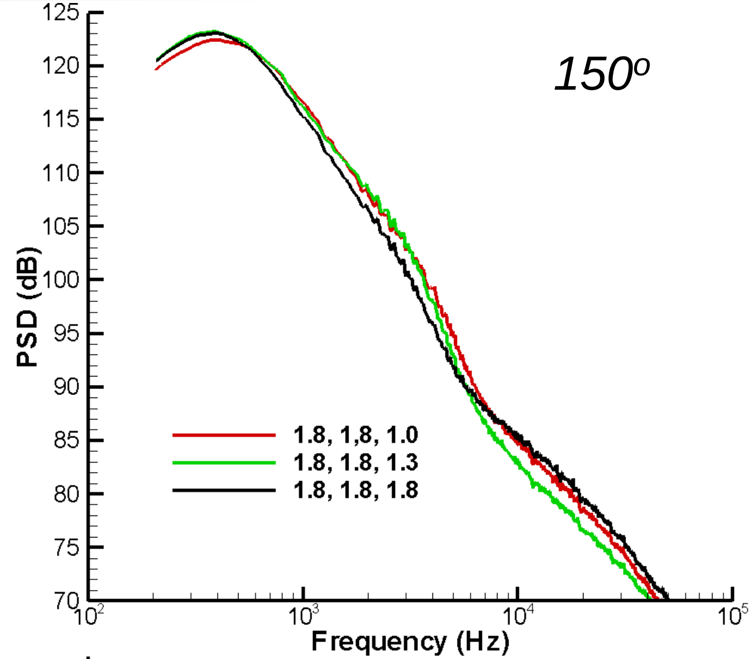


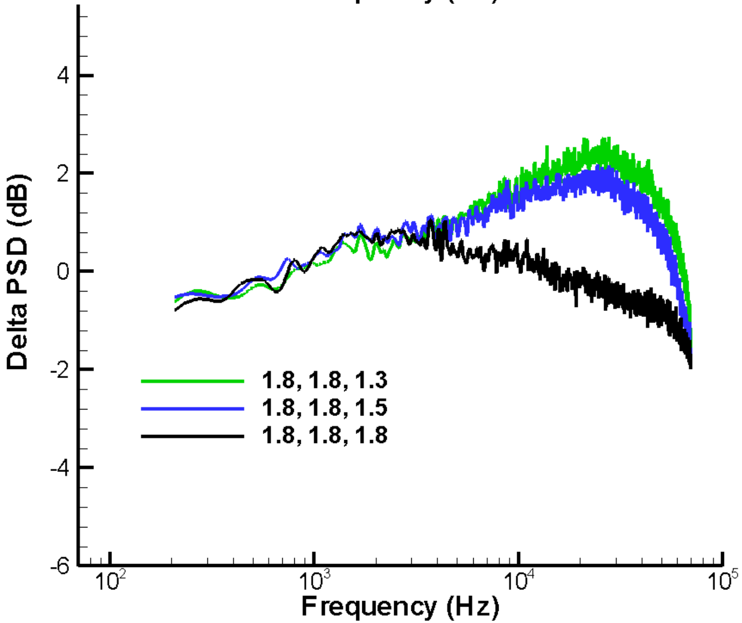


Increased Velocity Ratio (V_b/V_c)

90°



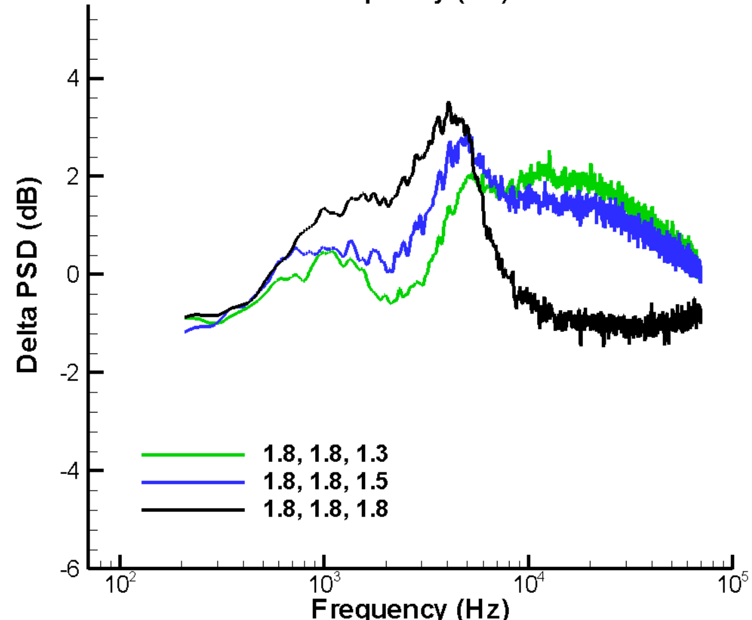




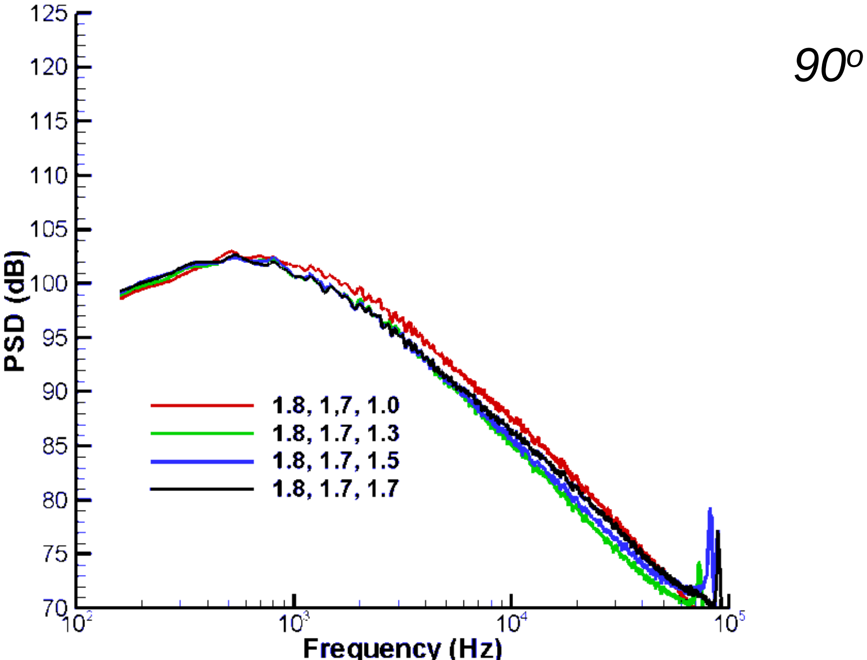
NTR_c = 2.8

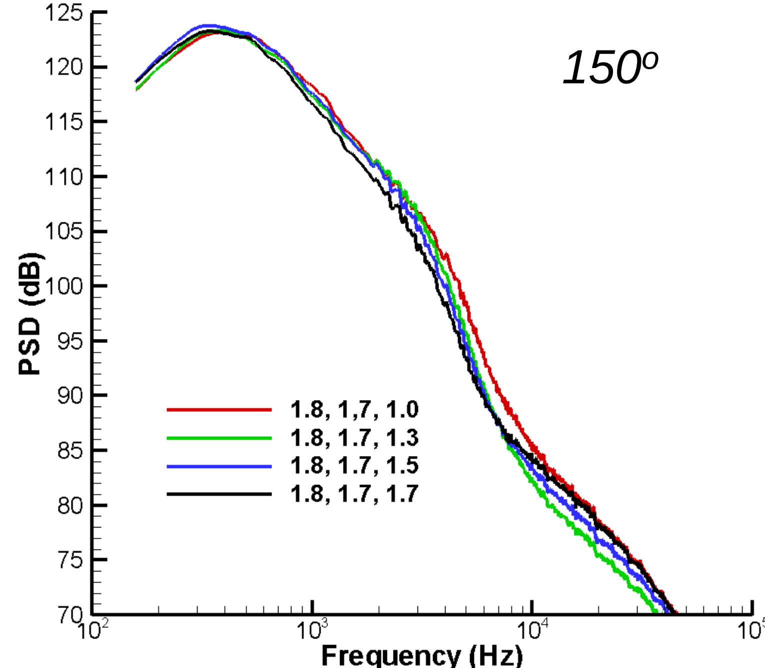
$V_b/V_c = 0.66$

$W_b/W_c = 4.3$



Reduced Velocity Ratio (V_b/V_c)

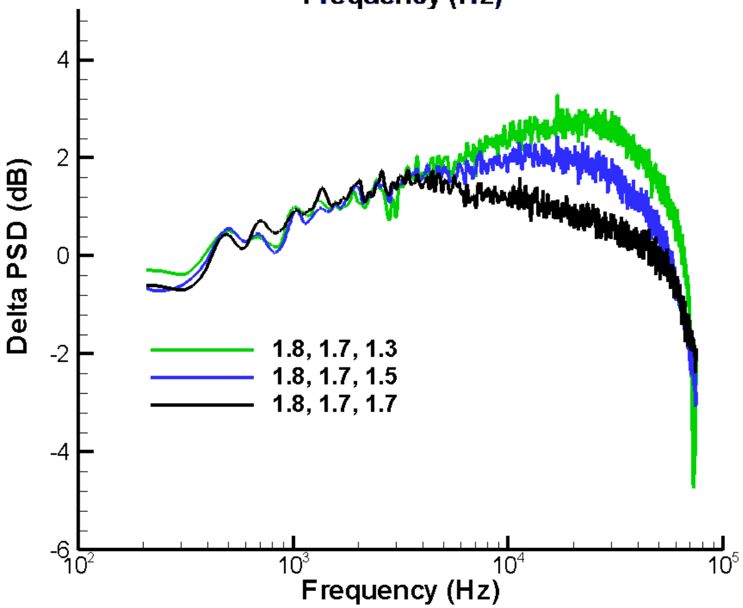


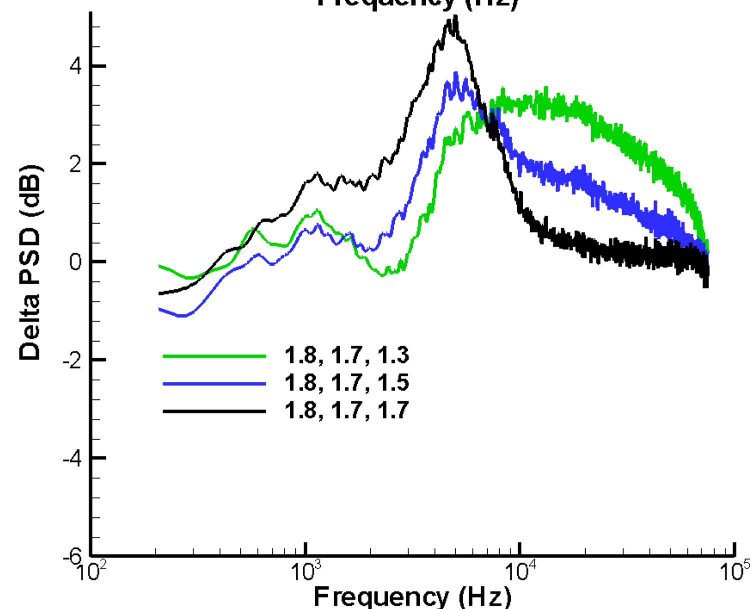


$NTR_c = 3.2$

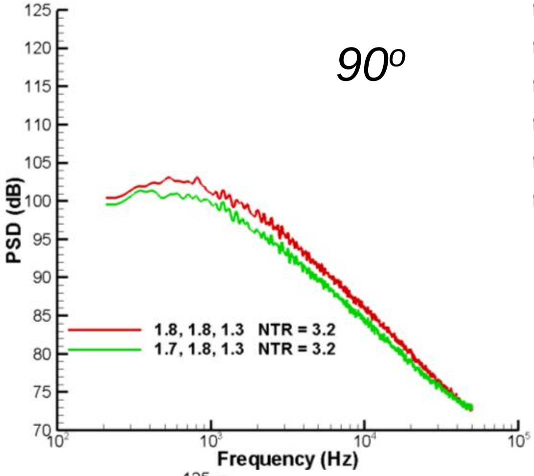
$V_b/V_c = 0.59$

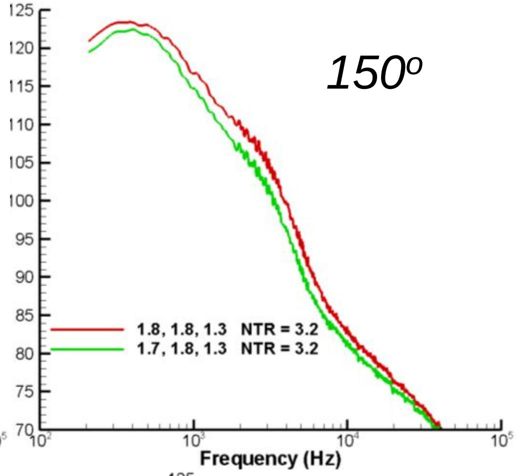
$W_b/W_c = 3.7$

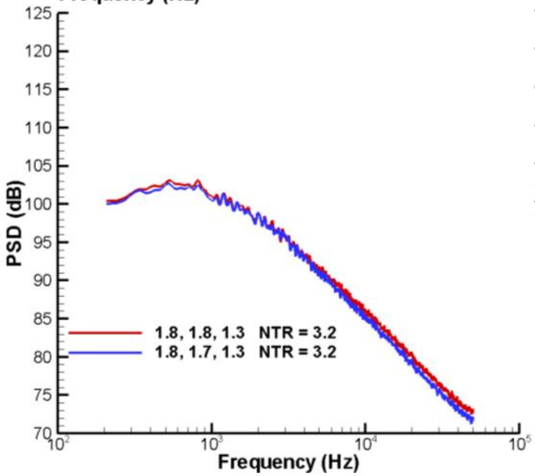


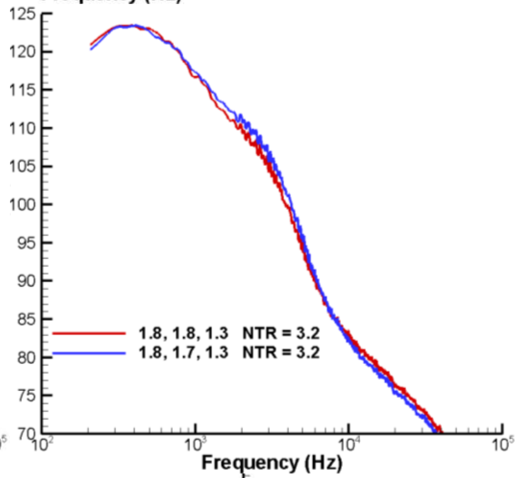


Impact of Velocity and Bypass Ratio

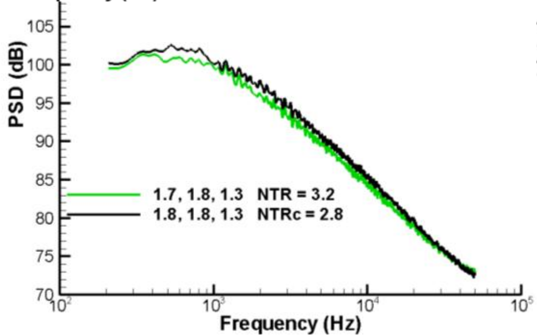


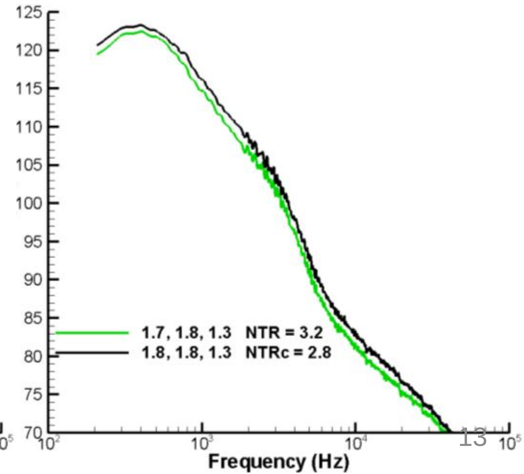




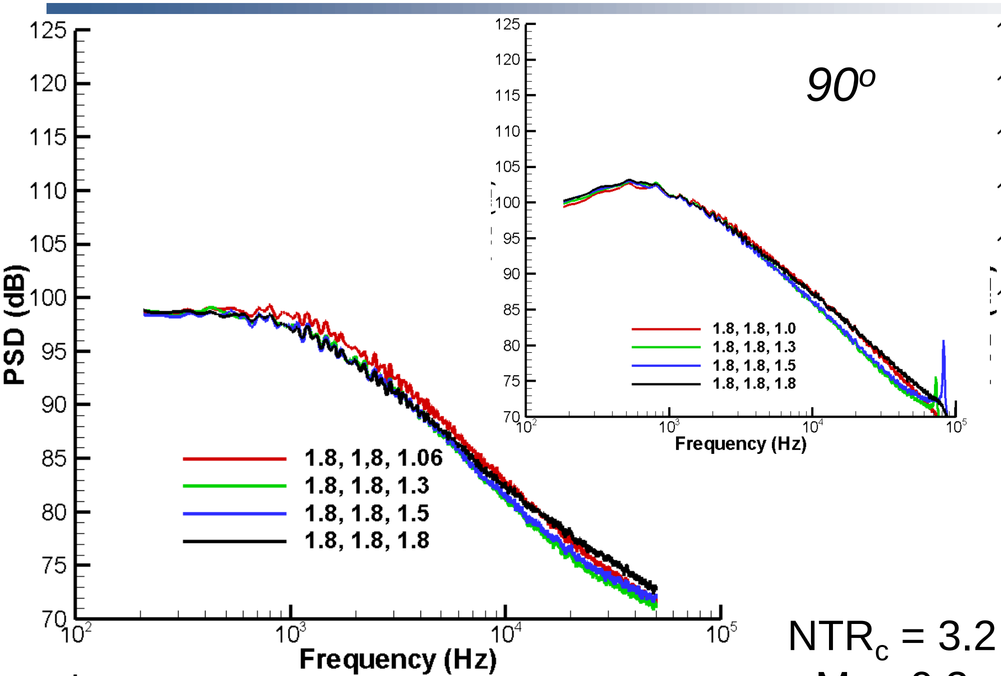


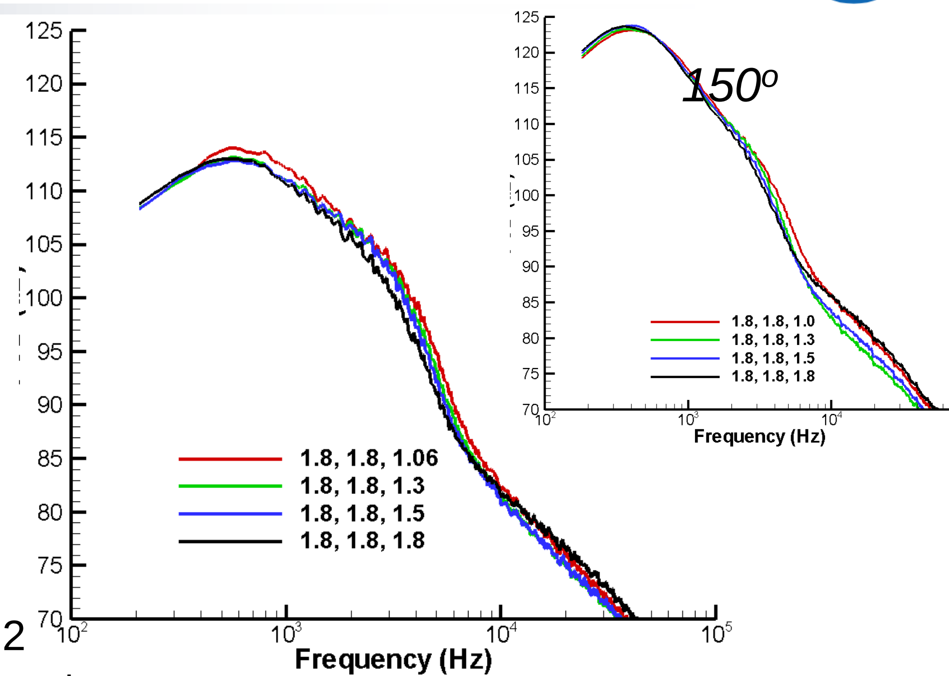
$V_b/V_c = 0.65$, $W_b/W_c = 6.0$
$V_b/V_c = 0.66$, $W_b/W_c = 4.3$



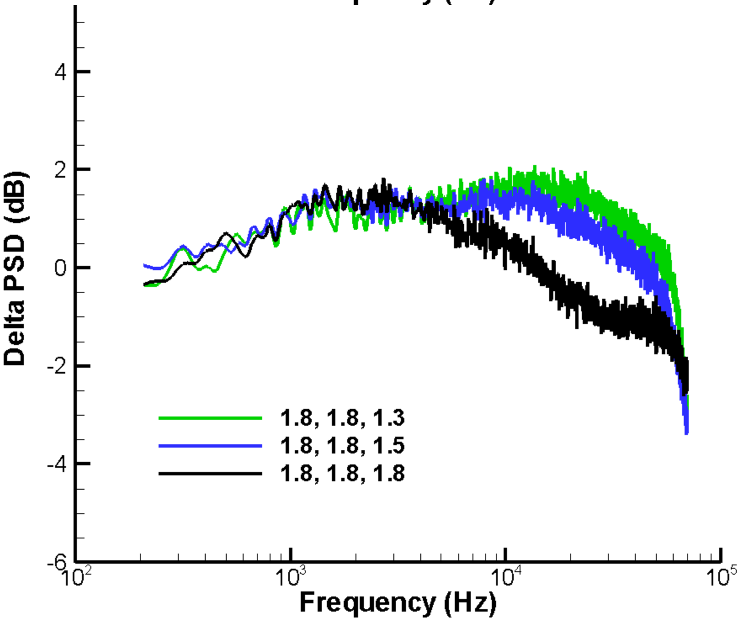


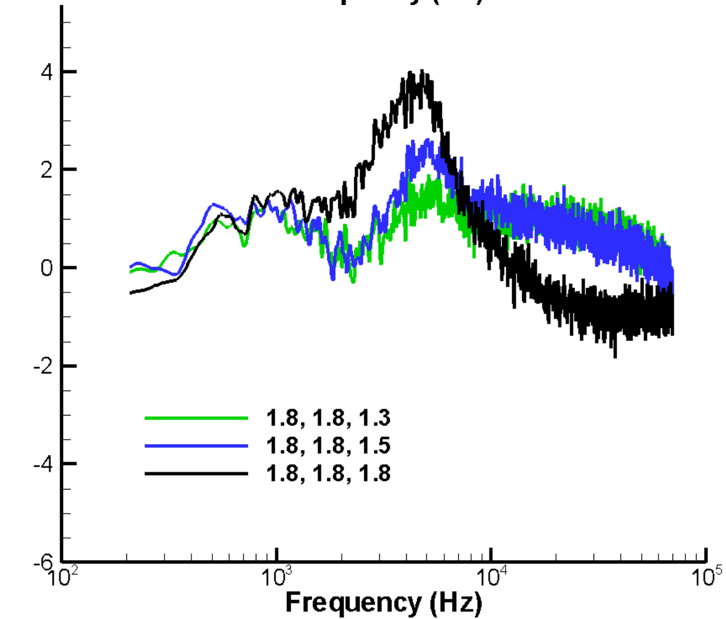
Impact of Simulated Forward Flight





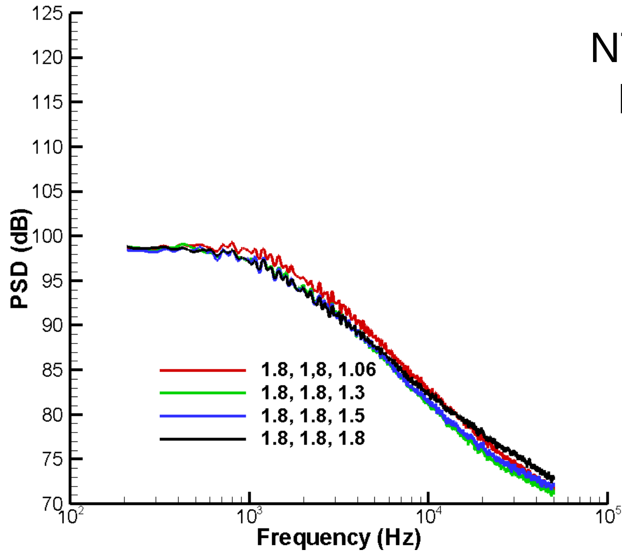
$NTR_c = 3.2$
$M_{fj} = 0.3$

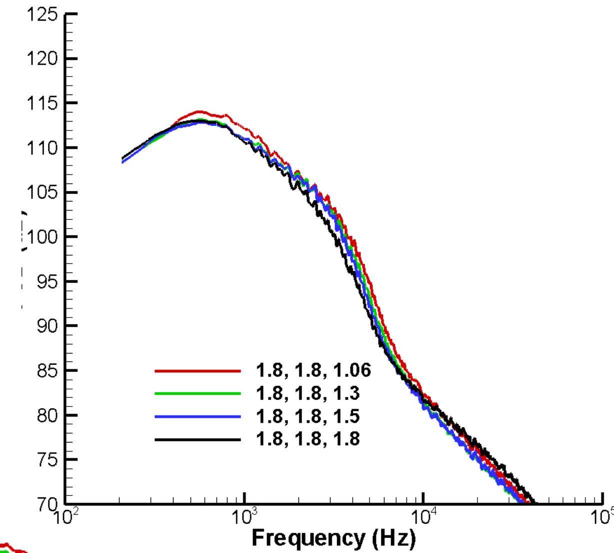


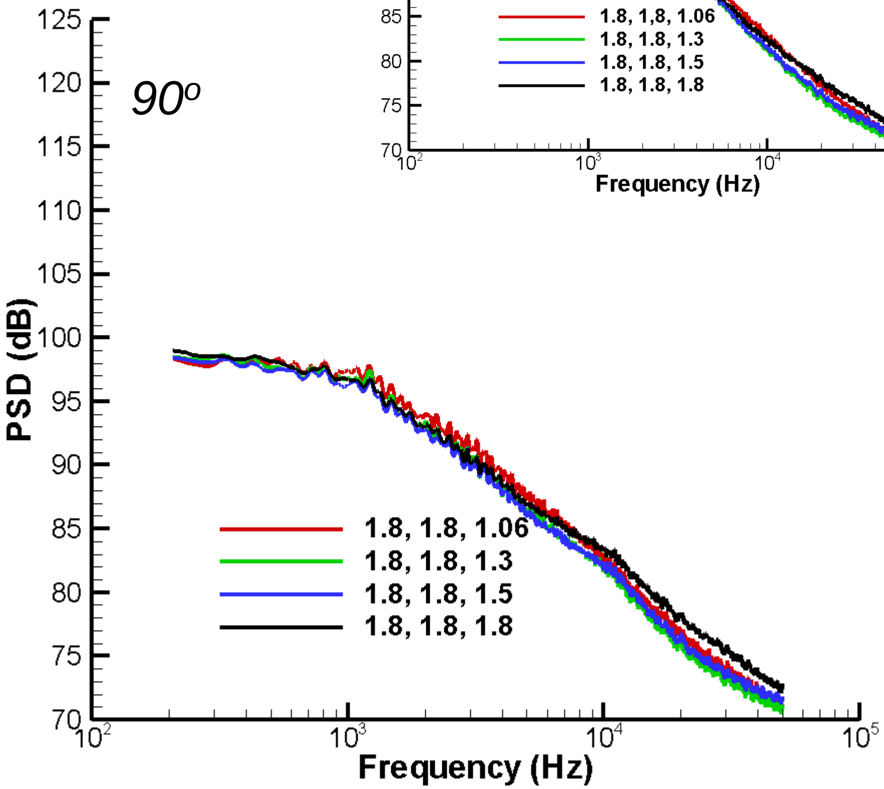


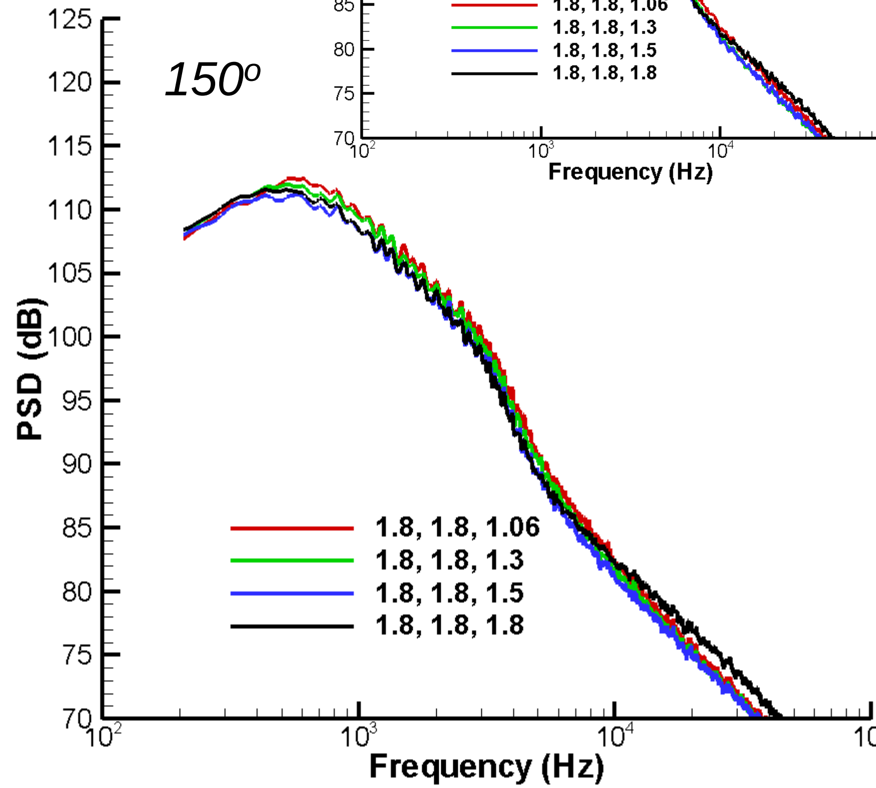
Impact of Partially Mixed Core and Fan

NTR$_c$ = 3.2
M$_{fj}$ = 0.3

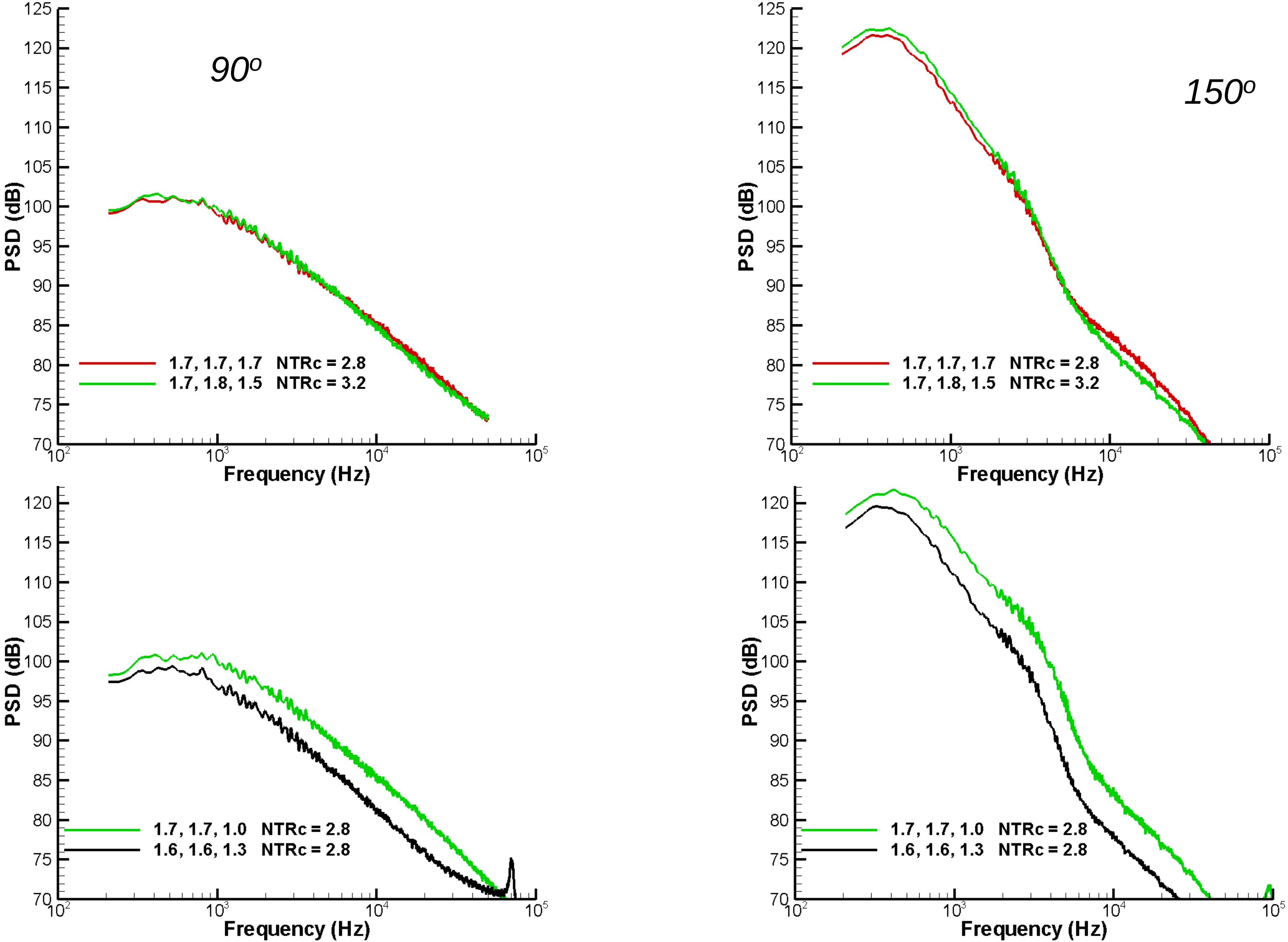








Equal Thrust Comparisons



Conclusions

- Addition of a third stream reduced high-frequency noise and impacted mid-frequency noise
- The presence of a simulated flight stream reduced the impact of the third stream
- The core-stream velocity had the greatest impact of all parameters investigated on the radiated noise
- Comparisons on an equal thrust basis show that three-stream jets are not inherently quieter than two-stream jets