Phased Array Measurements Made on the GE Counter-Rotating Open Rotor Model, F31/A31 Blades

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Csaba Horvath ASRC Aerospace

Acoustics Technical Working Group

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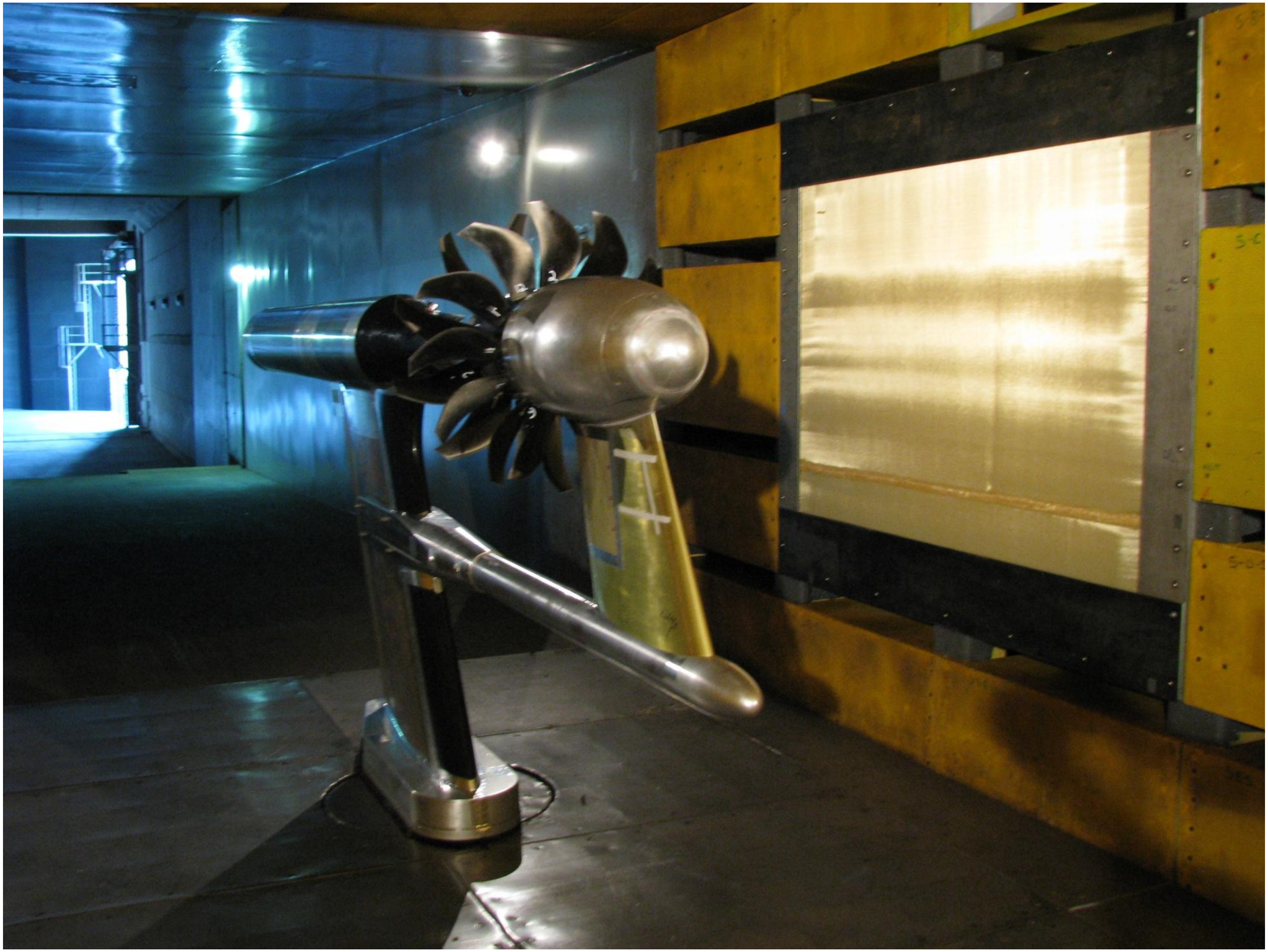
Support Provided by the Environmentally Responsible Aviation Program

GE Counter Rotating Open Rotor Model Installed in the NASA Glenn 9 x 15 Ft Wind Tunnel



Purpose

Locate the noise sources on the model

3D Schematic of 9 x 15 Ft Wind Tunnel

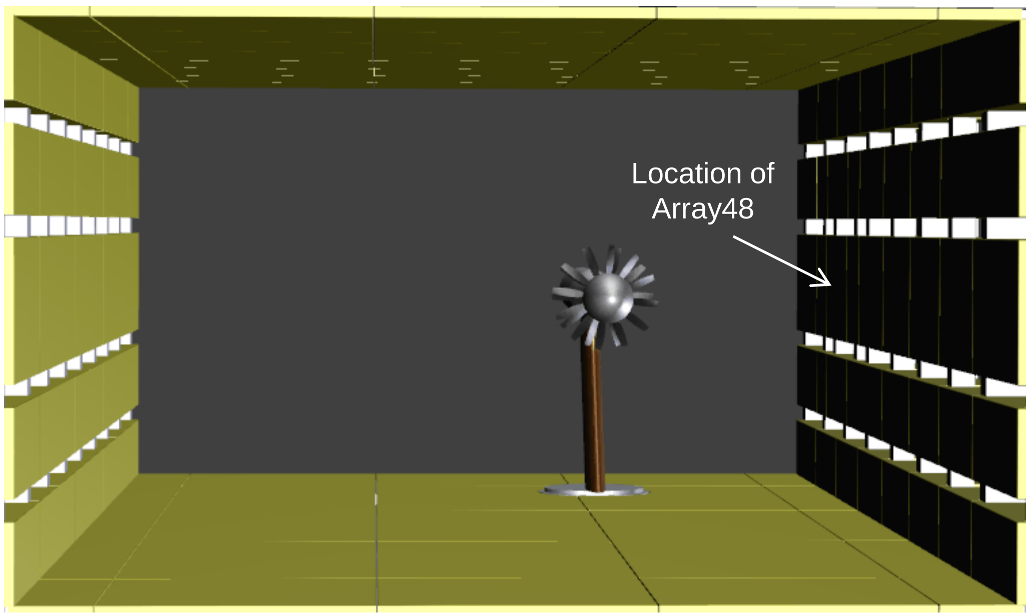
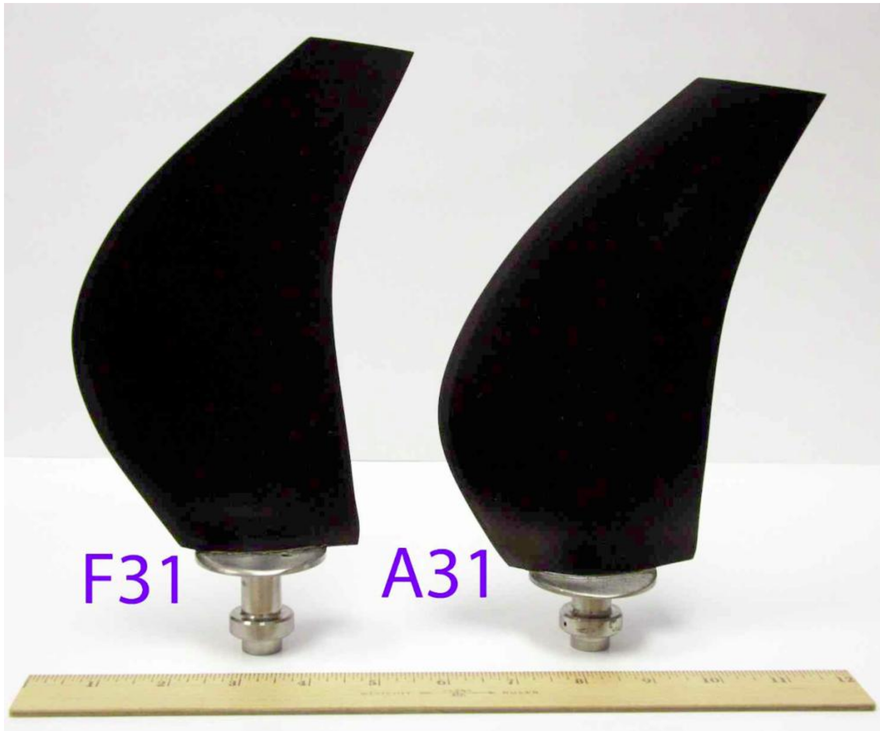


Photo showing Array48 in south wall of Wind Tunnel

F31/A31 Blades



12 Front Rotor Blades 10 Aft Rotor Blades

Front Rotor Speed = Aft Rotor Speed

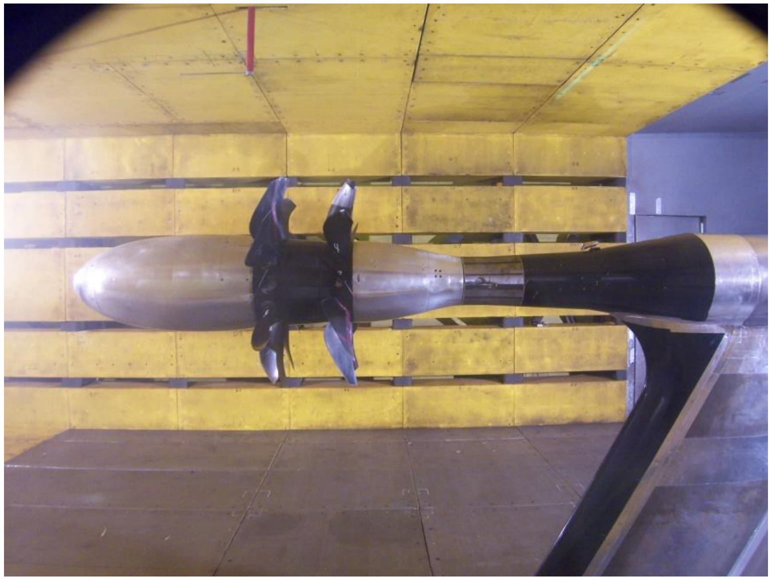
Test Conditions

Corrected Rotor Speeds, RPM

	Approach Blade Angle (33.5°/35.7°)	**Take-off Blade Angle (40.1°/40.8°)**
Mach 0.2 0° AOA	5598, 6325, 6773, 7245, 7487	4628, 5277, 5561, 6080, 6316, 6450
Mach 0.2 -3° AOA	5598, 6325, 6773	4628, 5561, 6316
Mach 0.2 -8° AOA	5598, 6325, 6773	4628, 5561, 6316
Mach 0.22 0° AOA	5903, 6617, 7054	4880, 5790, 6530

Front Rotor Speed = Aft Rotor Speed
Green designates Approach design speed
Red designates Take-off design speed

No Pylon



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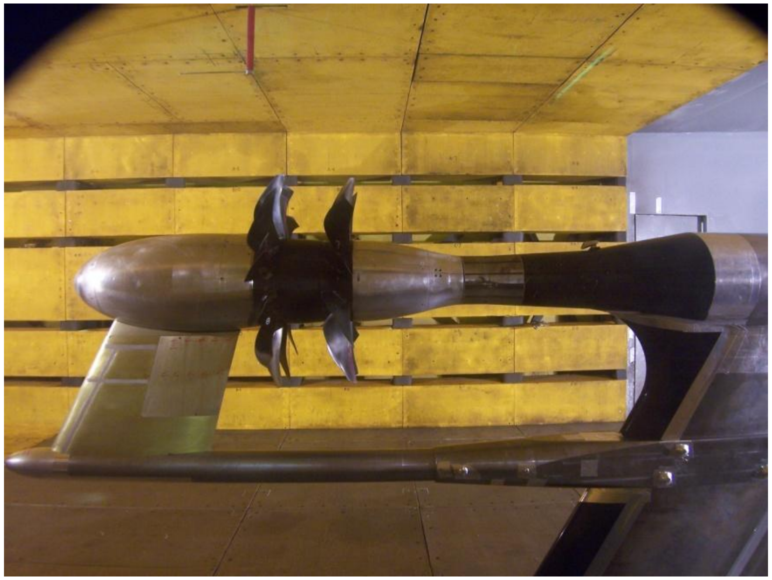
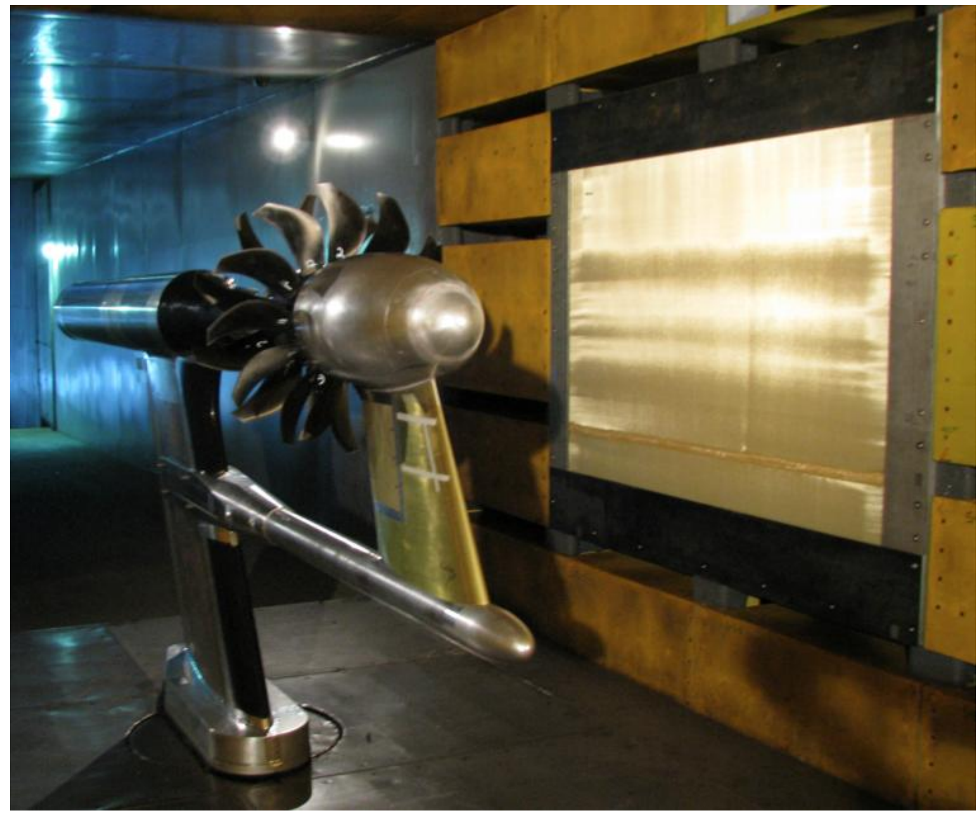
Pylon



First Use of Kevlar Window

No Kevlar Window

Kevlar Window



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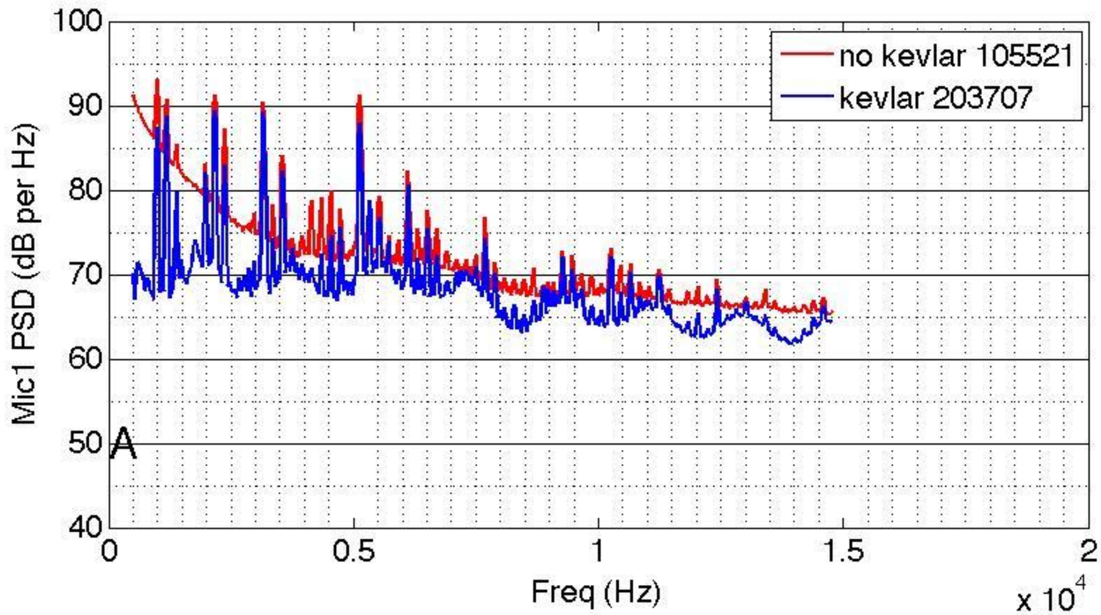
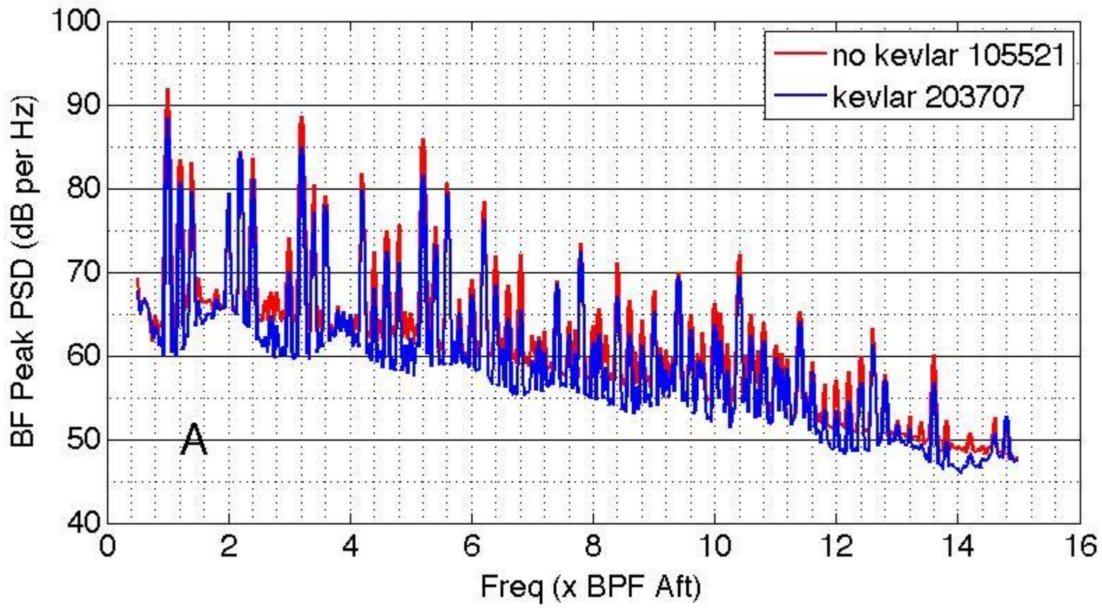
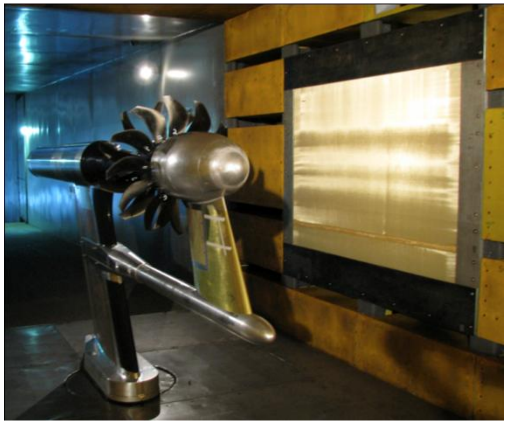


No Kevlar Window

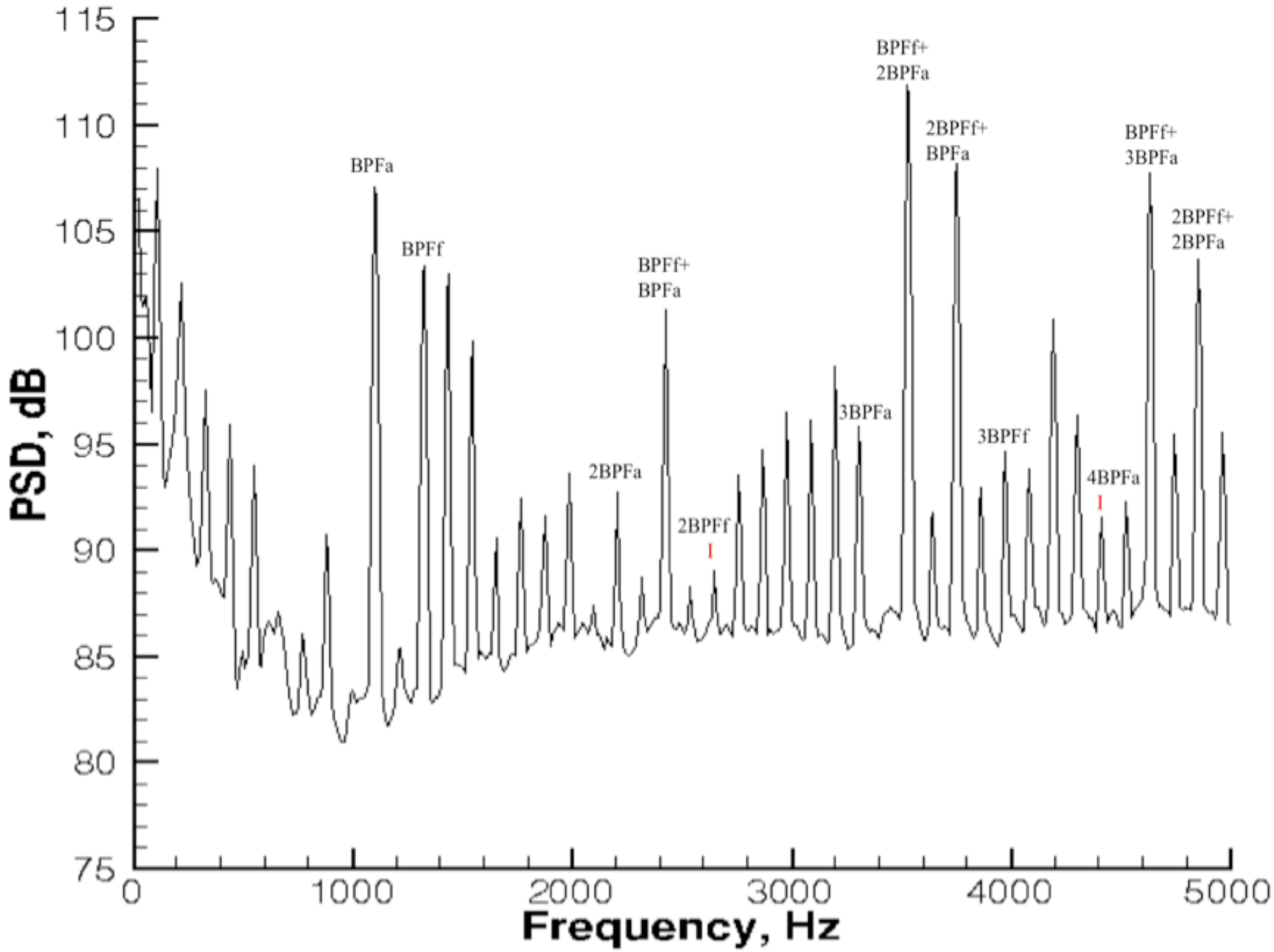


Kevlar Window



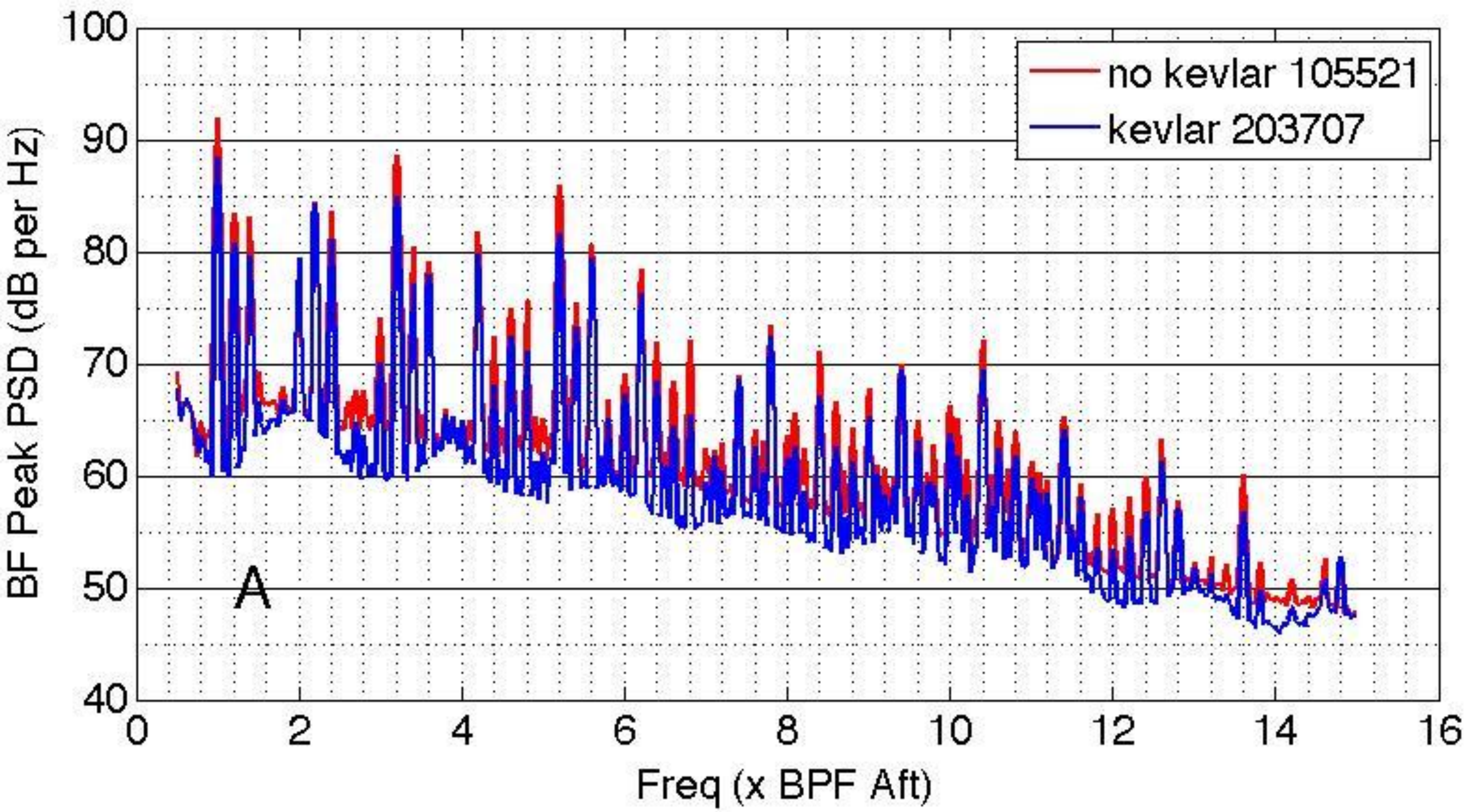
Data Processing Issues

Want to determine source location of each tone and the broadband noise between the tones



Data Processing Issues

Data processed between
0.5 BPFA and 15 BPFA



Data Processing Issues

Data processed between 0.5 BPFA and 15 BPFA

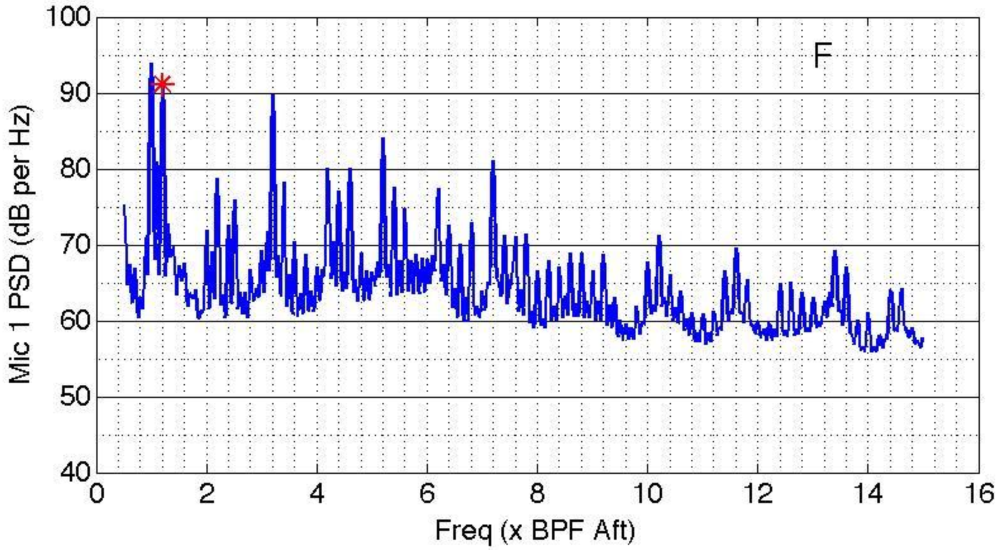
using bin widths that varied with RPM
(5 frequency bins between consecutive shaft orders)

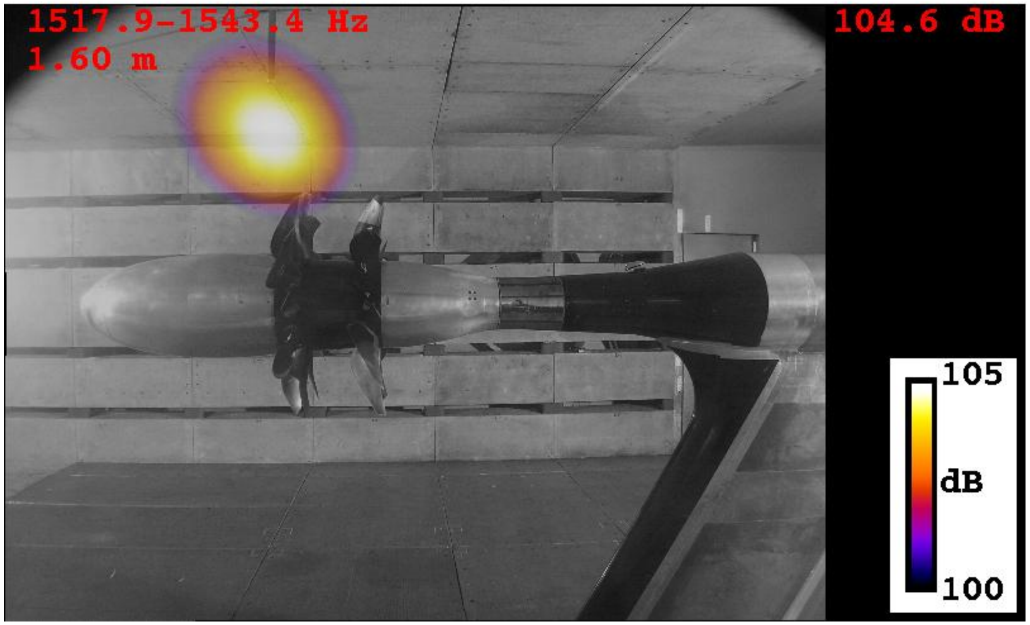
725 beamforming images per set

shaft order processing makes it easier to find images corresponding to certain tones

Data Processing Issues

Are the source locations accurate?





BPFF tone

7487 RPMC

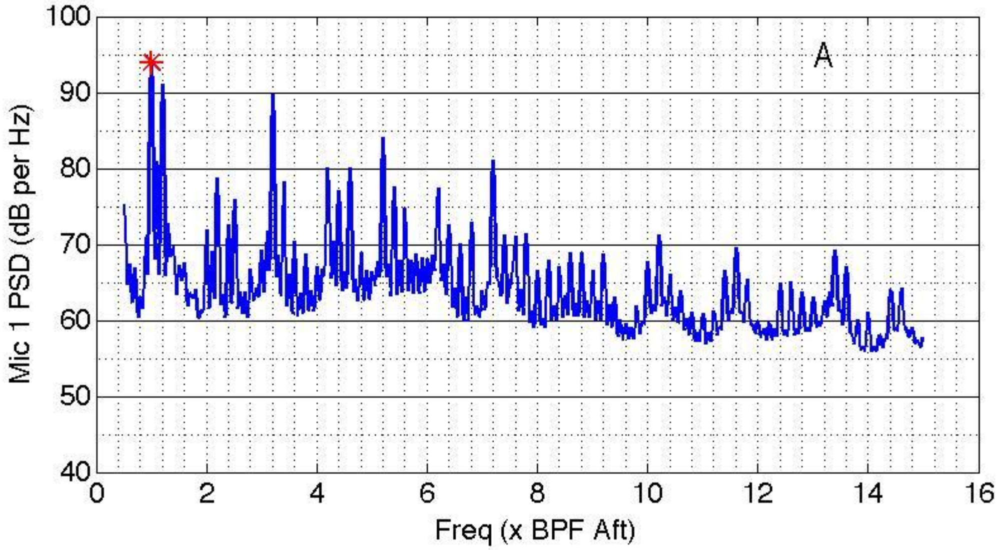
Approach Blade Angle Setting

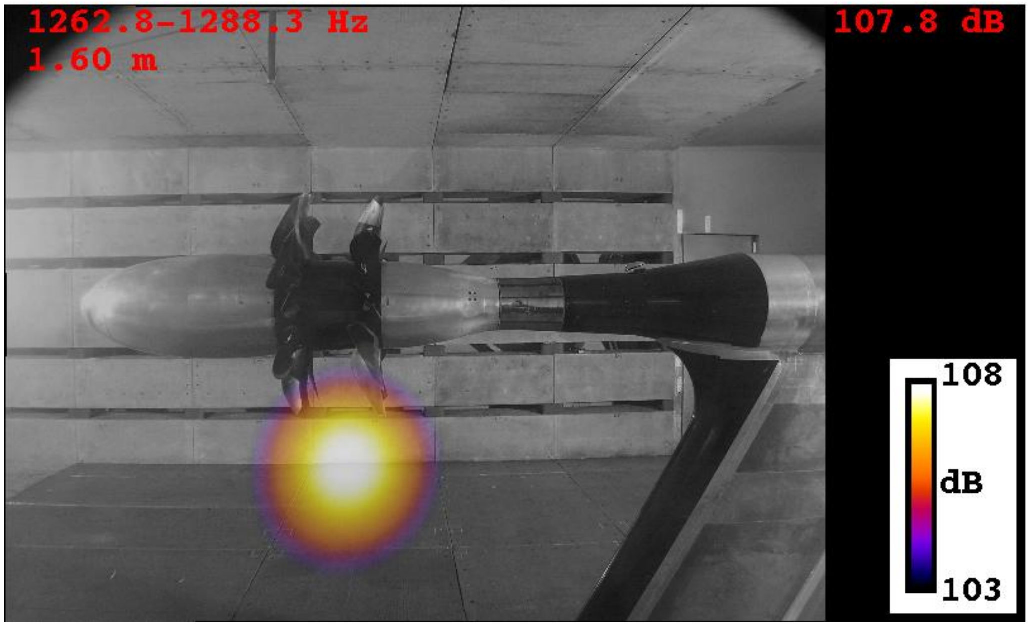
M=0.2

0° AOA

Data Processing Issues

Are the source locations accurate?





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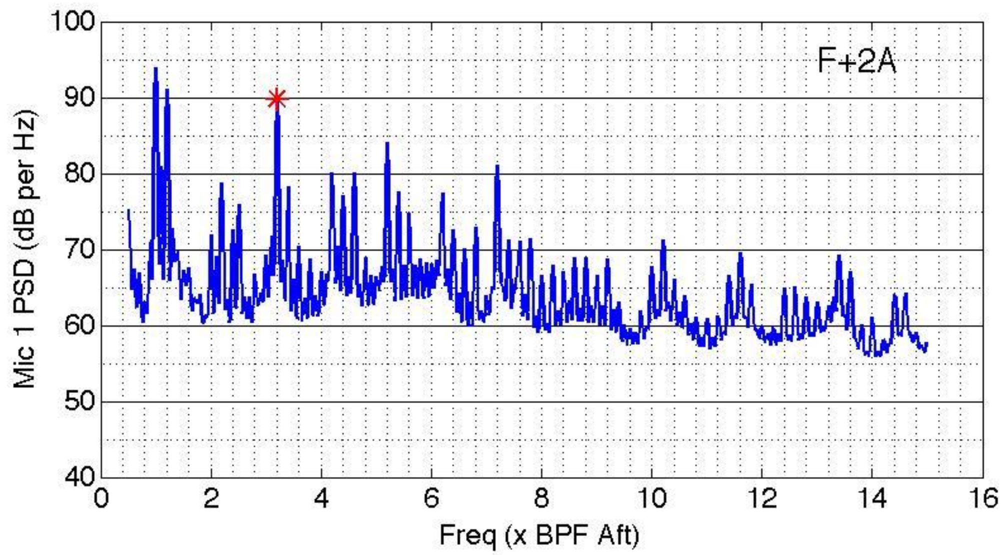
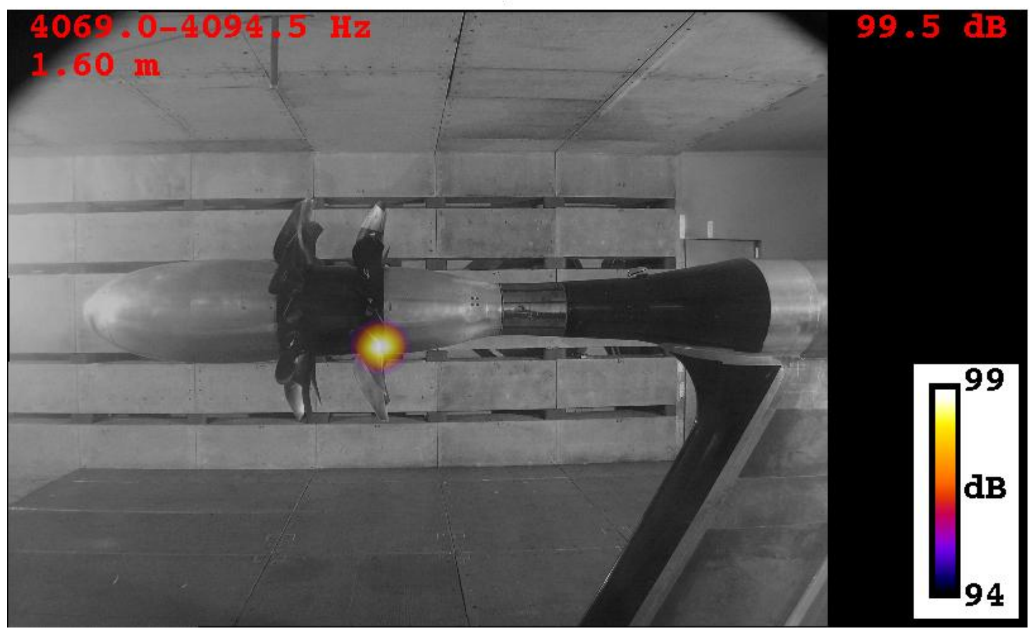




F+2A tone

7487 RPMC

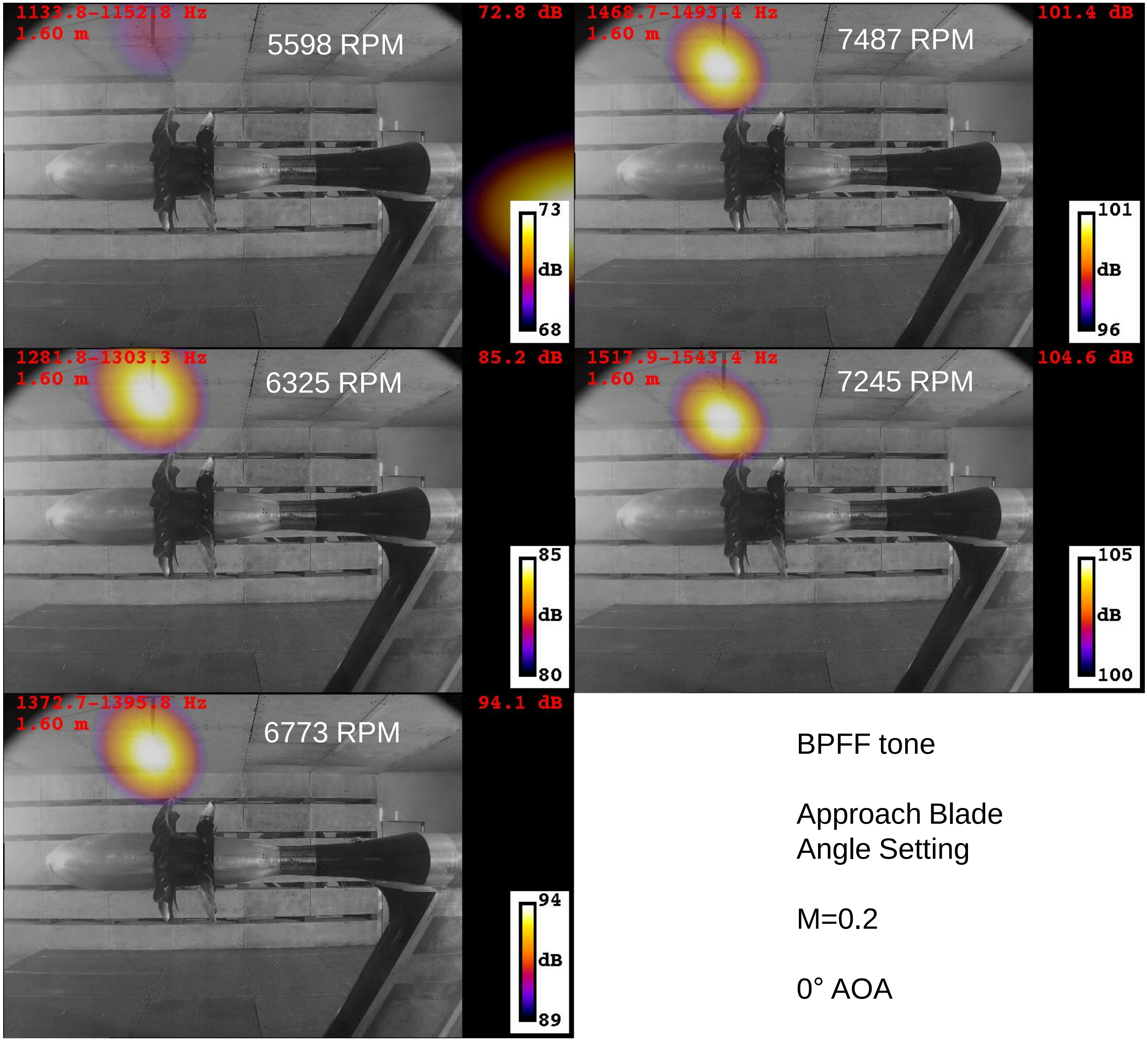
Approach Blade Angle Setting

M=0.2

0° AOA

Data Processing Issues

Are the source locations accurate?



BPFF tone

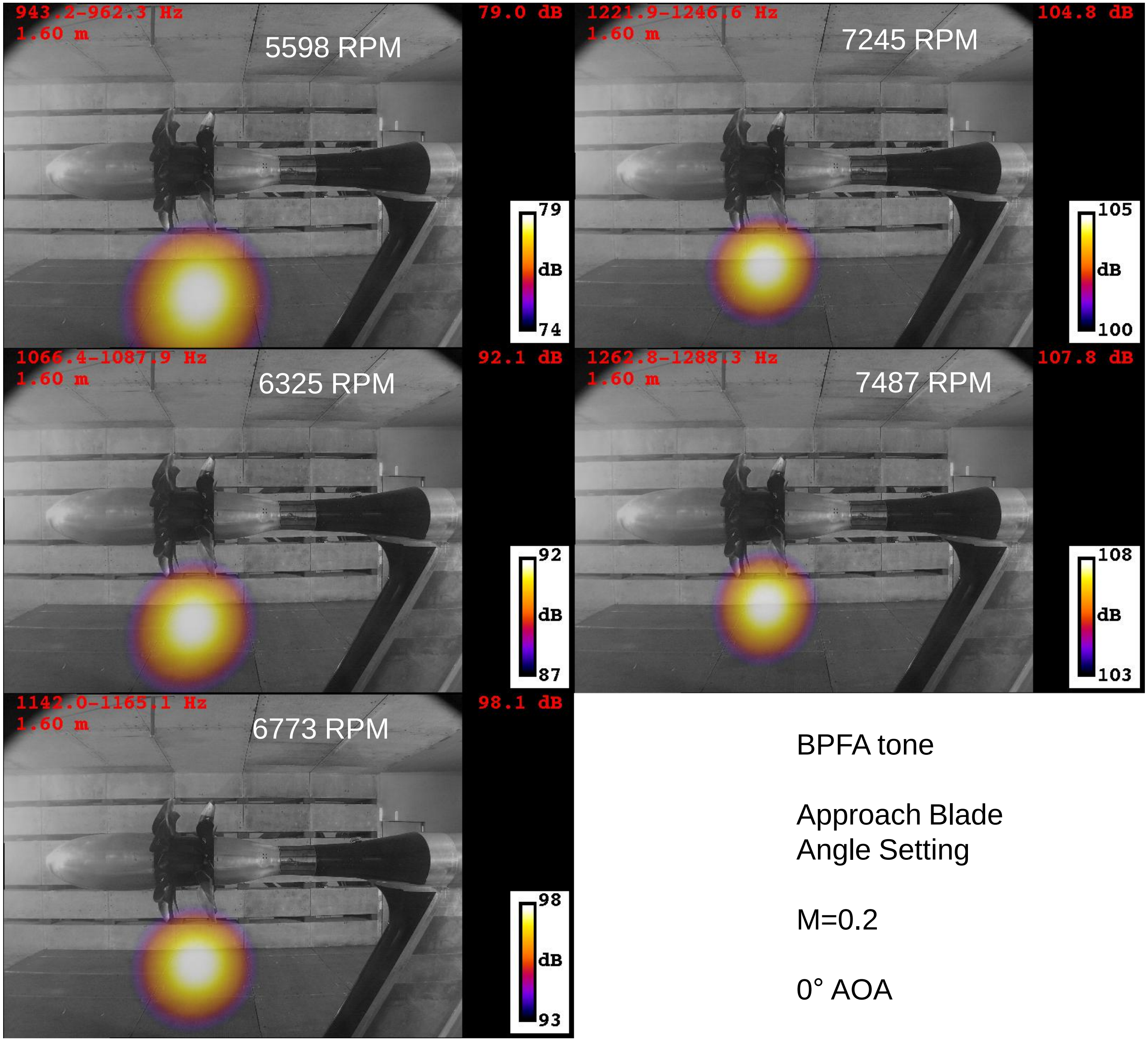
Approach Blade
Angle Setting

M=0.2

0° AOA

Data Processing Issues

Are the source locations accurate?



BPFA tone

Approach Blade
Angle Setting

M=0.2

0° AOA

Data Processing Issues

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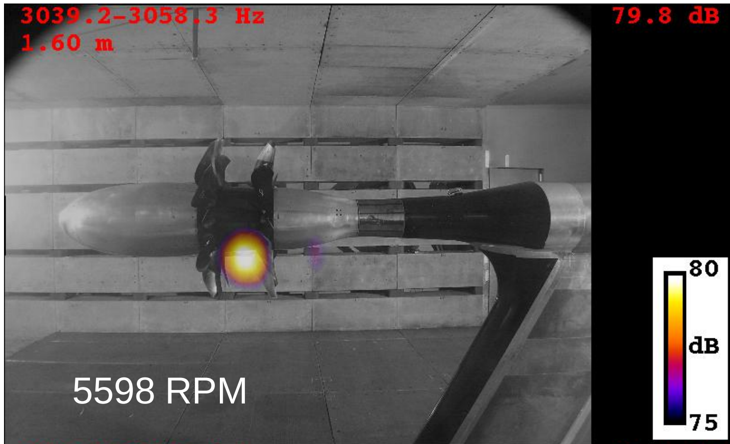

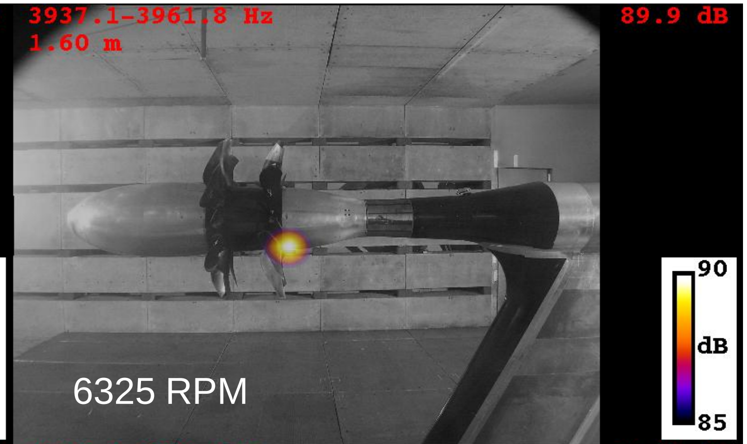

F+2A tone

Approach Blade
Angle Setting

M=0.2

0° AOA

Data Processing Issues

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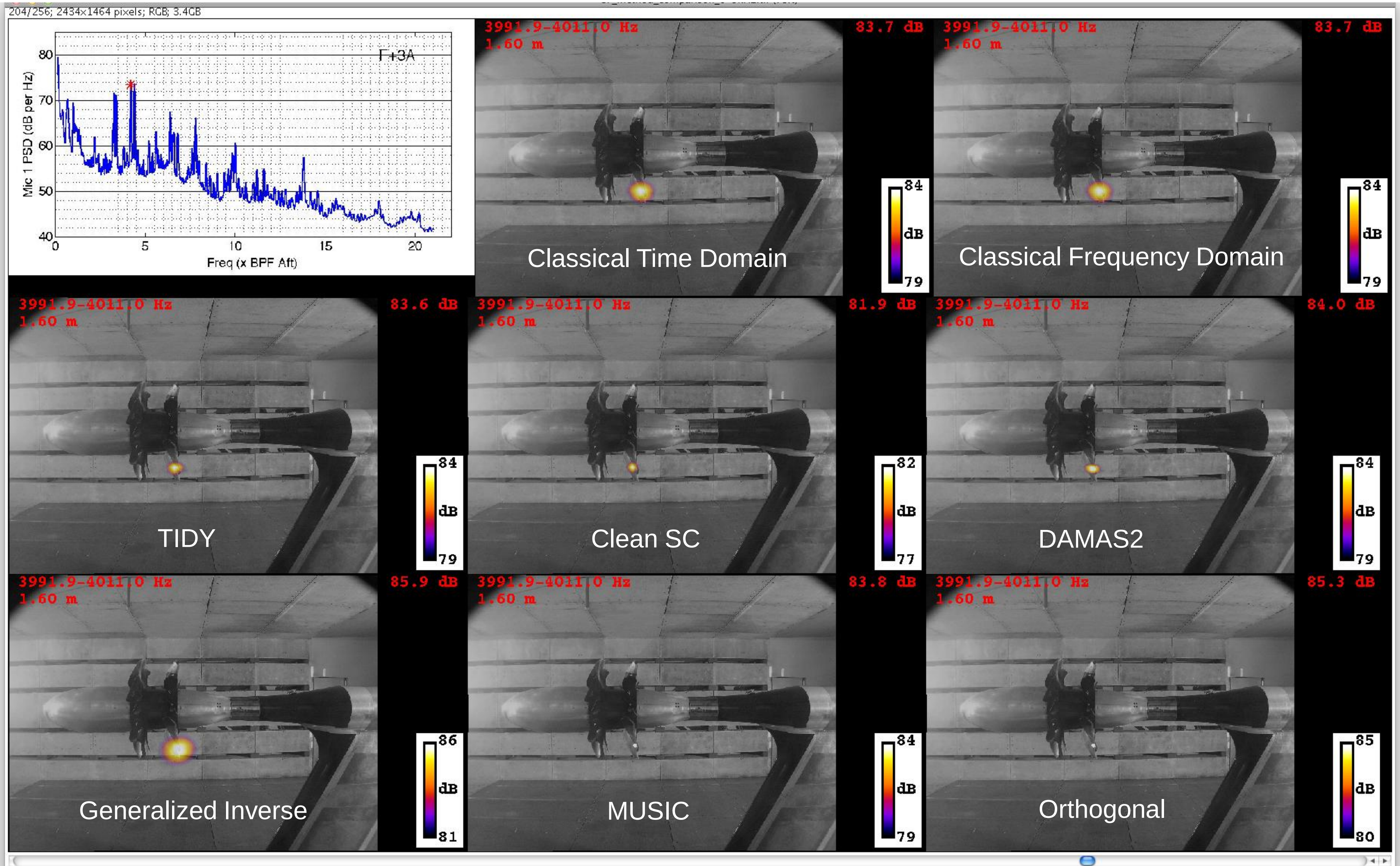

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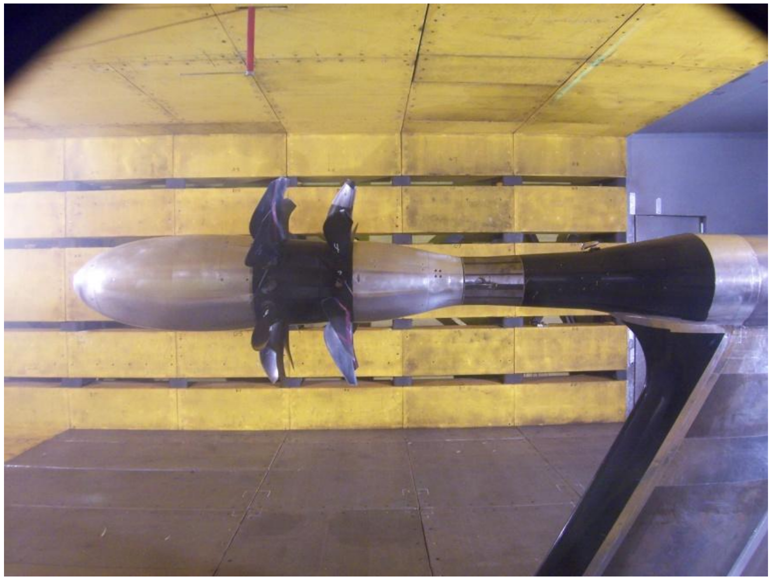
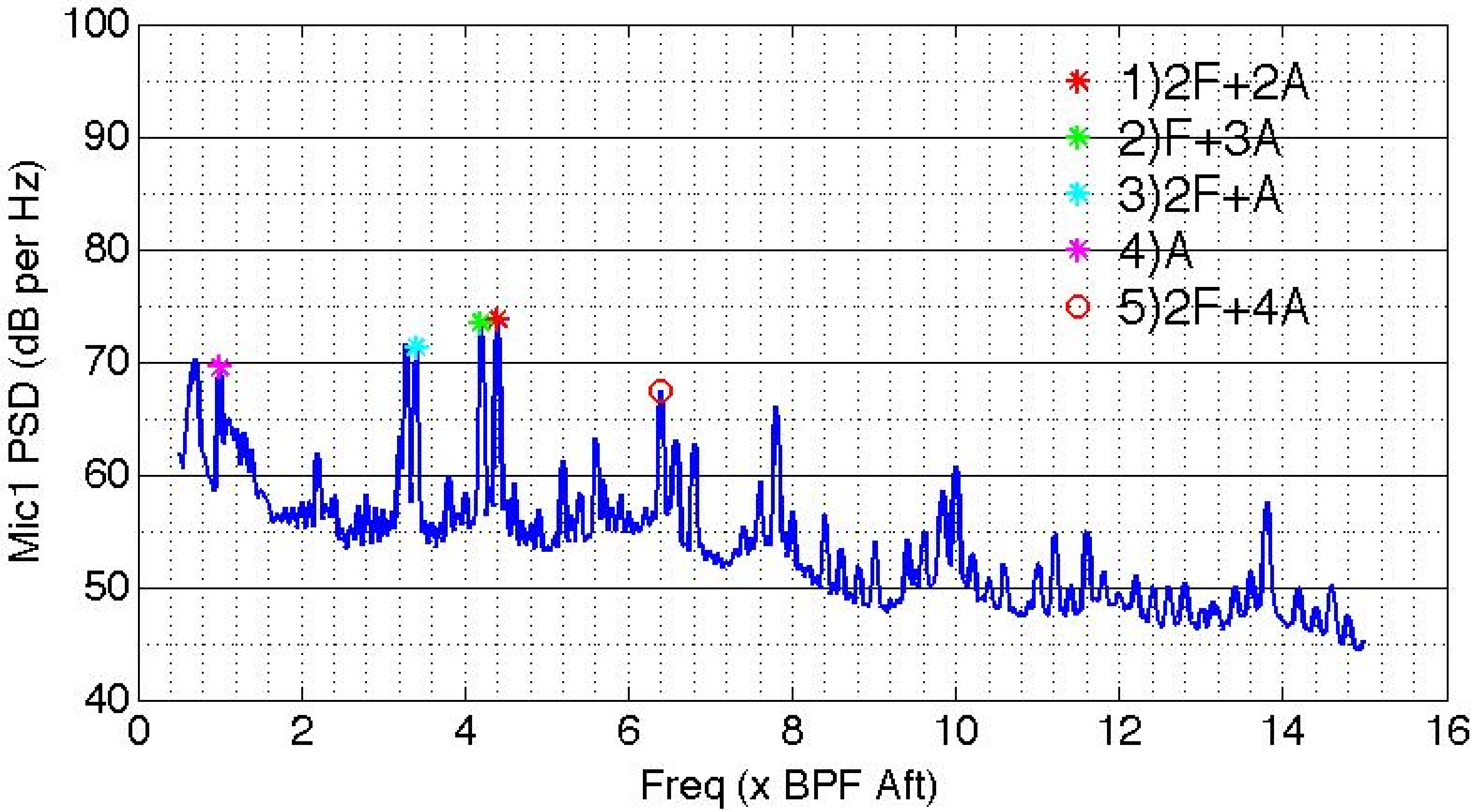
Front Rotor Speed = Aft Rotor Speed
Green designates Approach design speed
Red designates Take-off design speed

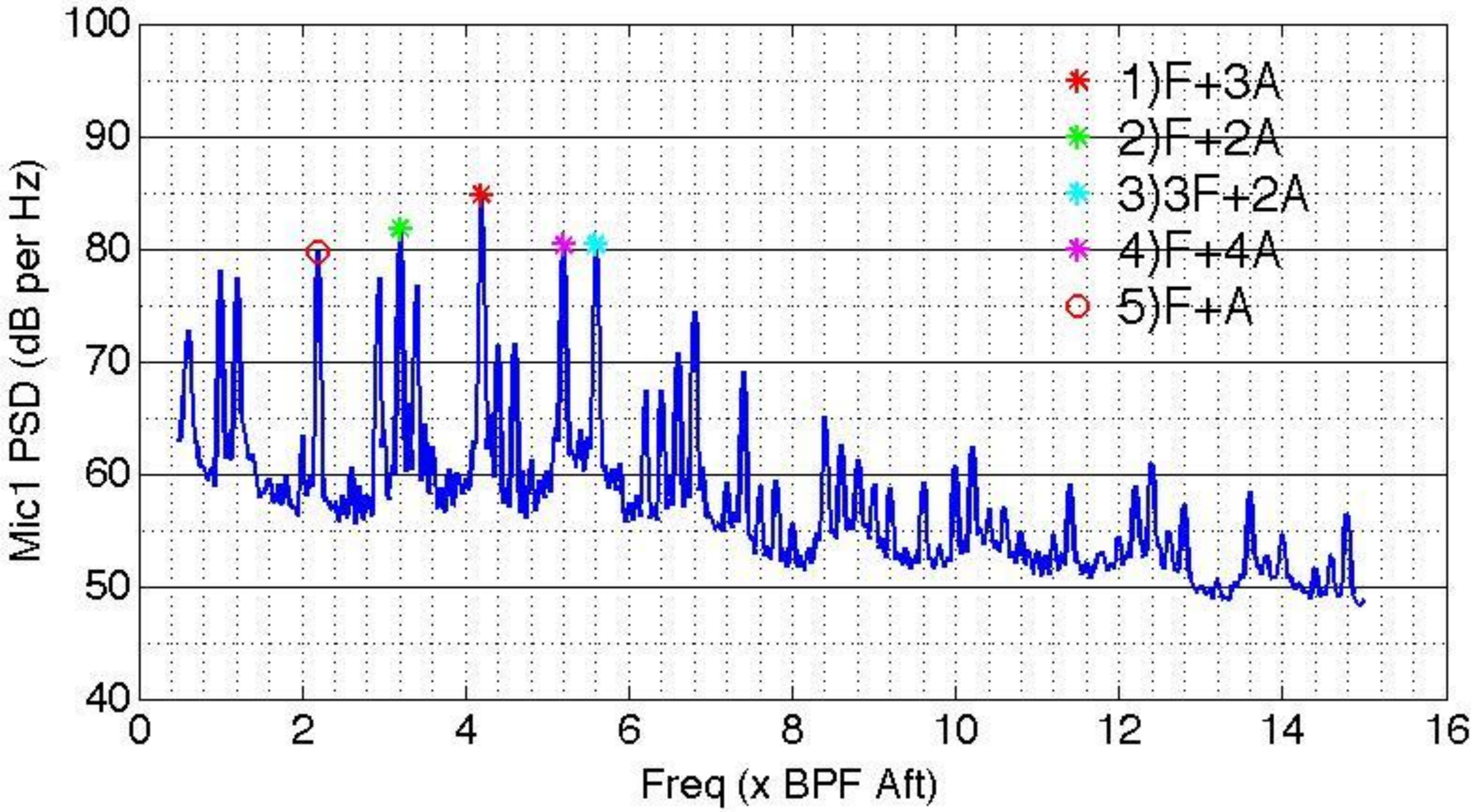
No Pylon



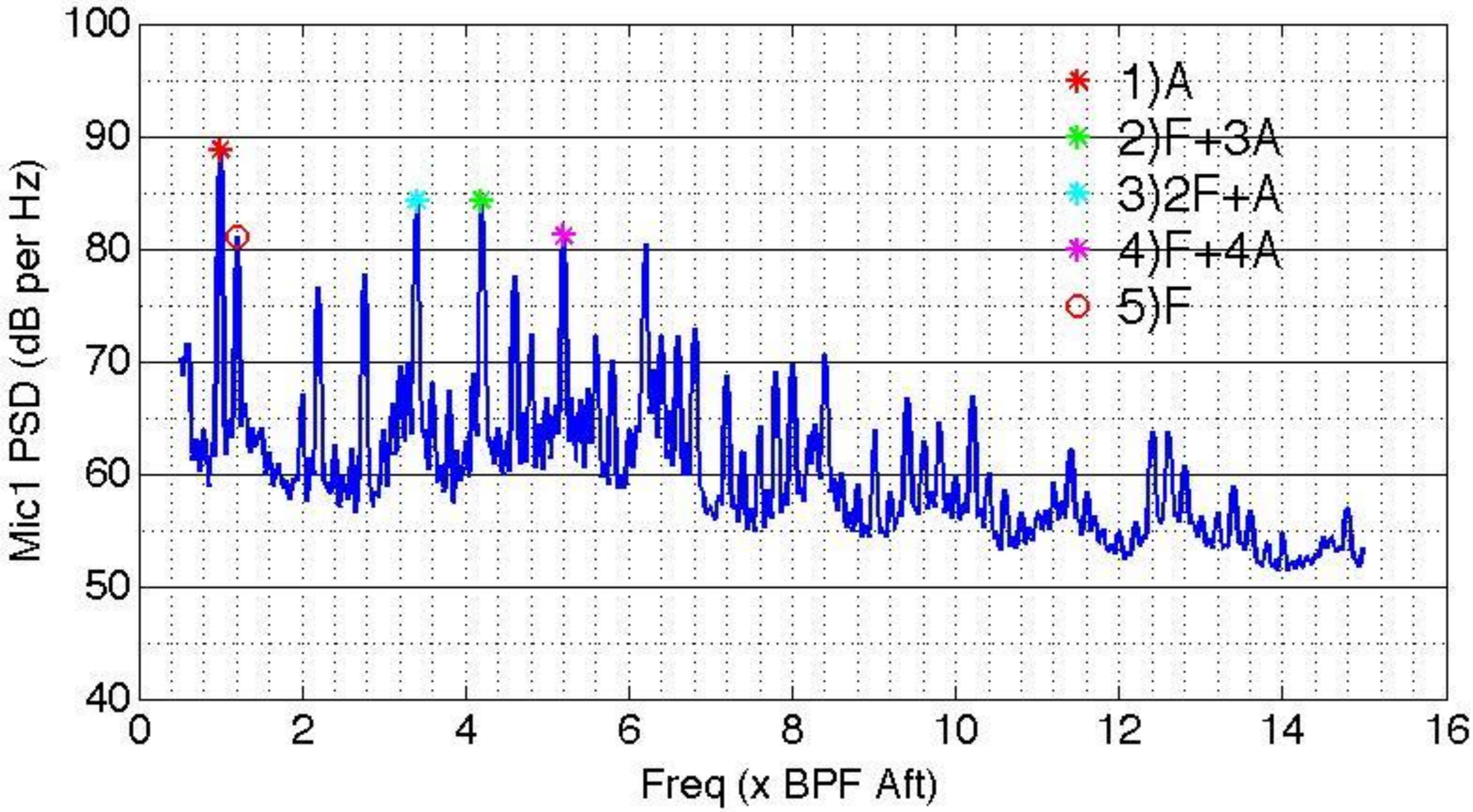
5598 RPM
M=0.2, 0°AOA, no pylon, Approach



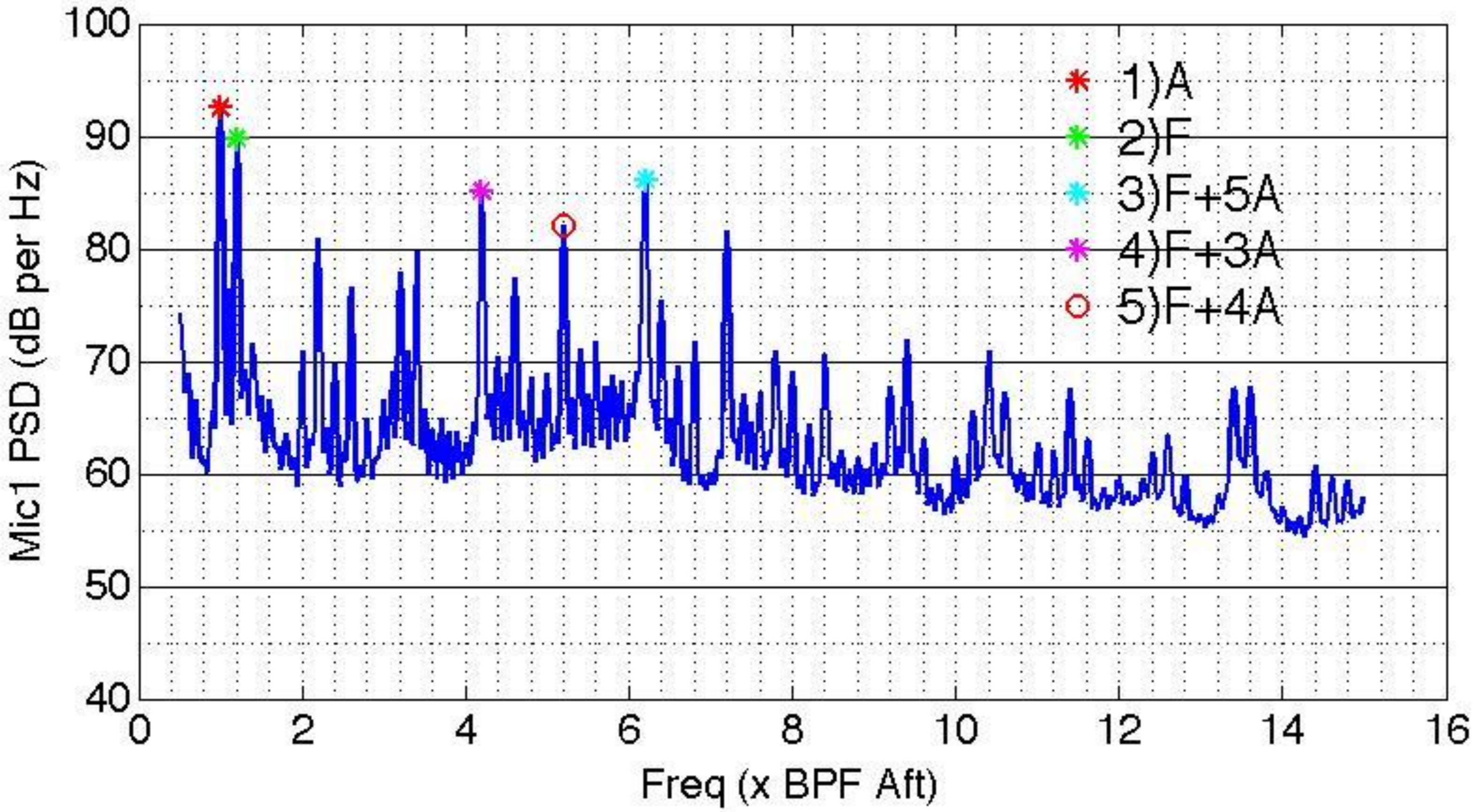
6325 RPM
M=0.2, 0°AOA, no pylon, Approach



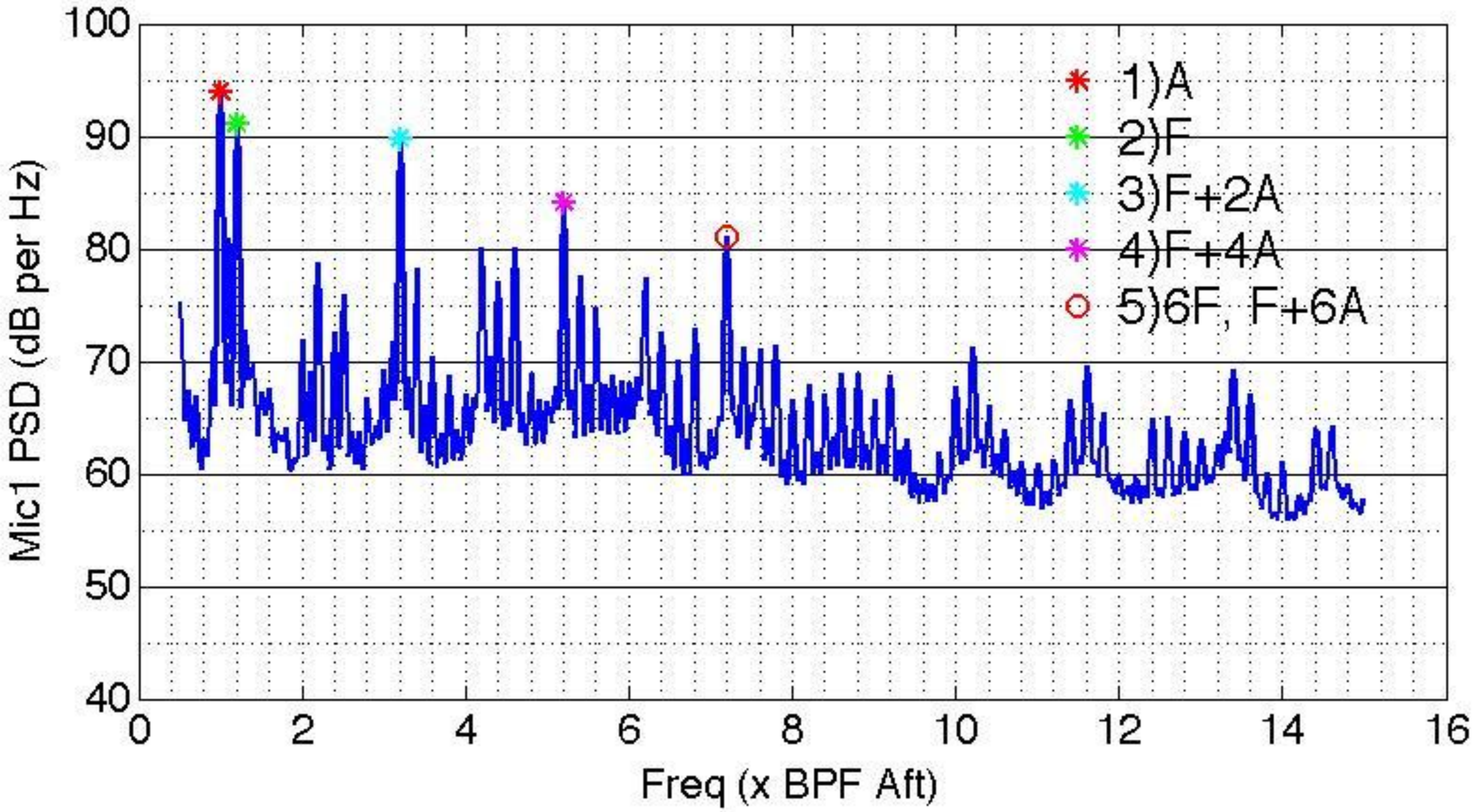
6773 RPM
M=0.2, 0°AOA, no pylon, Approach

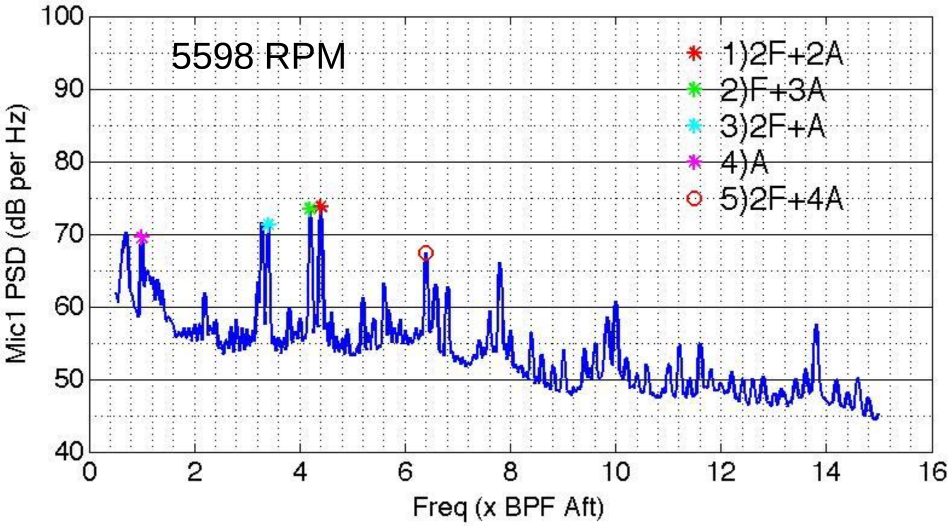


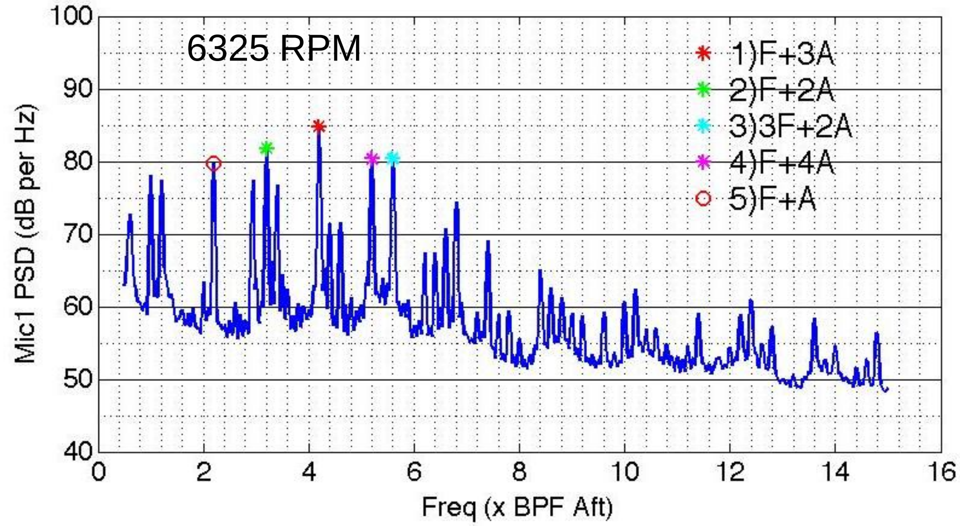
7245 RPM
M=0.2, 0°AOA, no pylon, Approach

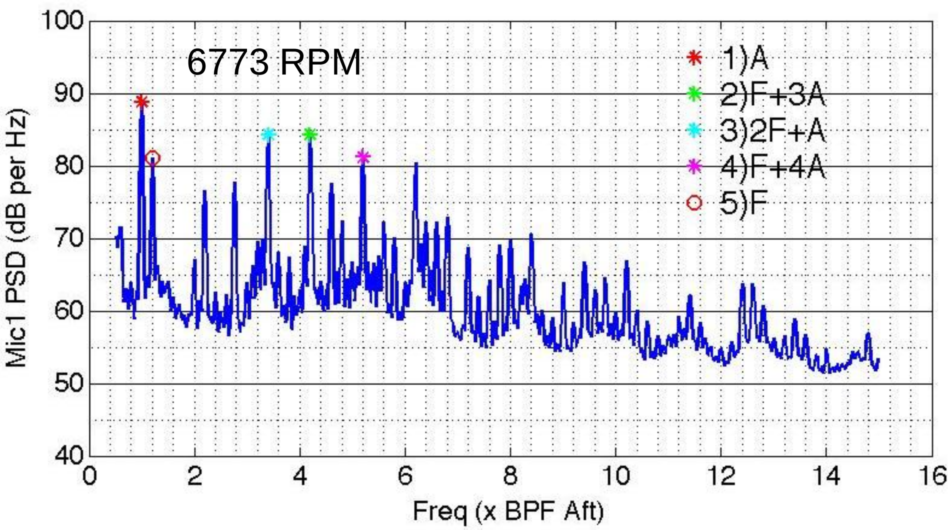


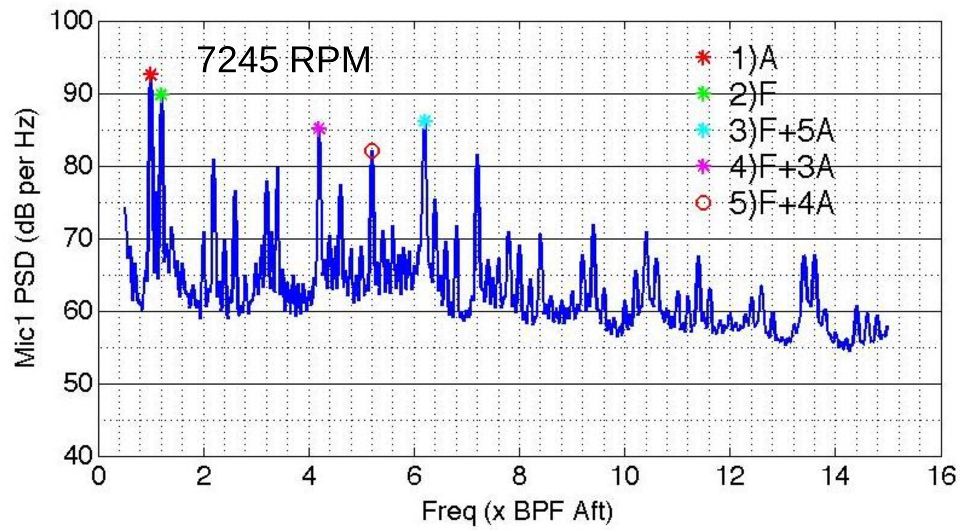
7487 RPM
M=0.2, 0°AOA, no pylon, Approach

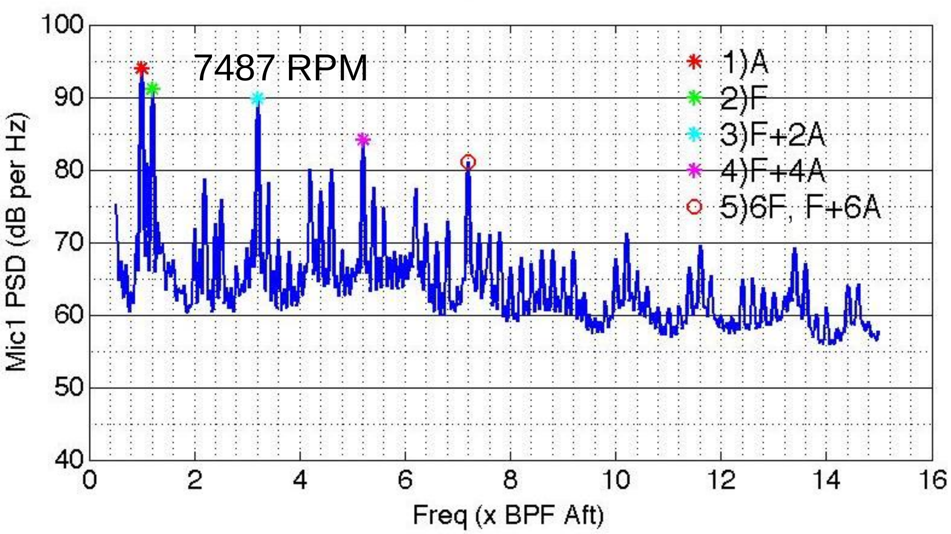












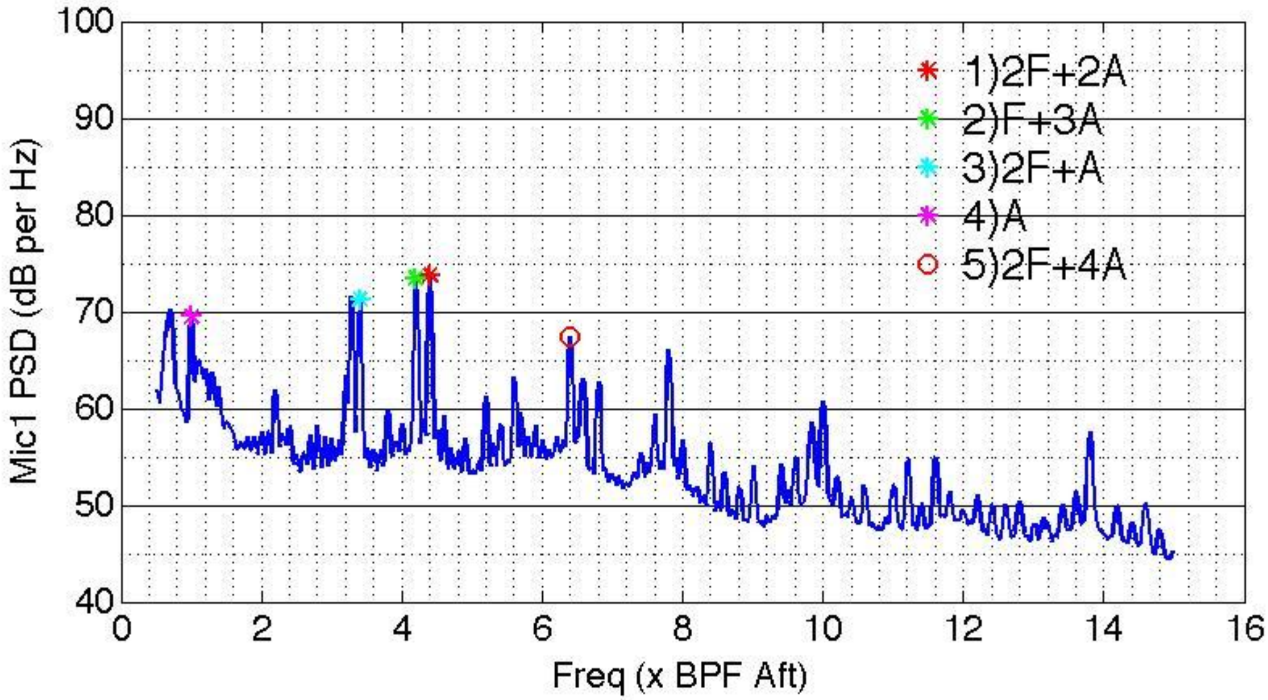
BPF tones become more important as HP increases

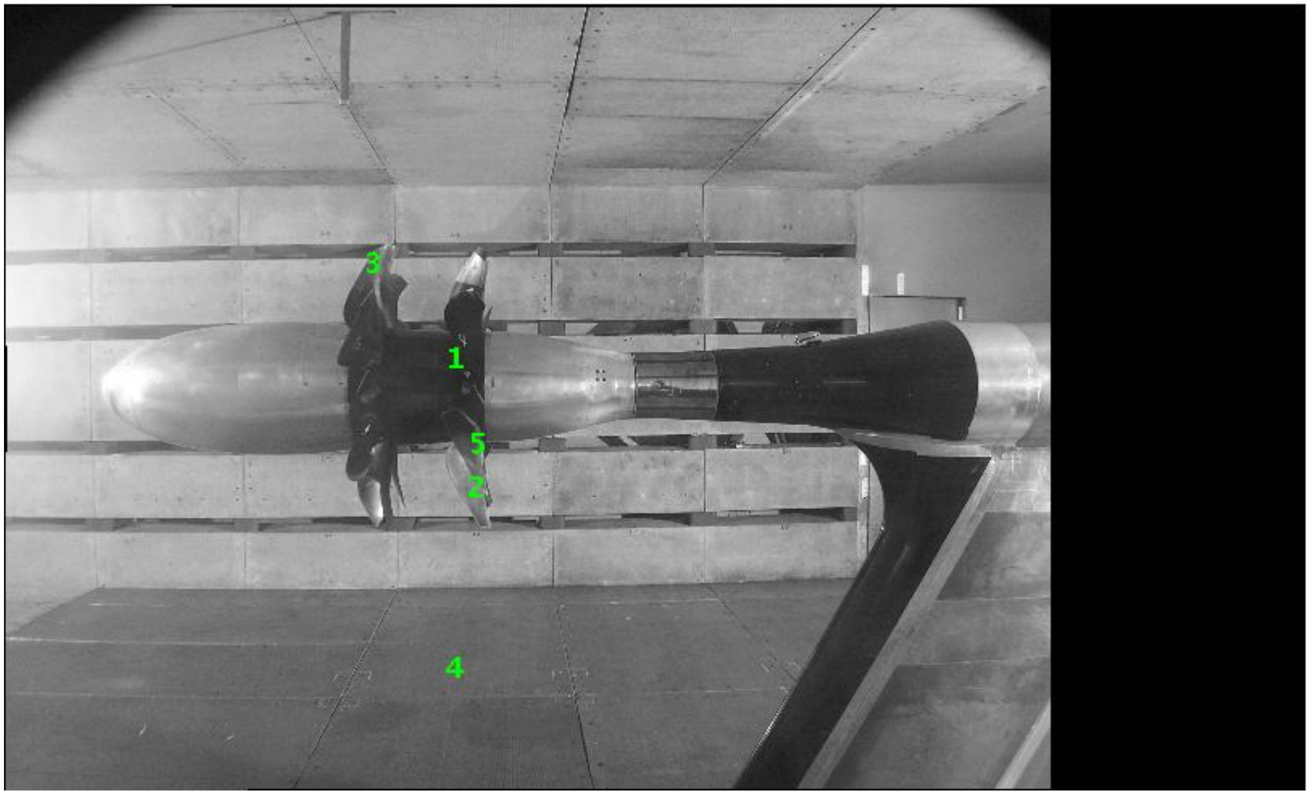
BPFA>BPFF

At high HP, F+xA interaction tones are important

Noise source location of dominant tones

M=0.2, 0° AOA, no pylon, Approach, varying HP



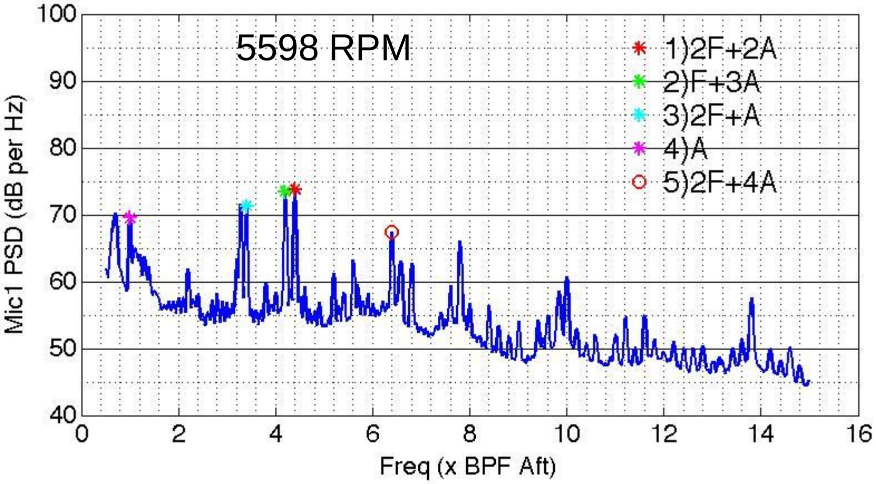


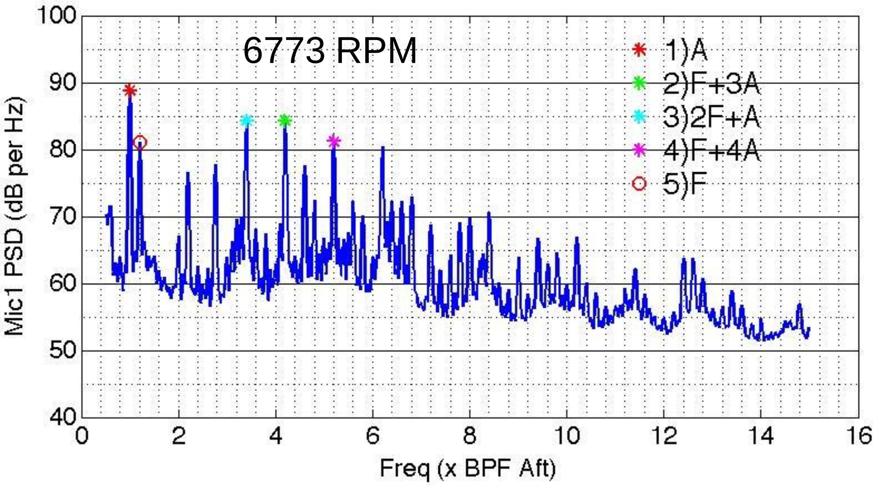
5598 RPM

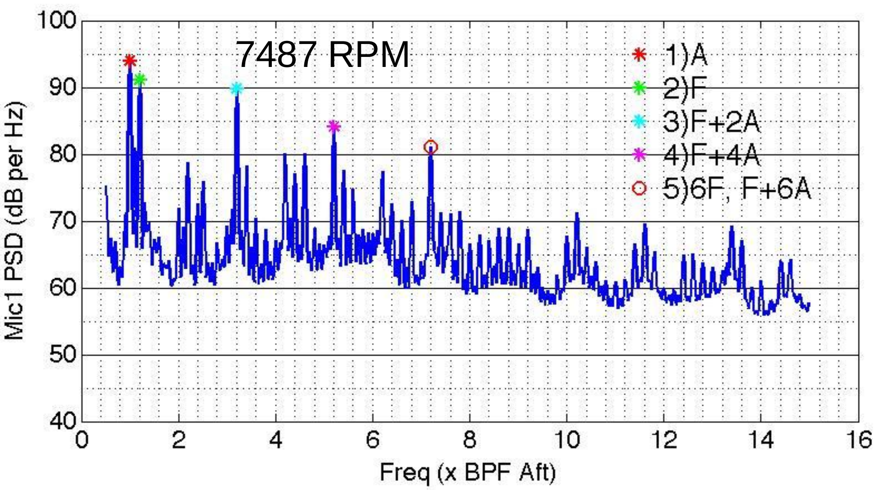
M=0.2

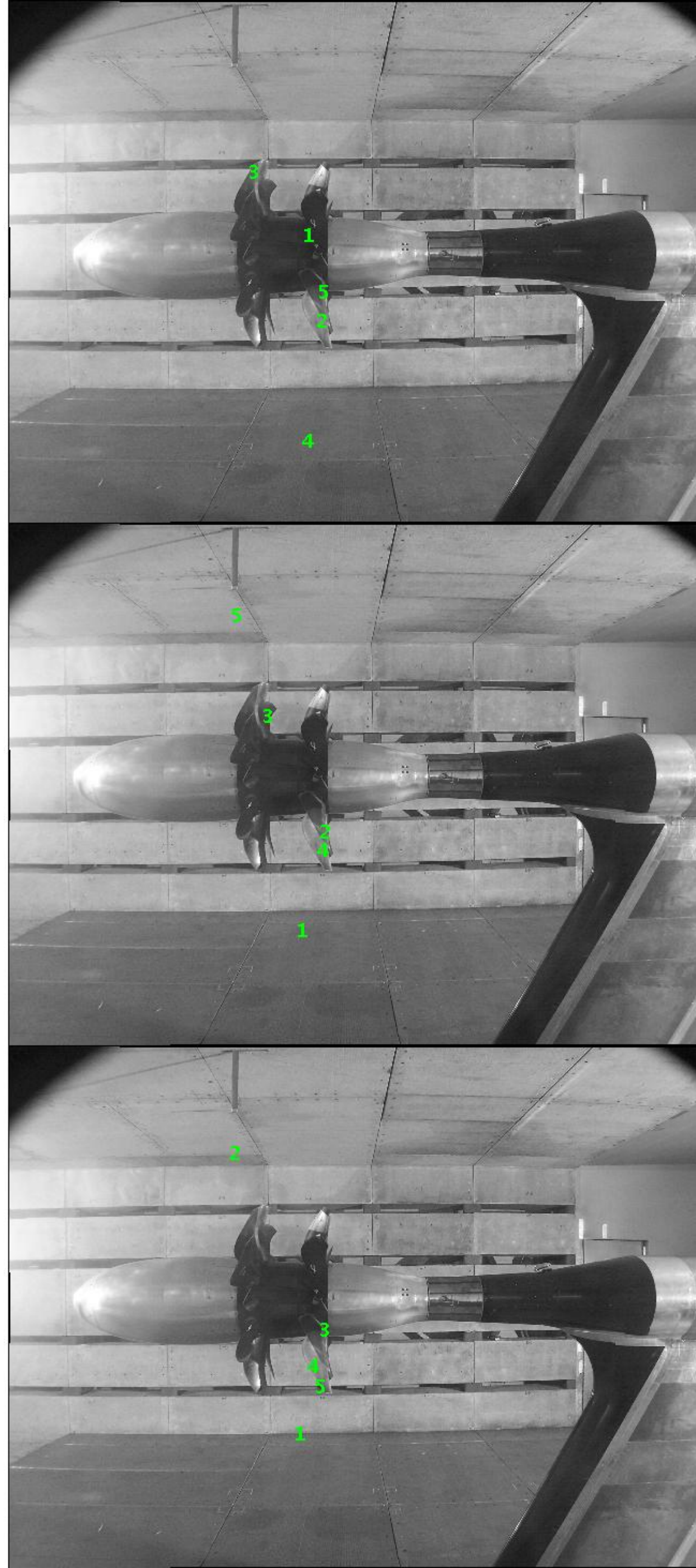
0°AOA

no pylon
Approach









-The dominant tones are, for the most part, located on the side of the rig where the blade is rotating toward the phased array.

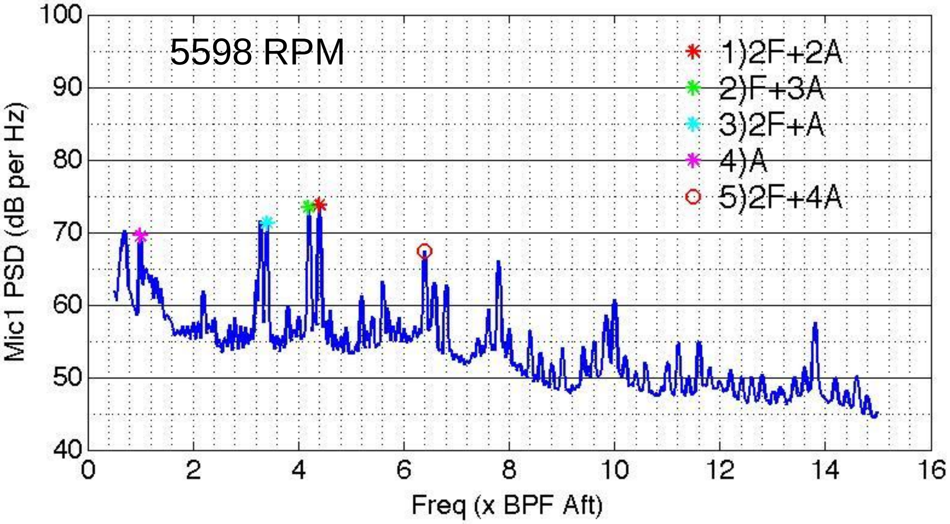
-A large percentage of the dominant tones are located on the aft rotor

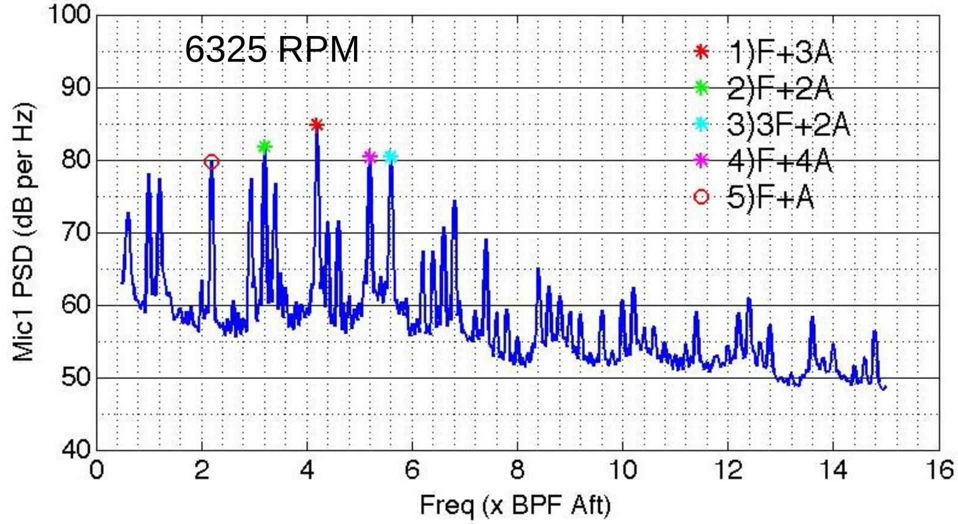
- The interaction tones seem to come from the rotor which has a higher multiple of its BPF in the interaction

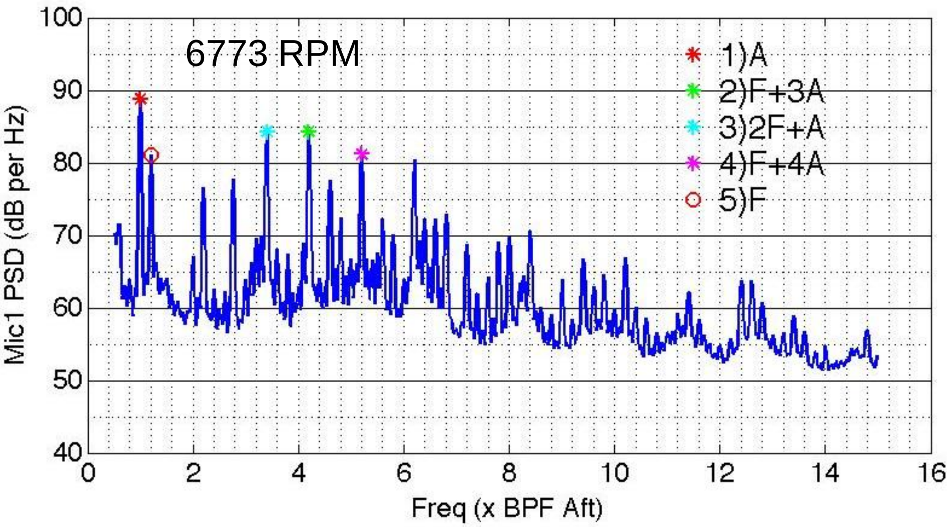
Comparison of Spectra

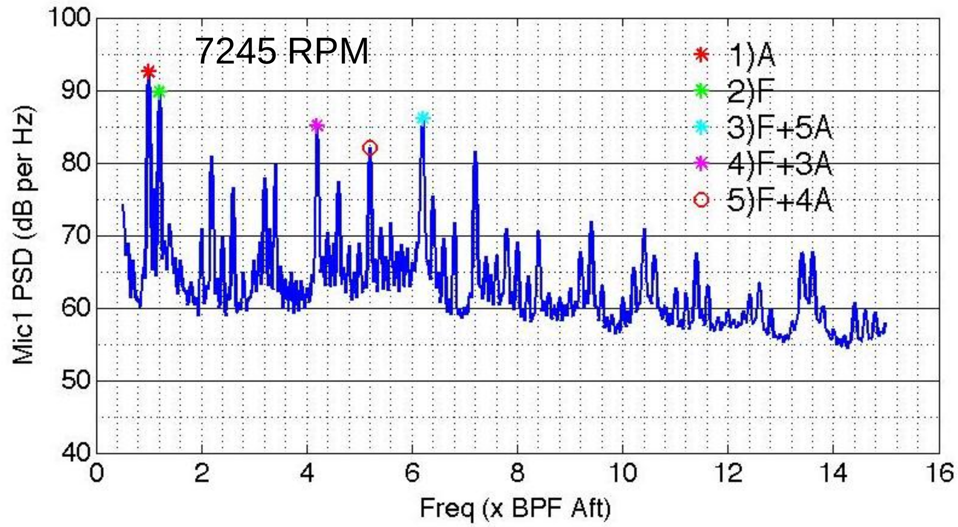
no pylon vs. pylon

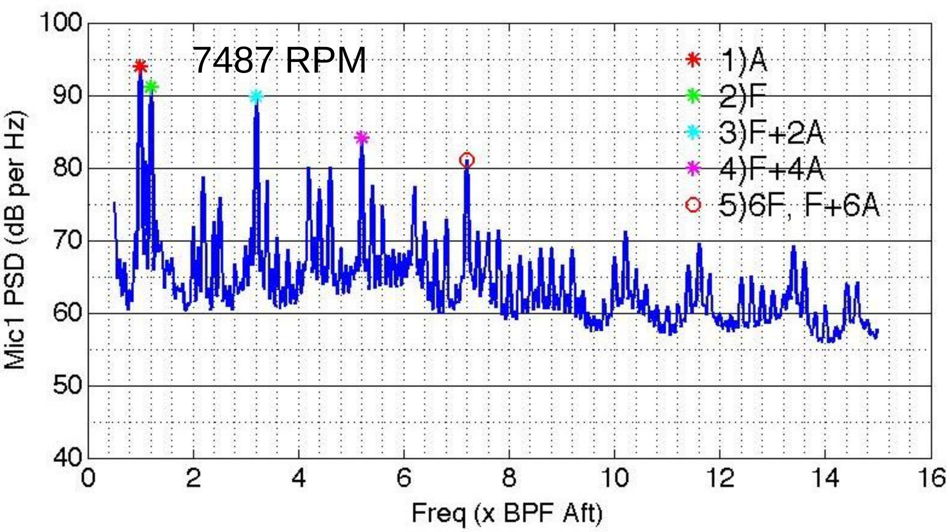
M=0.2, 0° AOA, approach, varying HP









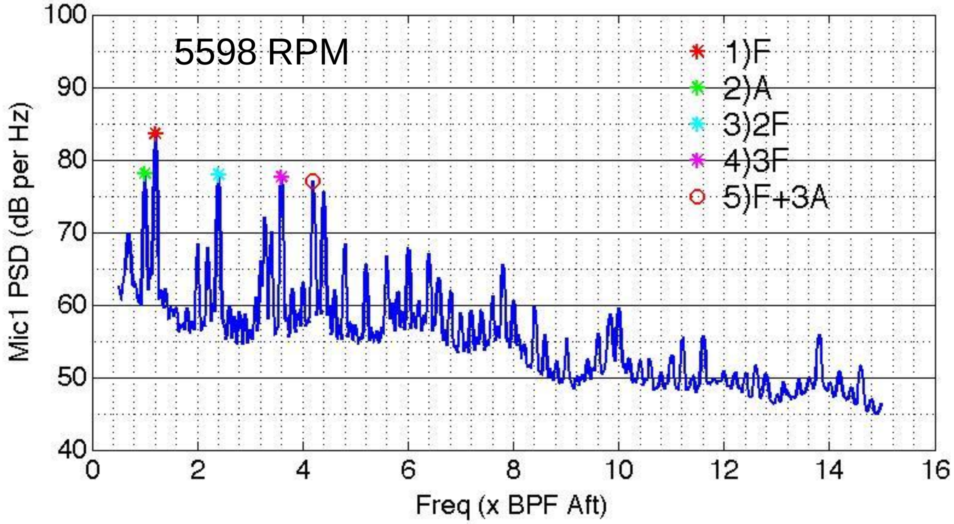


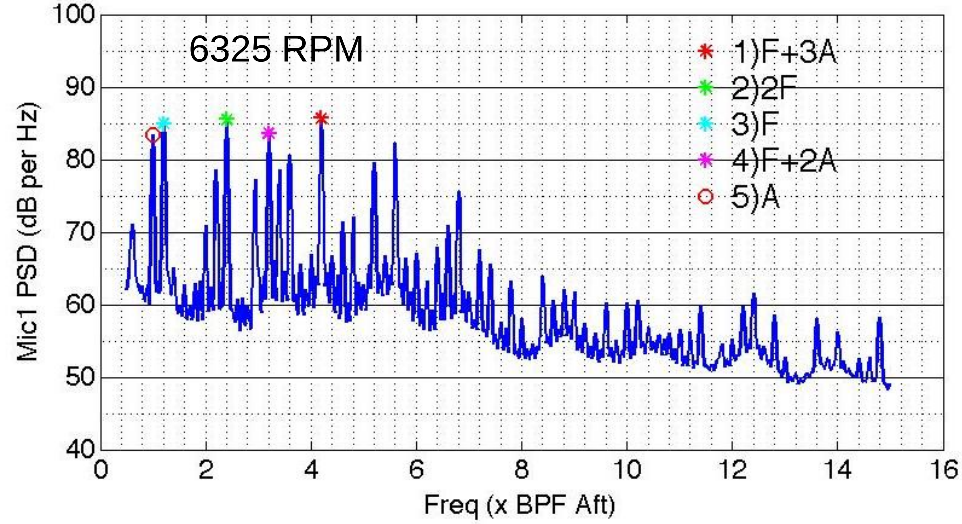
Without the pylon-

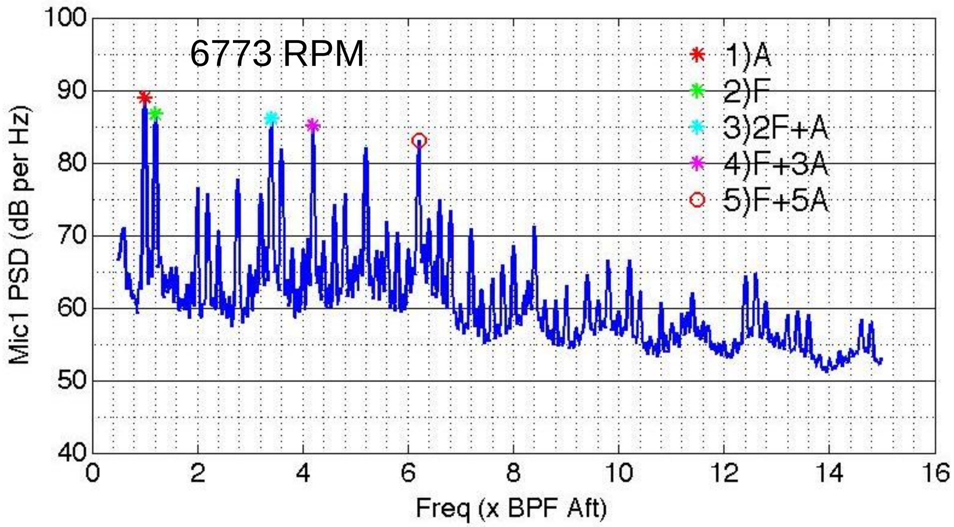
BPF tones become more important as HP increases

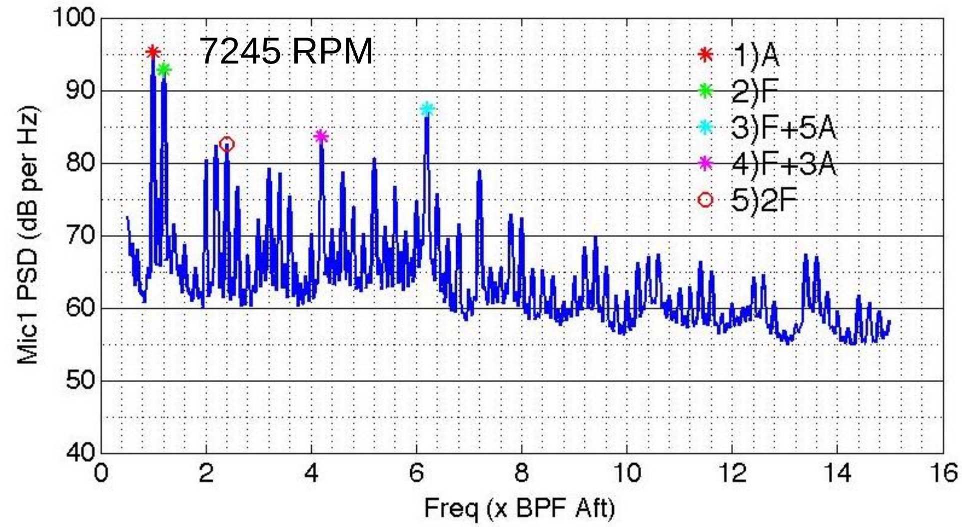
BPFA>BPFF

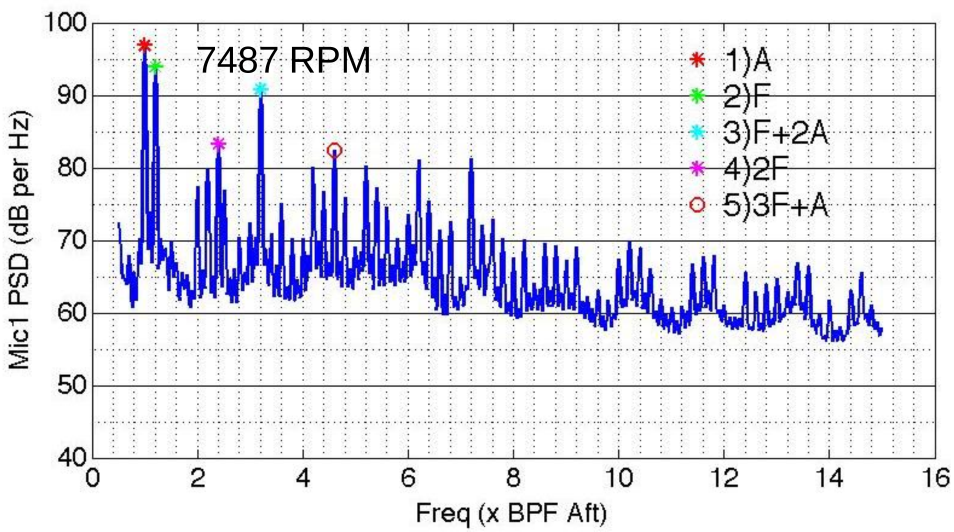
At high HP, F+xA interaction tones are important











With the pylon-

Both broadband and tones increase

BPF tones important even at low HP

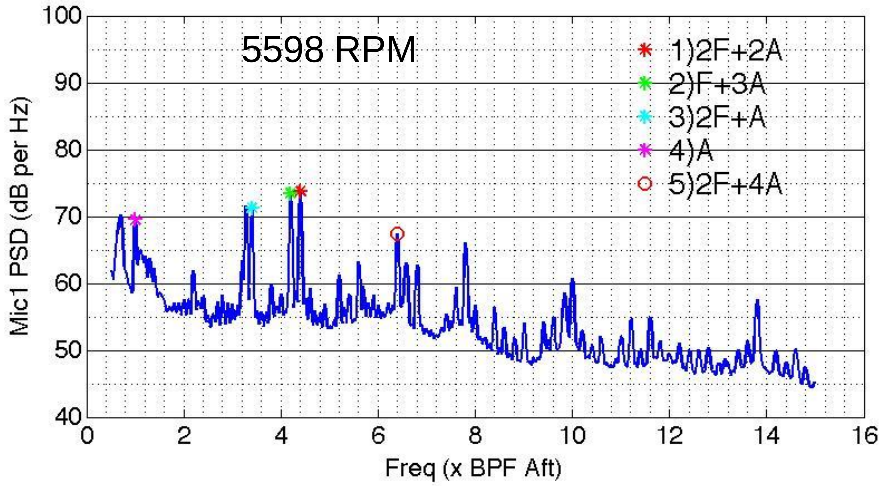
BPFF>BPFA at low HP, BPFA>BPFF at high HP

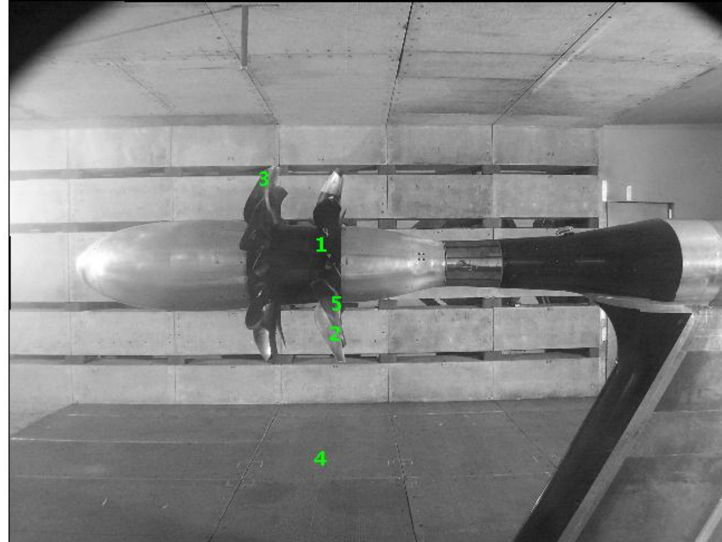
xF tones important at all speeds

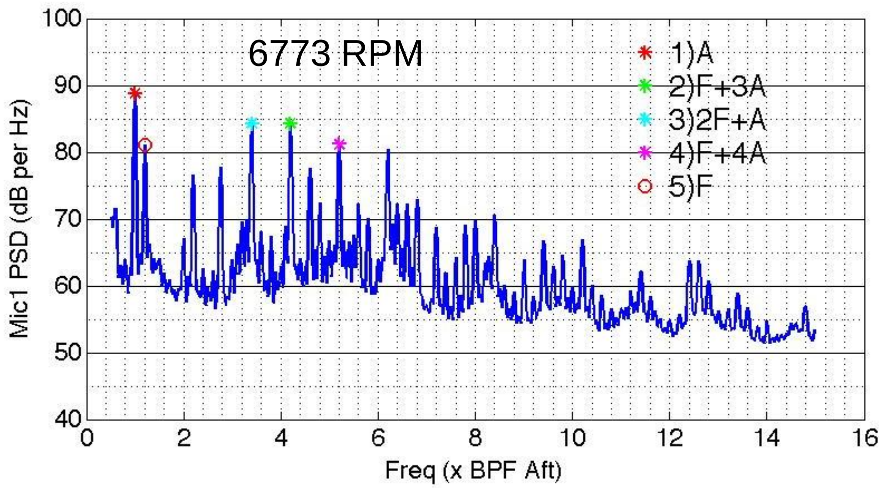
Comparison of Dominant Tone Location

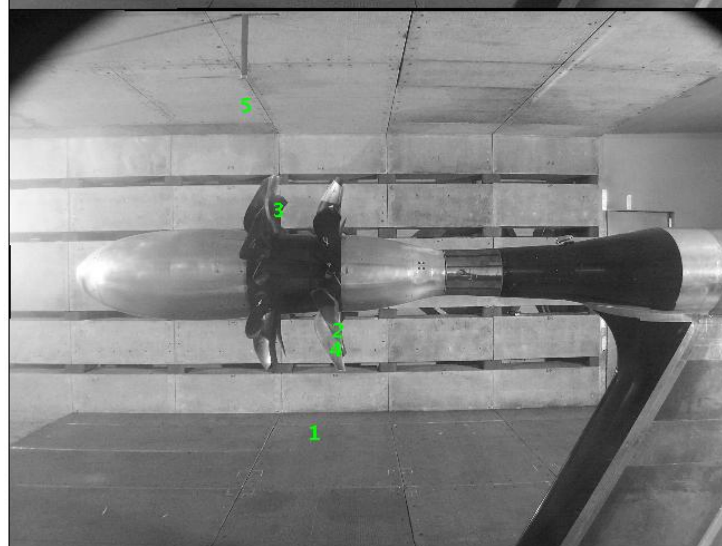
no pylon vs. pylon

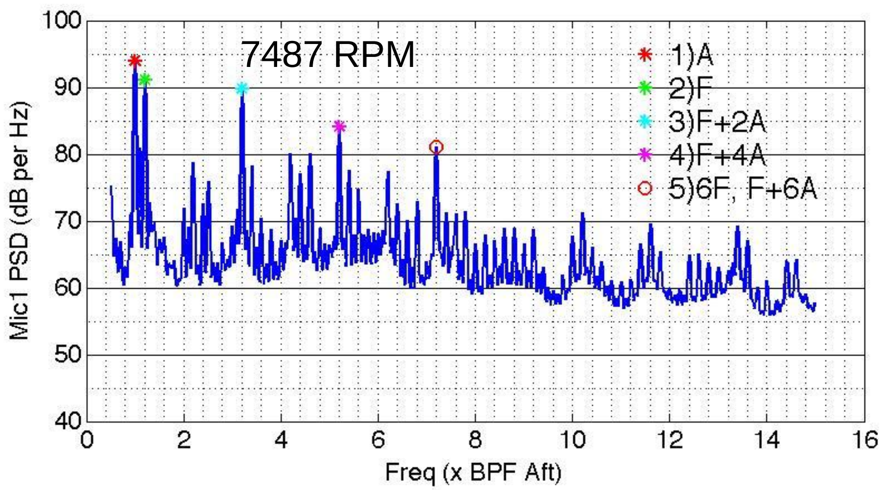
M=0.2, 0°AOA, approach, varying HP

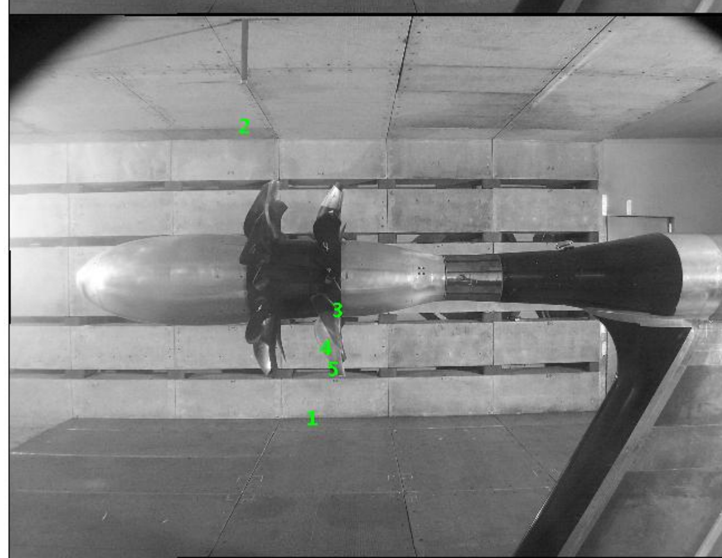








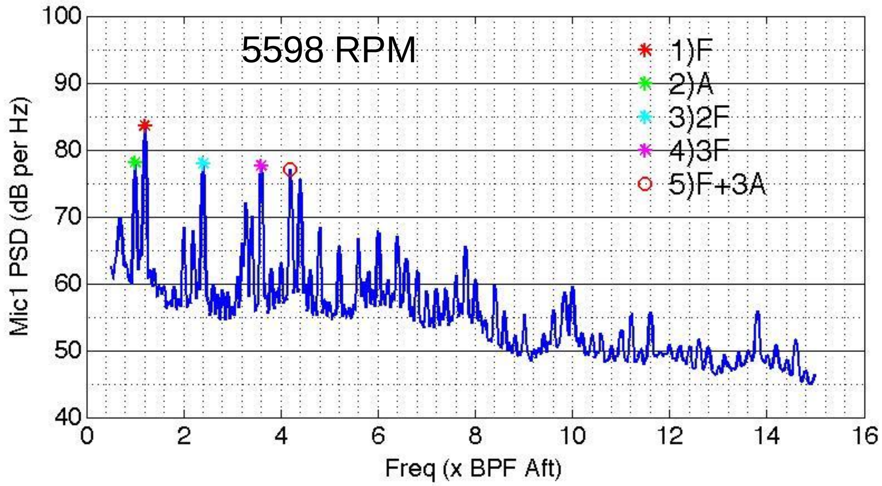


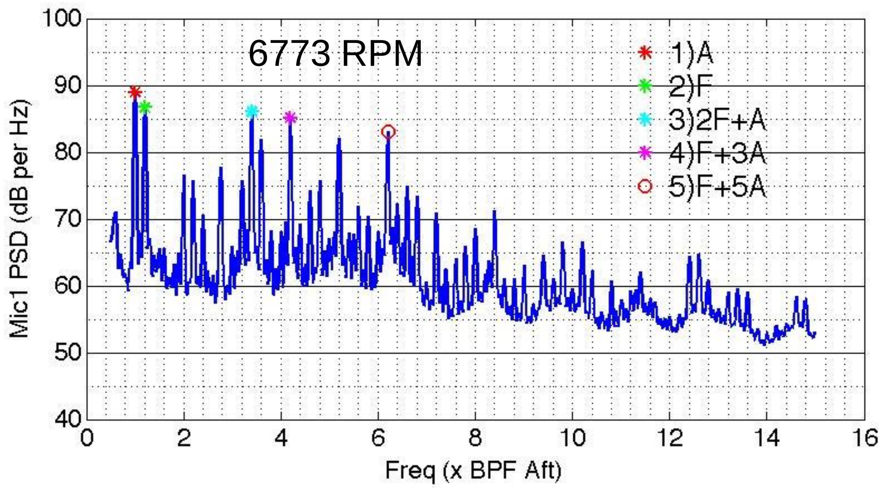


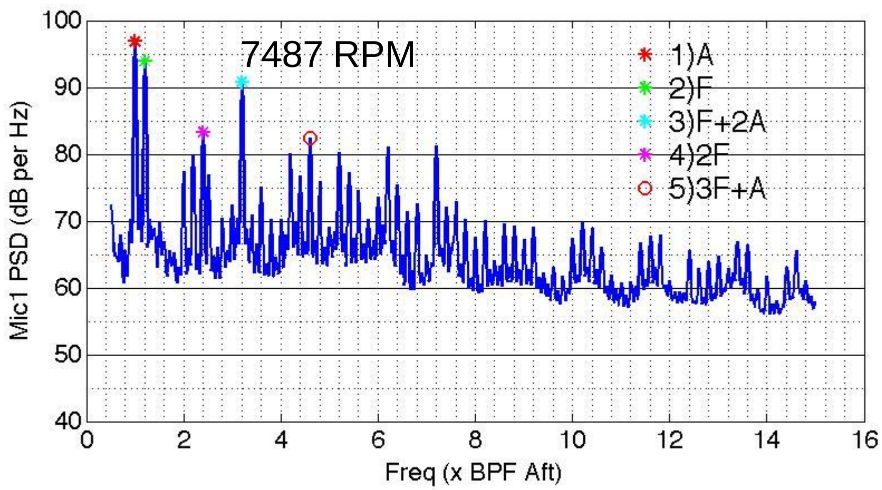
-The dominant tones are, for the most part, located on the side of the rig where the blade is rotating toward the phased array.

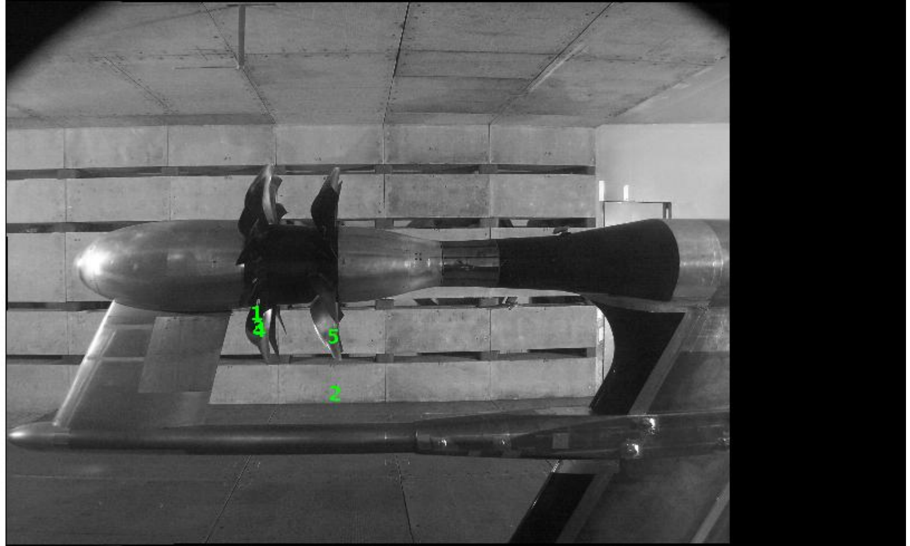
-A large percentage of the dominant tones are located on the aft rotor

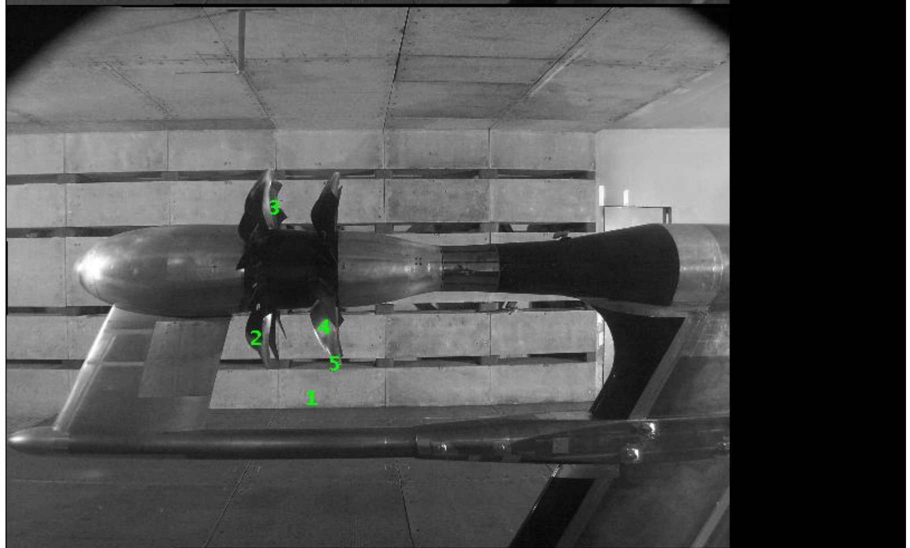
- The interaction tones seem to come from the rotor which has a higher multiple of its BPF in the interaction

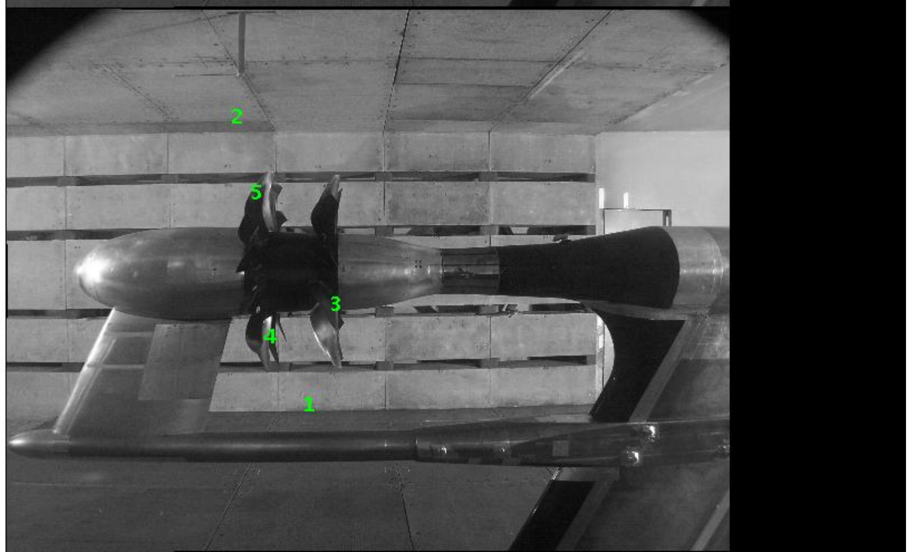












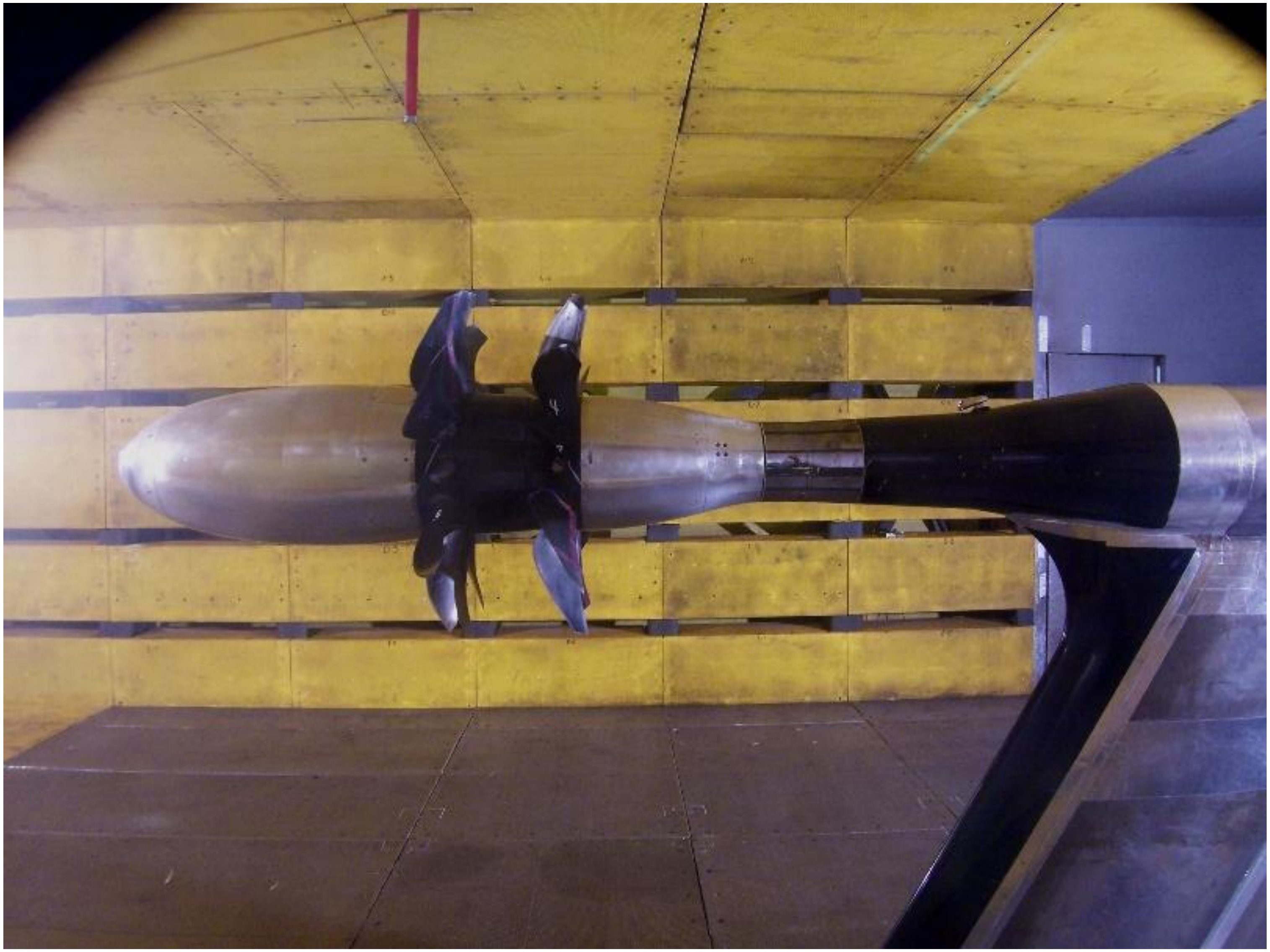
Unlike the no pylon case:

-The dominant tones are located on the lower side of the rig where the blade is passing the pylon, especially at lower HP

-A smaller percentage of the dominant tones are found on the aft rotor

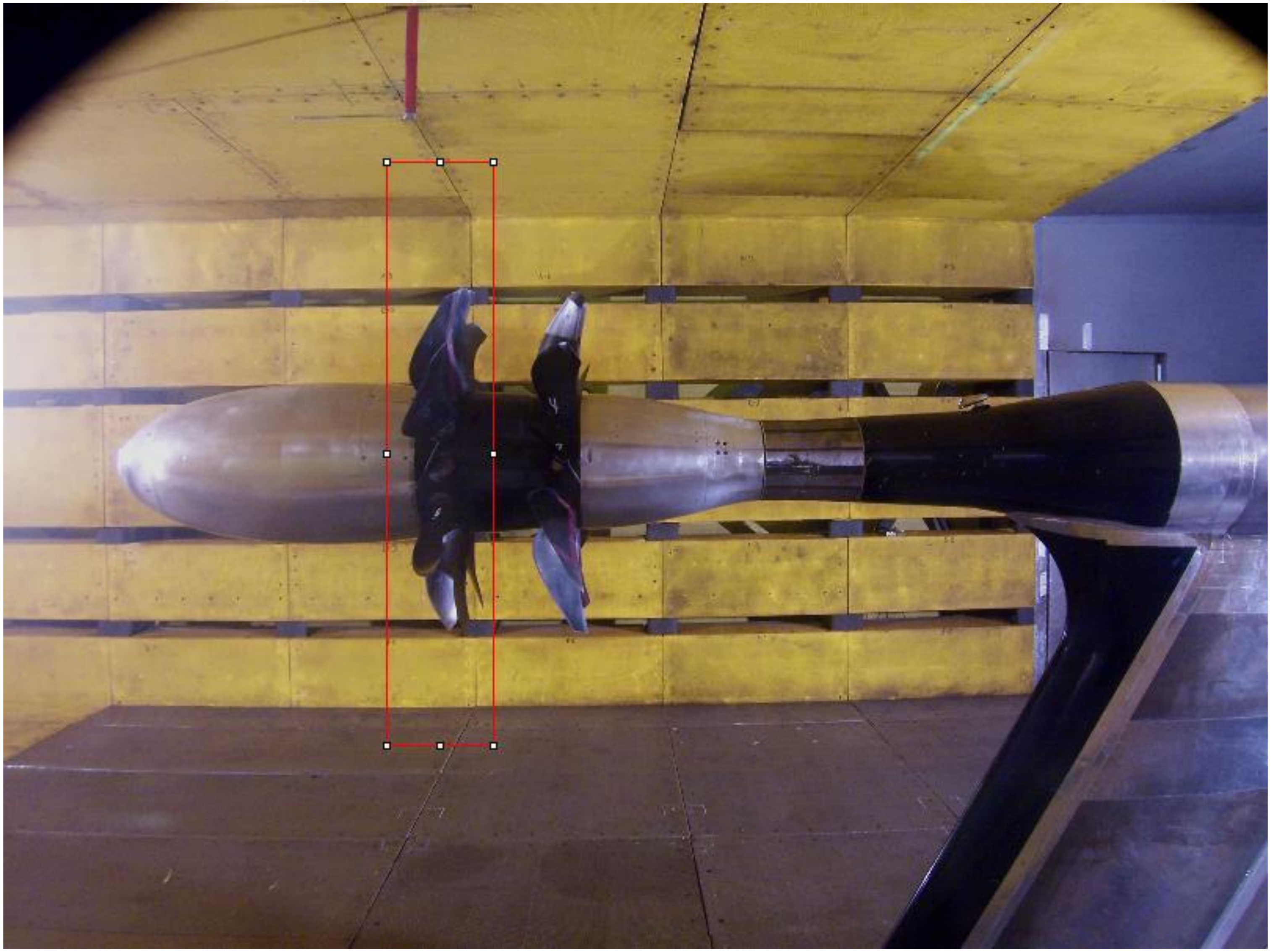
Regions of Interest

Can look for noise sources in entire image



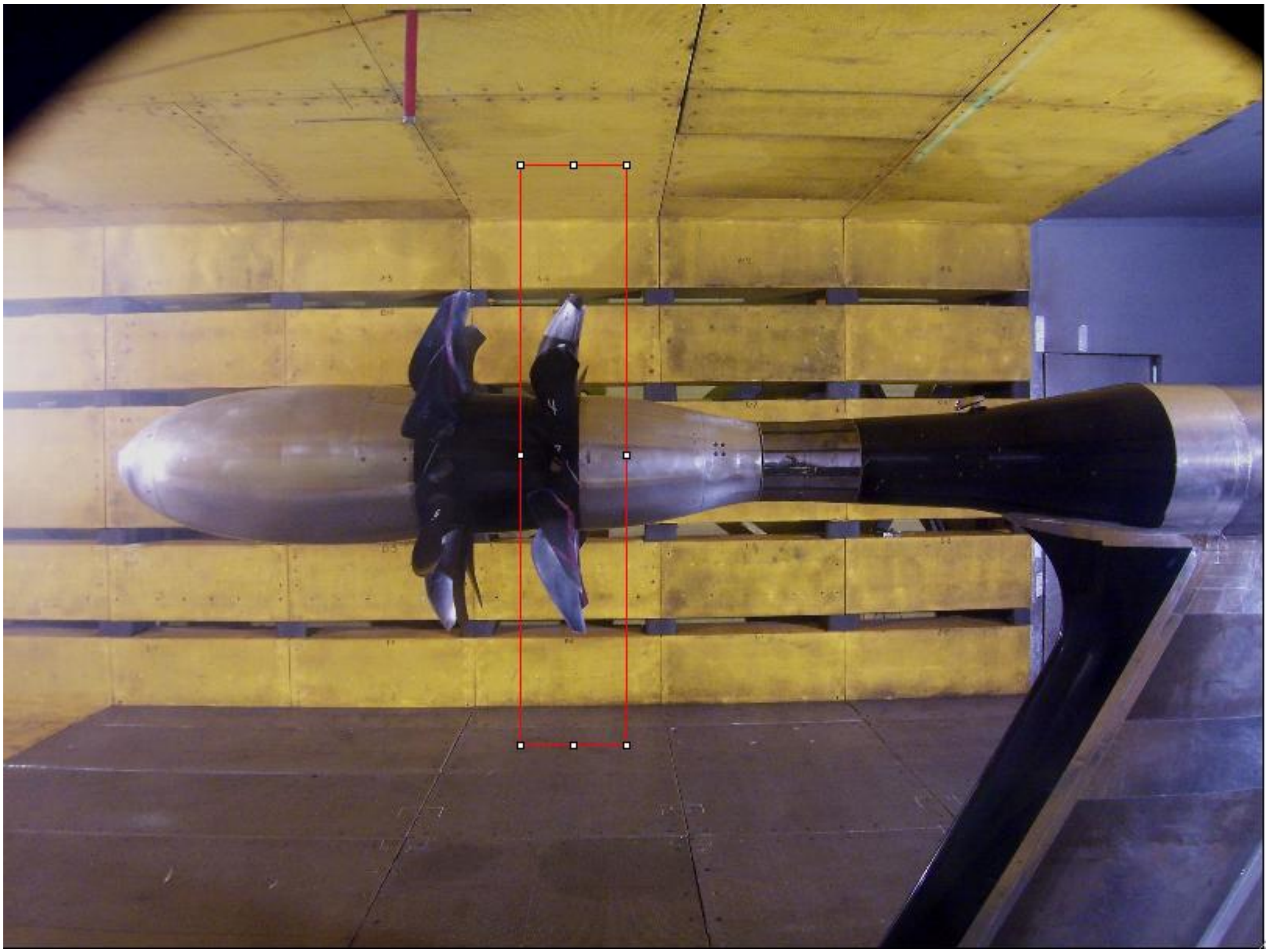
Regions of Interest

…or only around the front rotor



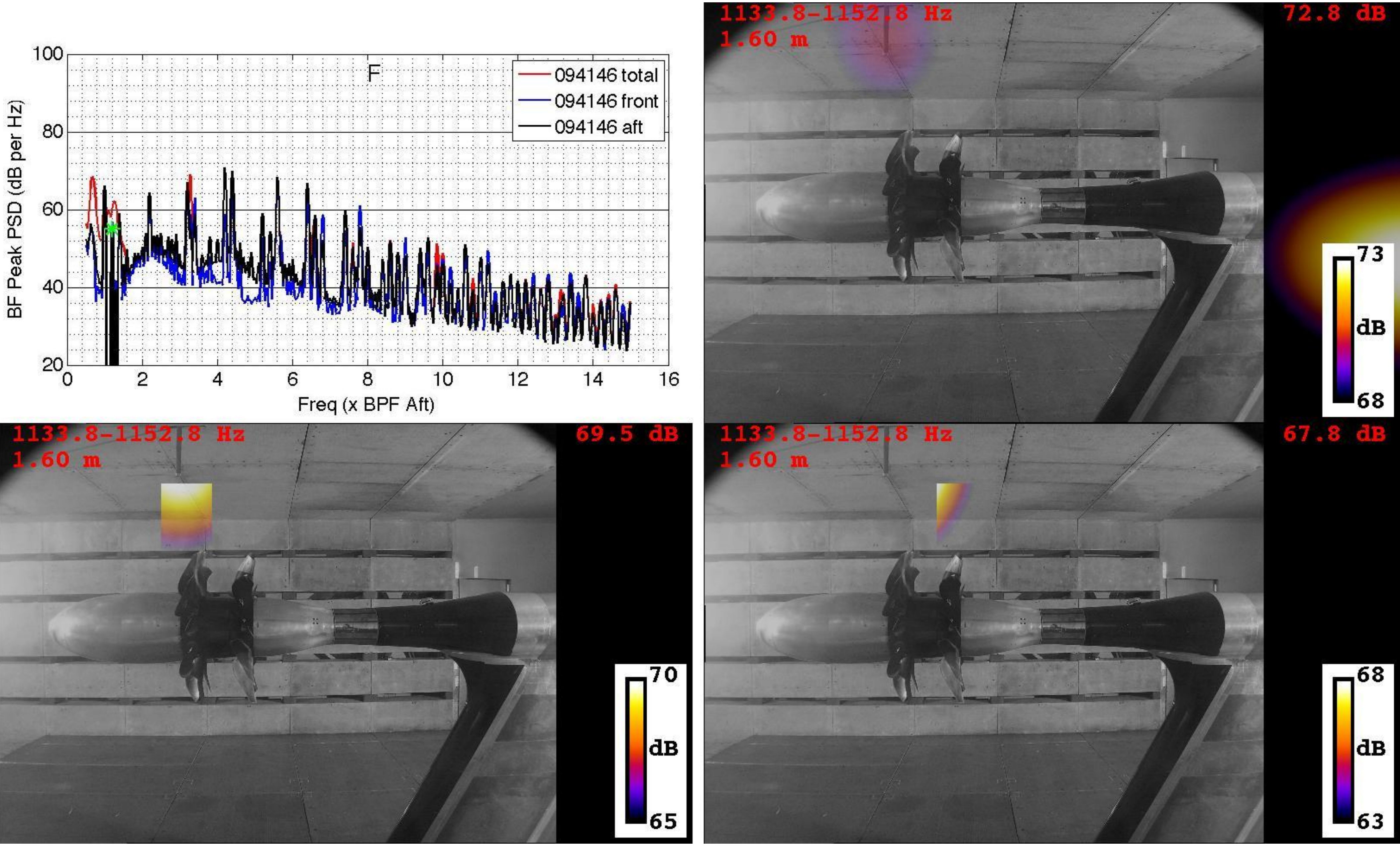
Regions of Interest

…or only around the aft rotor



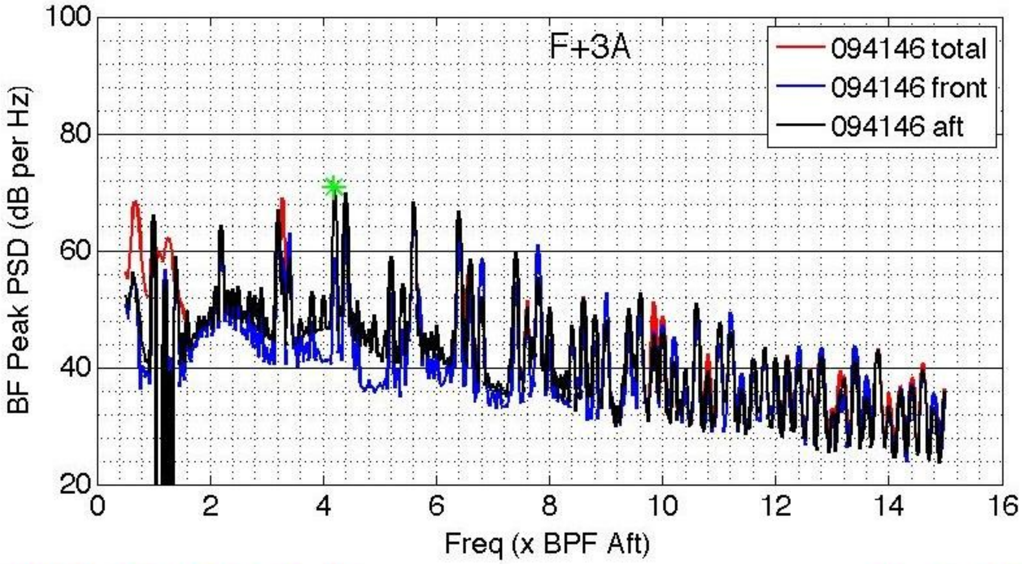
BPFF tone

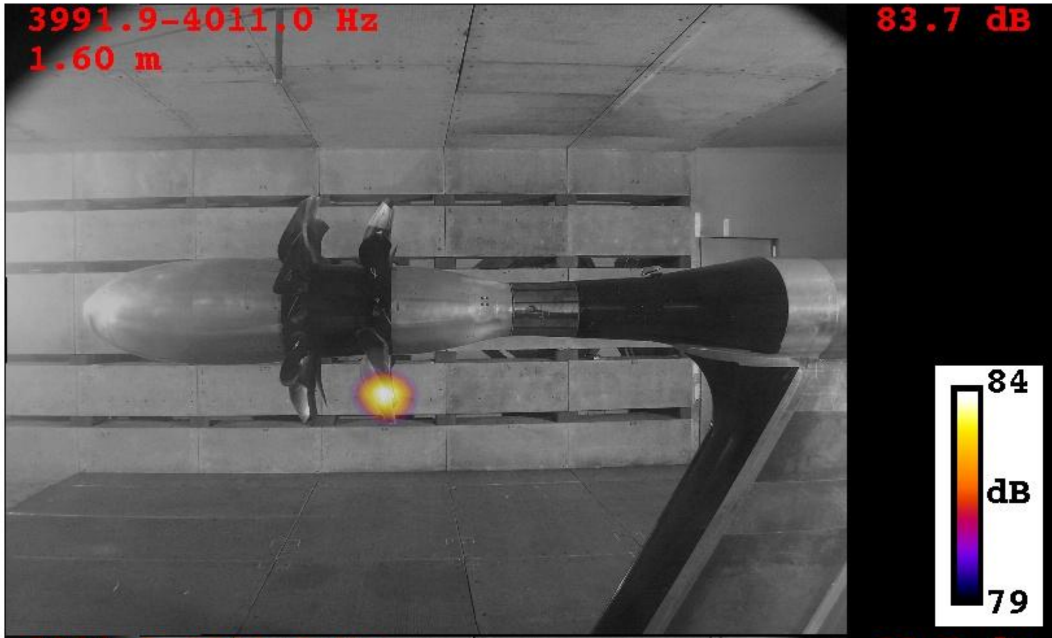
No pylon, Approach Blade Angle Settings , M=0.2, 0^0 AOA, 5598 RPM



F+3A Interaction tone

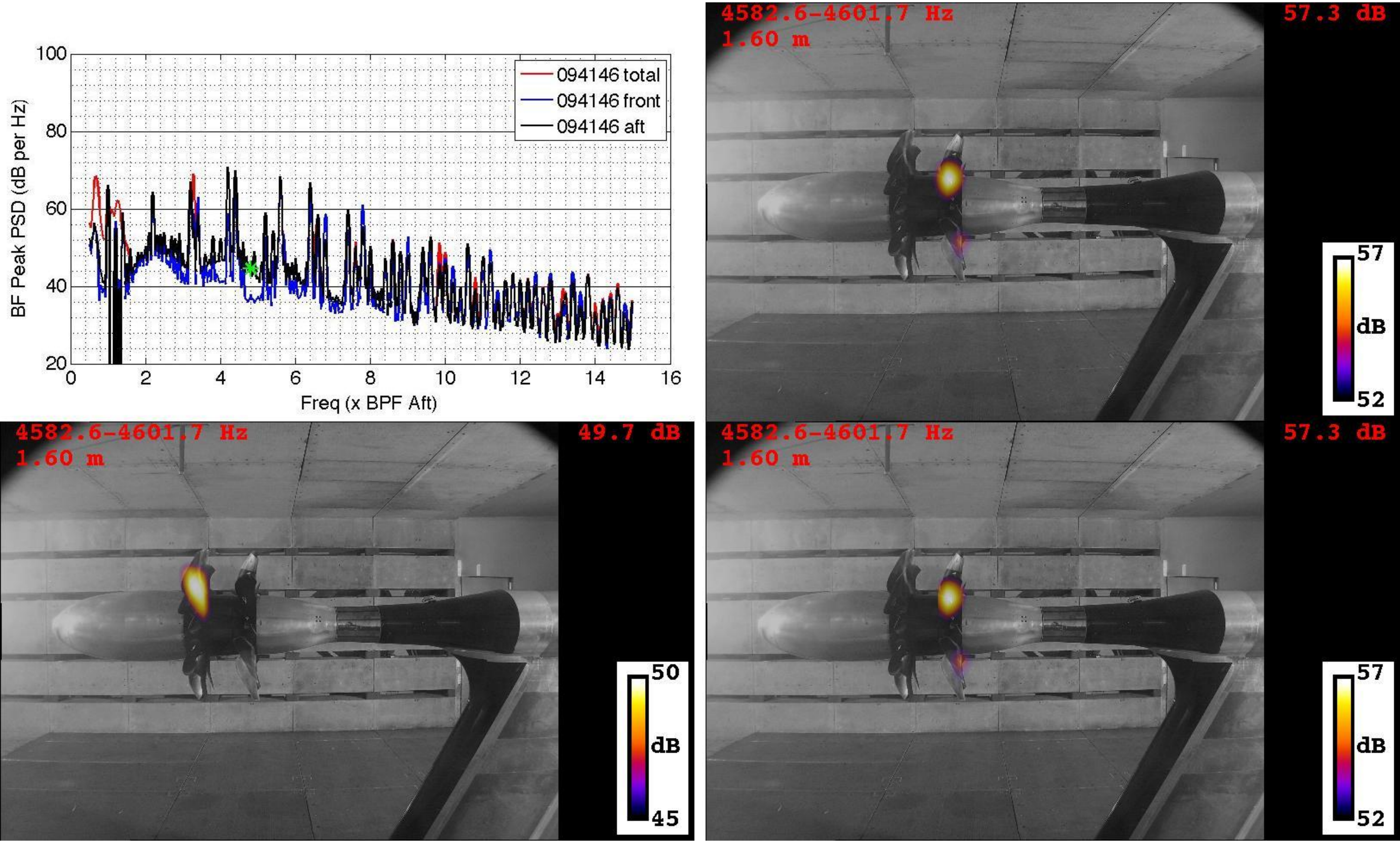
No pylon, Approach Blade Angle Settings , M=0.2, 0^0 AOA, 5598 RPM





Broadband noise

No pylon, Approach Blade Angle Settings , M=0.2, 0^0 AOA, 5598 RPM



Summary

Phased array data are presented for the GE Counter Rotating Open Rotor Model at 0° AOA, M=0.2, at the Approach condition blade angle settings.

Without a pylon:

1) interaction tones dominate over BPF tones at the design RPM
2) more broadband noise comes from the aft rotor than the front rotor at the design RPM
3) as RPM increases above the design speed: noise levels increase, more tones appear, and the BPF tones become more dominant. BPFA > BPFF. At high RPM, F+xA tones are important.
4) the tones tend to come from the side of the rotor rotating toward array (pressure side of the blades). Most tones come from the aft rotor. Dominant interaction tones tend to come from the rotor with the larger multiple in the interaction (ex: 3F+A from front, F+4A from back)

With a pylon:

1) at the design RPM, xF tones important
2) at the design RPM, BPFF>BPFA. At higher RPM, BPFA>BPFF
3) dominant tones located on the lower side of the rig, especially at low HP
4) dominant tones more evenly split between the two rotors
5) like the no pylon case, dominant interaction tones tend to come from the rotor with the larger multiple in the interaction

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