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On the effect of acceleration on trailing edge noise radiation from rotating blades

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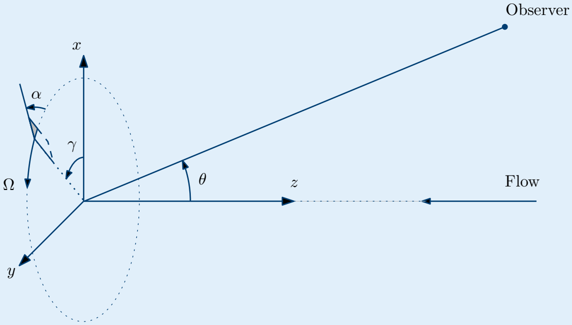
Outline

Background: isolated airfoils

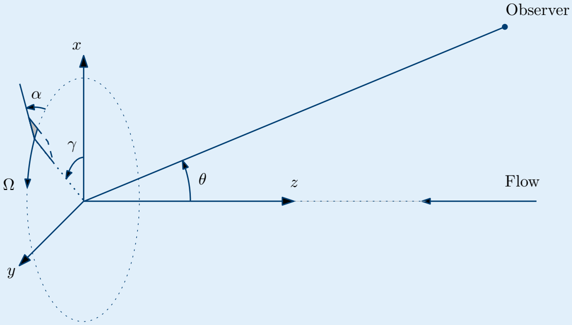
Amiet 1974, 1975, 1976

$$S'_{pp} = \boxed{a} \quad \boxed{|\Psi|^2} \quad \boxed{l_S} \quad \boxed{S_{qq}}$$

Background: rotating airfoils



Background: rotating airfoils



Schlinker and Amiet (1981)

$$\overline{S}_{pp}(\omega) = \frac{1}{T}\int_0^T S_{pp}(\omega, t)\,dt$$

Amiet's key idea

Lowson (1965)

$$p \sim \dot{F} + aF\dot{M}$$

$$\dot{F} \sim \omega' F \qquad \dot{M} \sim \Omega M$$

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Amiet's key idea: $\omega' \gg \Omega$

Lowson (1965)

$$p \sim \dot{F}$$

$\rightarrow$ Source in rectilinear motion

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Previous work: theory

Sinayoko, Kingan and Agarwal (AIAA 2012, arXiv 2013)

Formulations for time averaged PSD

Without acceleration:

$$\overline{S}_{pp} = \int \boxed{A} \quad \boxed{|\Psi|^2} \quad \boxed{l_y} \quad \boxed{S_{qq}} \; d\gamma$$

With acceleration:

$$\overline{S}_{pp} = \sum_m \boxed{B} \quad \boxed{|\Psi|^2} \quad \boxed{l_y} \quad \boxed{S_{qq}}$$

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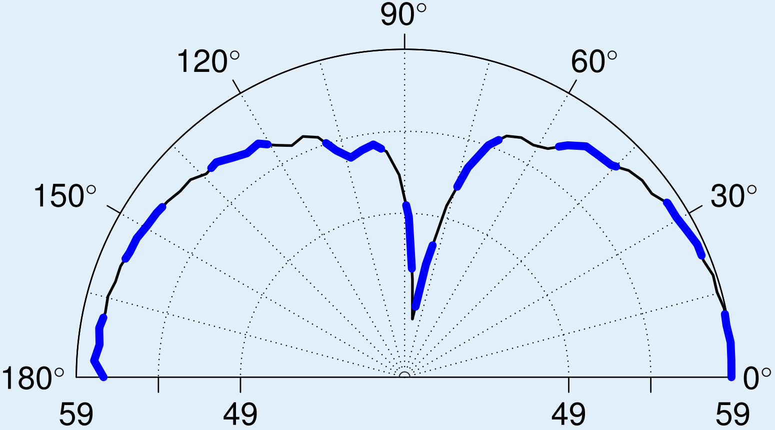
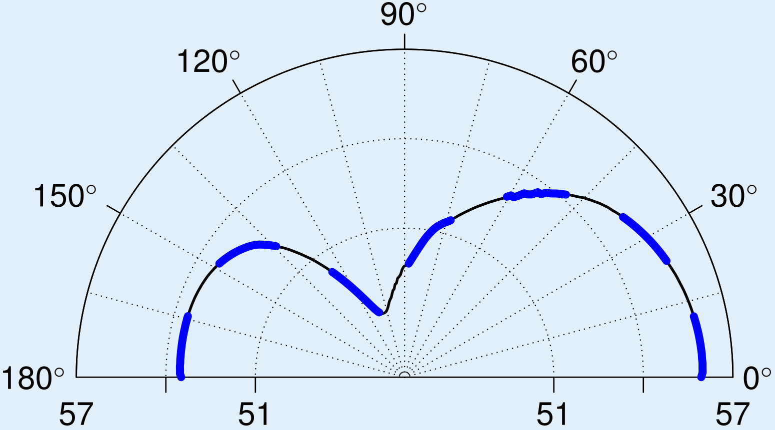
Previous work: results – Wind Turbine $\mathrm{kC} = 50$



Previous work: results – Propeller Cruise $kC = 50$ (2013)



Objectives

- Range of validity?
- Is error due to acoustic lift or acceleration?

Outline

Background

Point source model

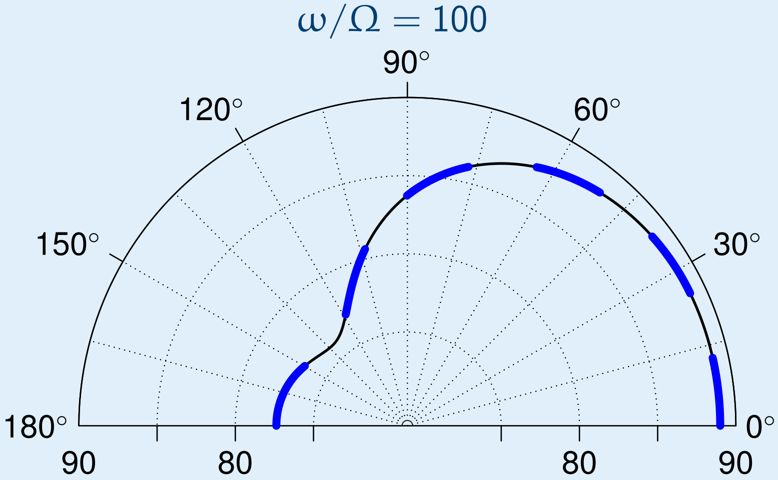
Distributed source model

Conclusions

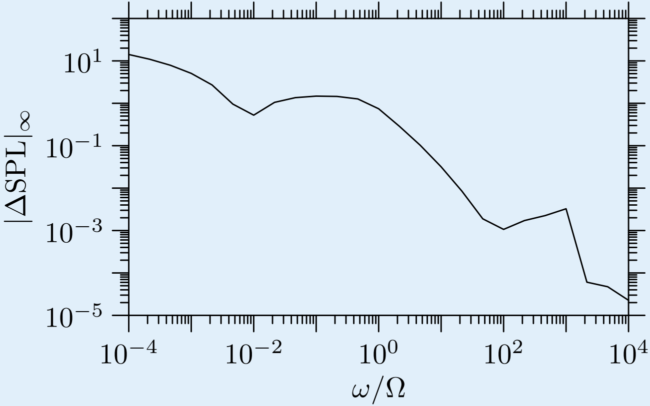
Theory

- Rotating dipole
- Solved exactly with or without acceleration
- Source spectrum by Chou and George (1984)
- Not using the acoustic lift

Directivity: propeller at cruise



Sound pressure level



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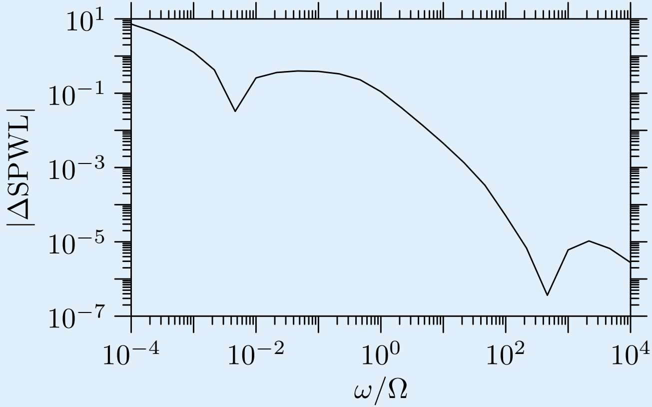

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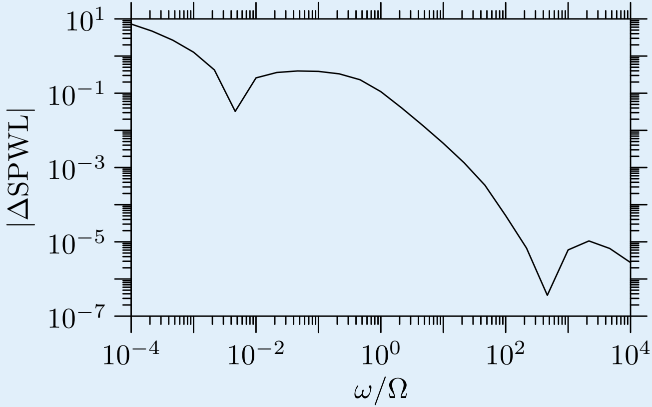


$\rightarrow$ Works even at low frequencies...?

Instantaneous PSD: theory

Inverse Fourier transform over ϖ of cross-correlation function

$$R_{pp}(\omega, \varpi) = E[p(\omega + \varpi/2)p^{\star}(\omega - \varpi/2)]$$

Instantaneous PSD: theory

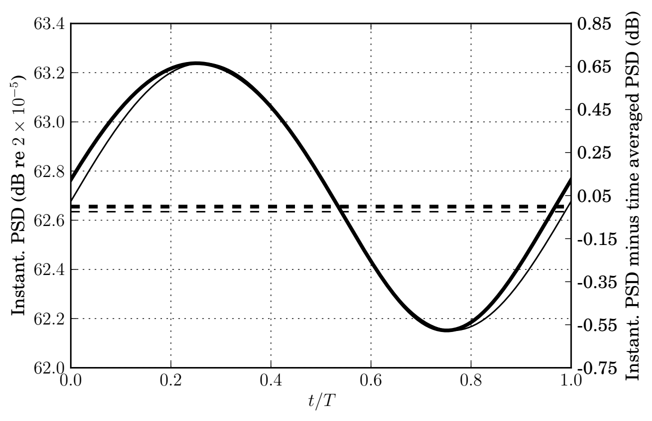
Inverse Fourier transform over ϖ of cross-correlation function

$$R_{pp}(\omega, \varpi) = E[p(\omega + \varpi/2)p^{\star}(\omega - \varpi/2)]$$

$$\rightarrow \quad S_{pp}(\omega, t)$$

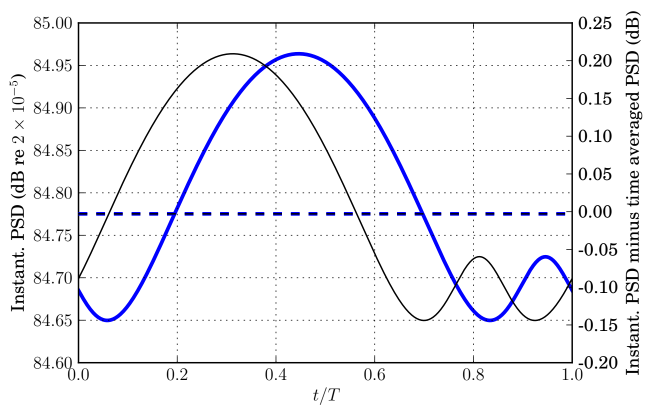
Instantaneous PSD: wind turbine

$\omega/\Omega = 10$



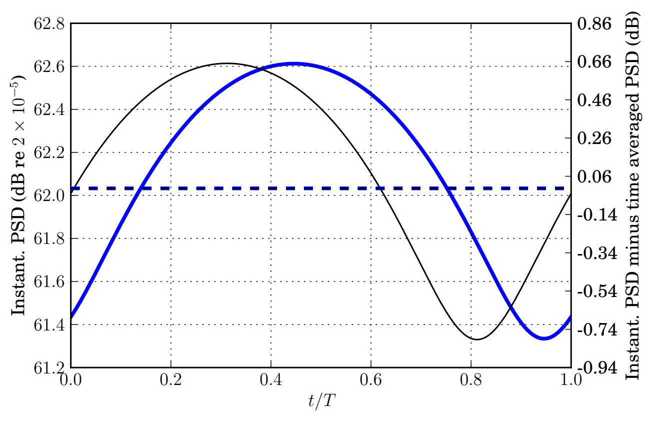
Instantaneous PSD: propeller at cruise

$$\omega/\Omega = 10$$



Instantaneous PSD: propeller at cruise

$$\omega/\Omega = 1$$



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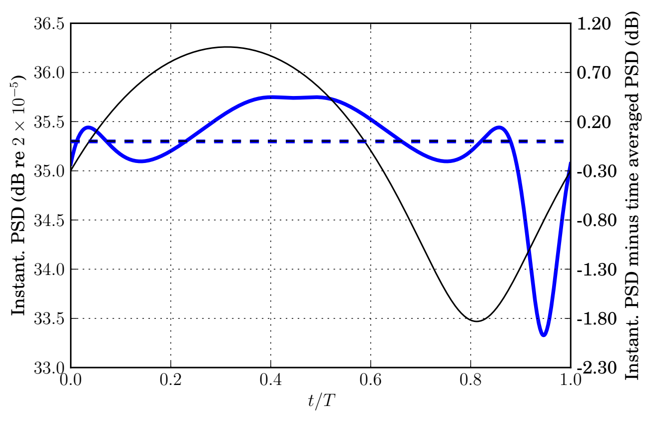
Instantaneous PSD: propeller at cruise

$\omega/\Omega = 0.1$



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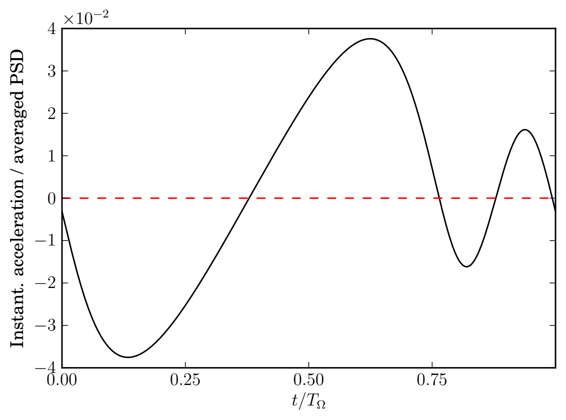

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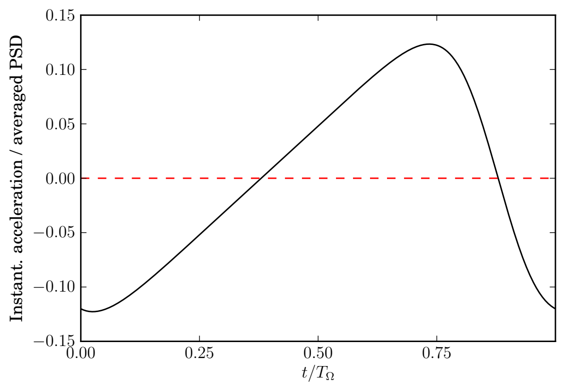

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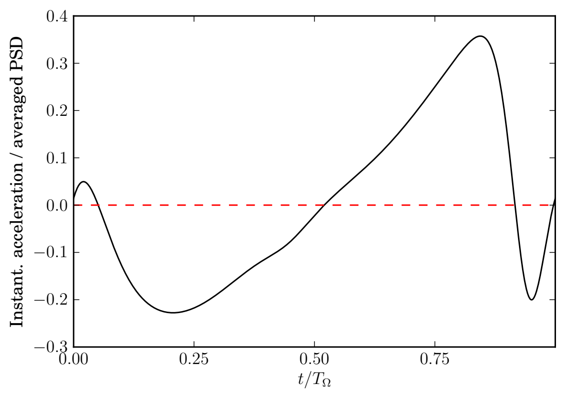
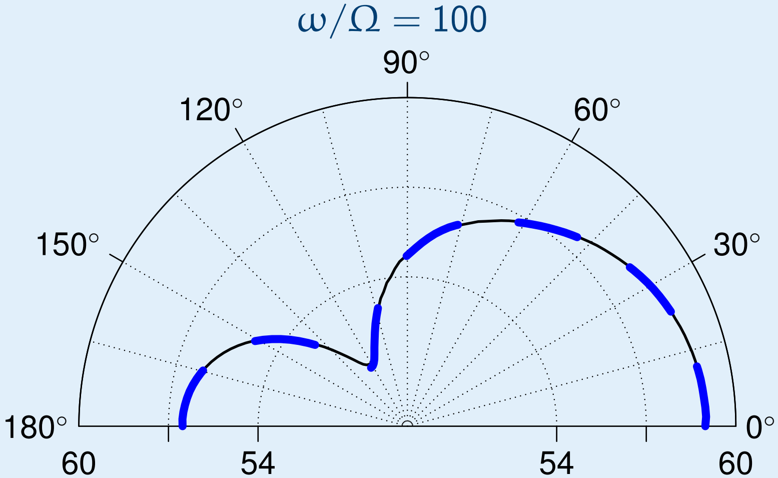
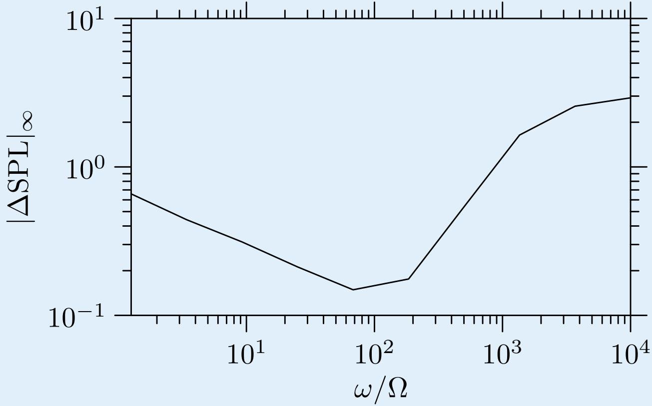


Outline

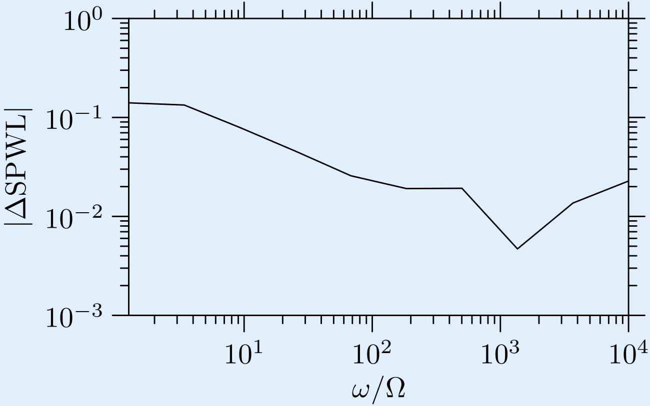
Directivity: propeller at cruise



Sound pressure level



Sound power level



Instantaneous PSD: propeller at cruise

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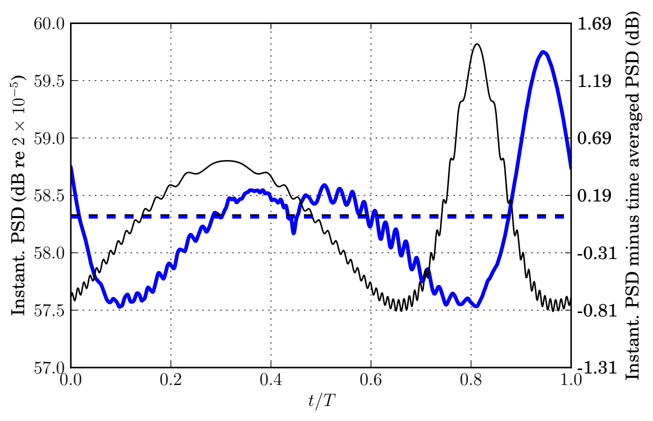

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Instantaneous PSD: propeller at cruise

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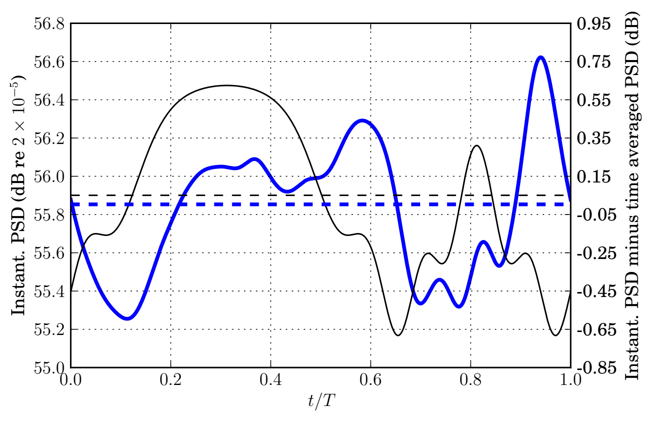

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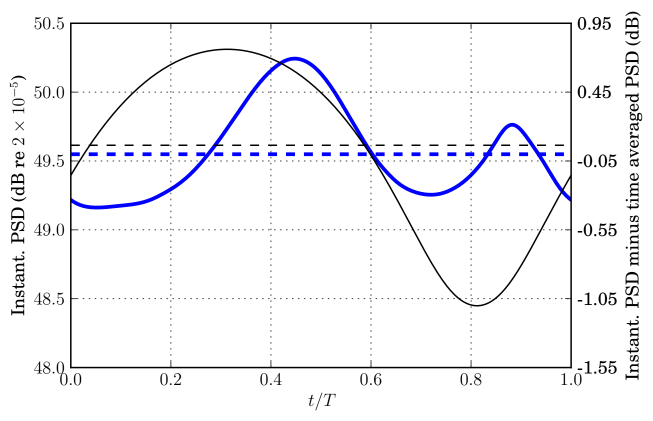

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Conclusions

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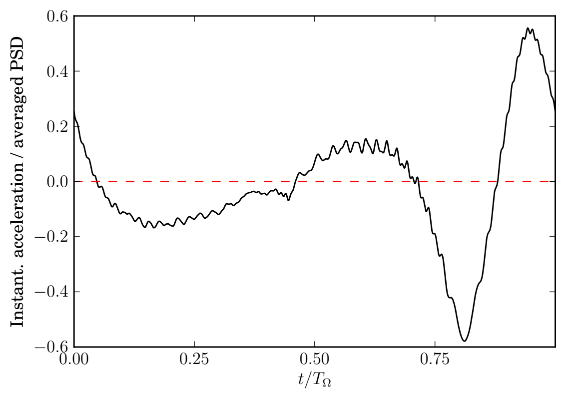
Conclusions

1. Schlinker and Amiet's theory is applicable even at high subsonic speeds
2. It is most accurate when $\omega \gg \Omega$
3. It remains accurate at much lower frequencies $\omega \approx \Omega$
4. The limiting factor is likely to be the acoustic lift, not the effect of acceleration.

Thank you!

Instantaneous PSD: propeller at cruise

$$\omega/\Omega = 10$$



Instantaneous PSD: propeller at cruise

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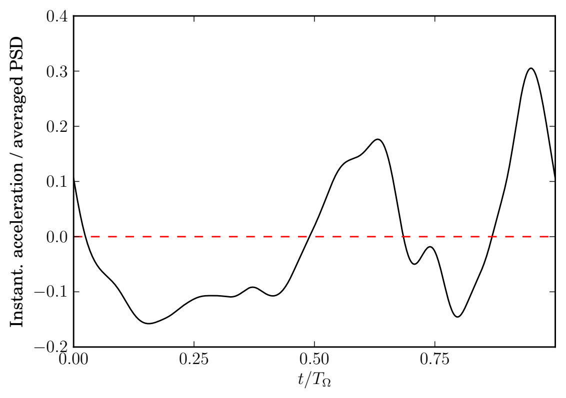

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Instantaneous PSD: propeller at cruise

$\omega/\Omega = 0.1$