BEHAVIOR AND DIAGNOSTIC ANALYSIS FOR AIRCRAFT ENGINES

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ESR 15
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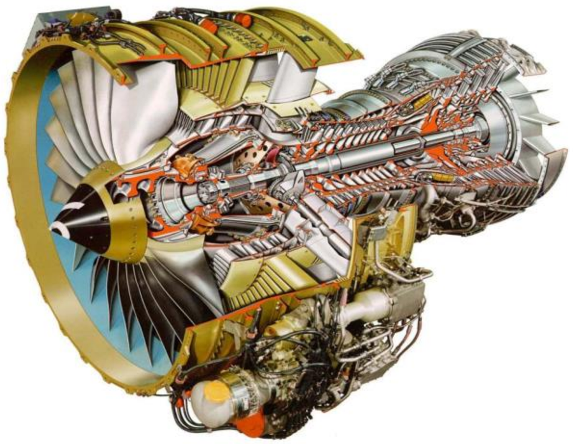
Why Aircraft Engine Diagnostics?

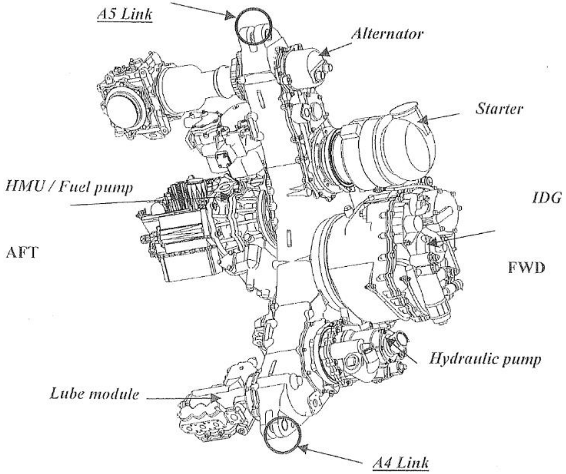
An Aircraft Environment

Aircraft Engine → Multi subsystems / Multi sources →

- Radial Drive Shaft
- Hand Cranking
- Integrated Drive Generator
- High Pressure Shaft
- Accessory Gear Box
- …

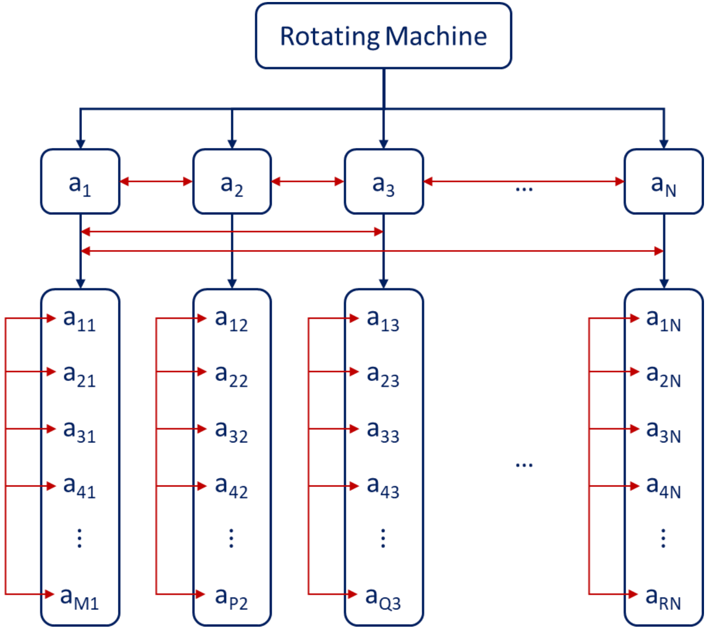
+ Aerodynamics Contribution





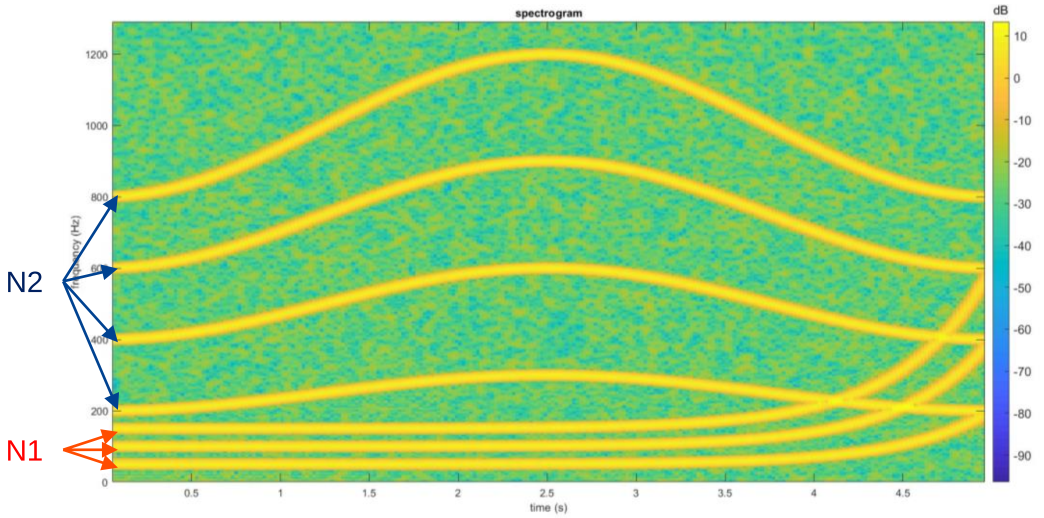
Mechanical Fault Characteristics

- **Each subsystem consists of several mechanical component**
- **Each mechanical component rotates at given frequency**
- **Each corresponding fault frequency is related to the component base frequency**
- **Several subsystems + Several harmonics = Several interferences**
- **What if the component base frequency is not constant?**

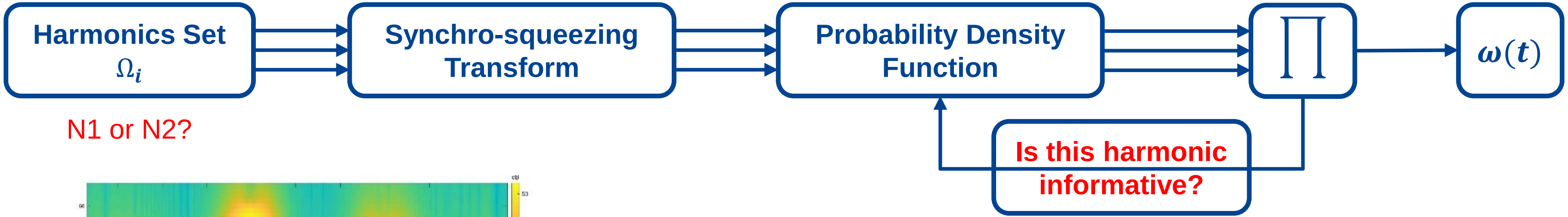


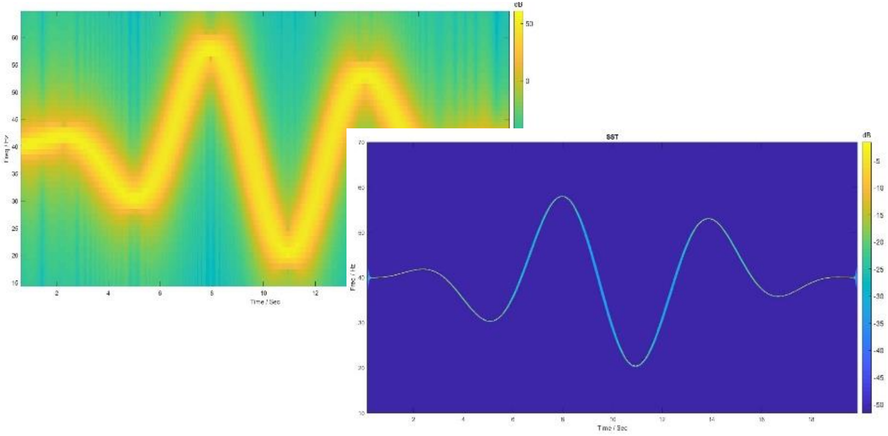
Instantaneous Angular Speed (IAS) Estimation

- **Frequency characteristics varying over time**
  - N1 or N2?
- **Characterization of $\omega(t)$**
  - Repetitive profile due to harmonics
- **Noisy Harmonics**
  - Signal to noise ratio and interferences

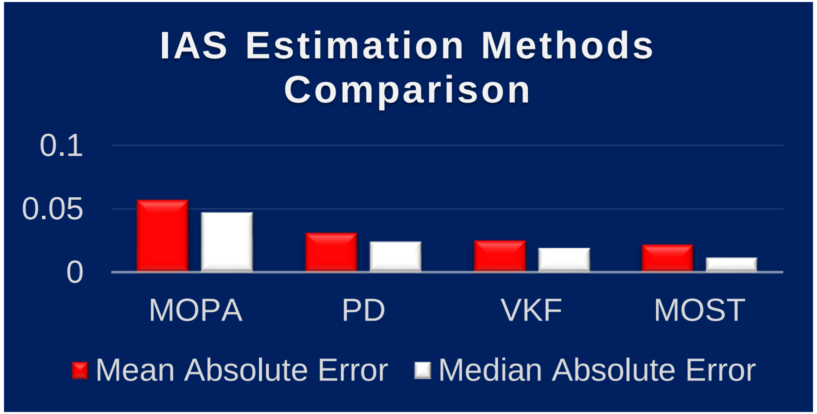


Multi Order Synchro-squeezing Transform





$$S(t,f) \rightarrow S(t,\omega(t))$$



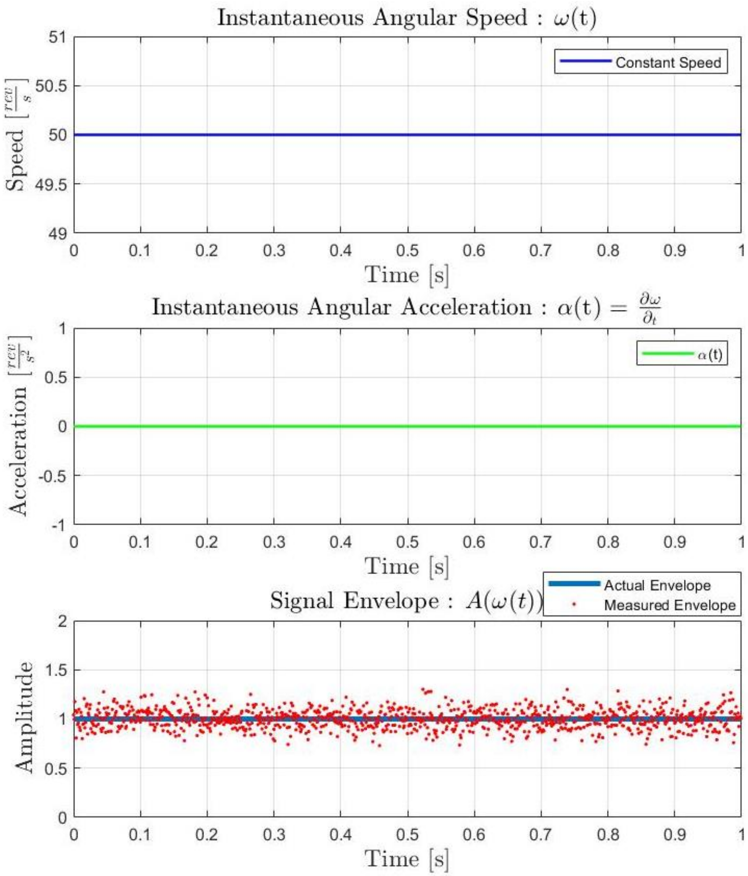
Components Signatures

- **Model :** $y(t) = A(t)e^{j\theta(t)} + \nu(t)$

- **For Stationary Signals :**

- $\frac{\partial A(\omega(t))}{\partial \omega} = \frac{\partial A(t)}{\partial t} = \varepsilon(t)$

Resulting an uncertainty error variance of : σ_{ε}^{2}



Components Signatures

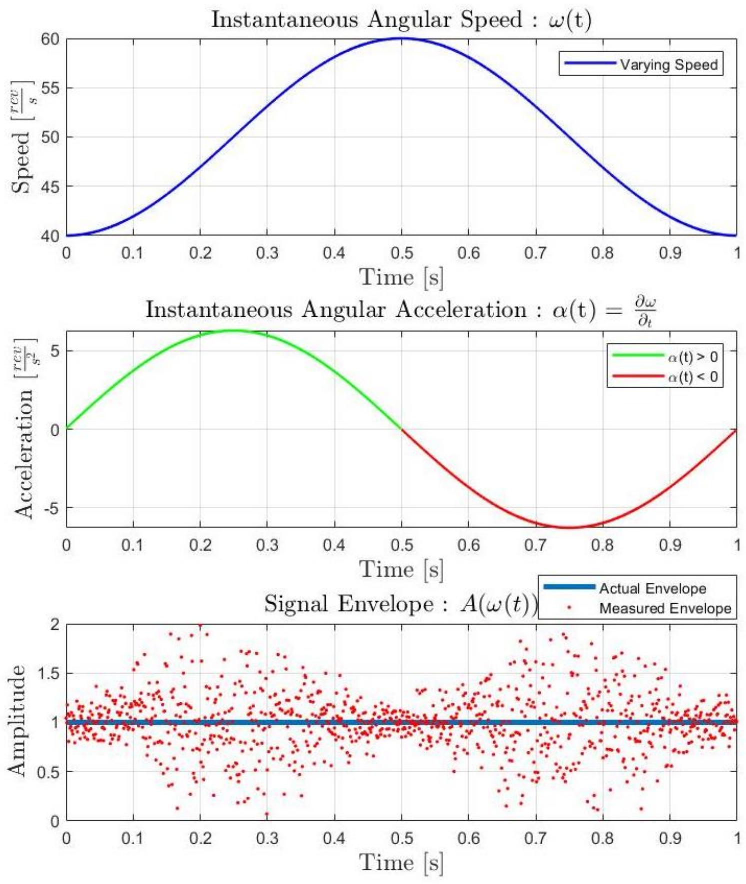
- **Model :** $y(t) = A(t)e^{j\theta(t)} + \nu(t)$

- **For Non Stationary Signals :**

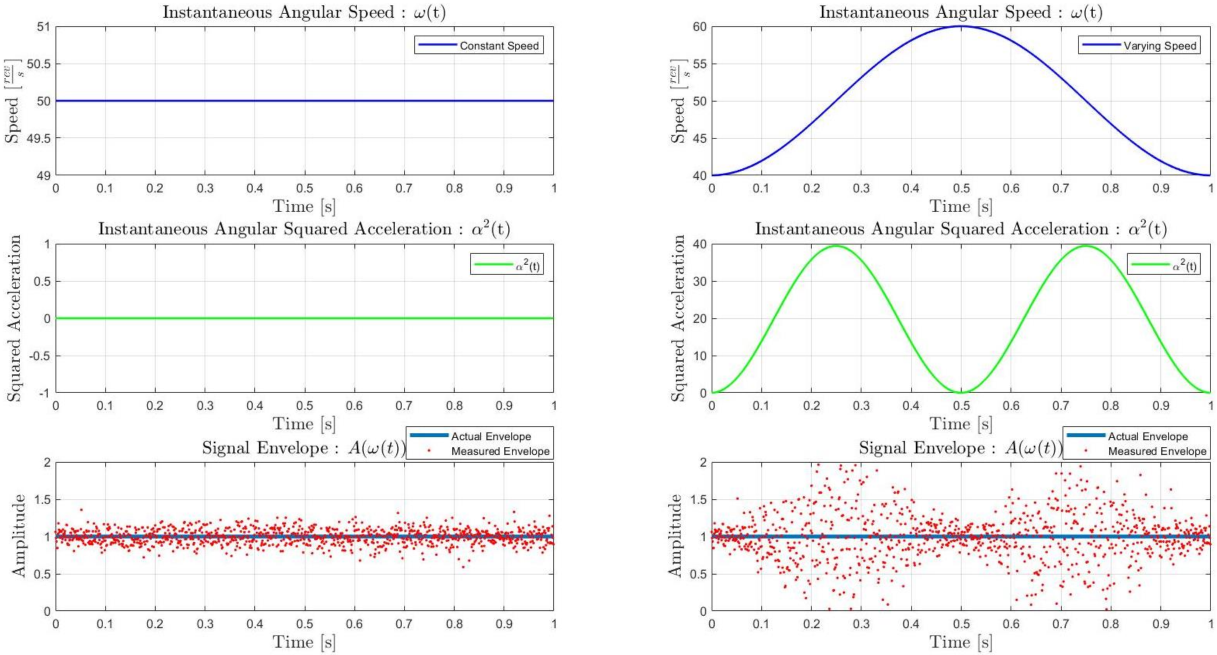
- $\frac{\partial A(\omega(t))}{\partial \omega} \neq \frac{\partial A(t)}{\partial t} = \varepsilon(t)$

$\rightarrow \frac{\partial A(\omega)}{\partial t} = \alpha \times \varepsilon(t)$

Resulting an uncertainty error variance of : $\alpha^2 \sigma_\varepsilon^2$



Components Signatures



Stationary
Non Stationary

A More Generic Interpretation : $\boldsymbol{error\ variance = \sigma_\varepsilon^2 + \alpha^2\sigma_\varepsilon^2 = (1+\alpha^2)\sigma_\varepsilon^2}$

Discussion and Conclusion

- **Upcoming works**
- Deterministic component extraction
- Envelope analysis

- **Component Diagnosis**
- Subsystem health state evaluation
- Fault localization and identification

- **Industrial Applicability**
- Kinematics and Frequency band a priori knowledge
- Estimation of both noise and uncertainty errors

THANK YOU

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