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InnoTesting 2014

Future Technologies and Processes for Simulation and Testing

Wildau

February 20 - 21, 2014

Validation of Tip Timing Blade Vibration Measurement Systems with Synthetic Signals

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Siemens AG Energy

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Motivation

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- GT/ST mechanical integrity is mandatory for safety
- TT systems are essential components for GT integrity evaluation
- TT systems are cost effective in comparison to traditional strain gauge telemetry systems
- TT systems are reliable and maintenance free systems
- TT systems can be used as life time monitoring systems for turbine and compressor health and maturing measure
- TT measurements delivering blade individual informations

TT = Tip Timing

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TT Systems are Measurement Systems

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- all measurement systems to be used for GT & ST evaluation and monitoring must be able to be certified according to ISO 9000

- all measurements must be traceable to national/international standards

How this can be accomplished for TT systems ?

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TT-Measurement Pulse Train Signals

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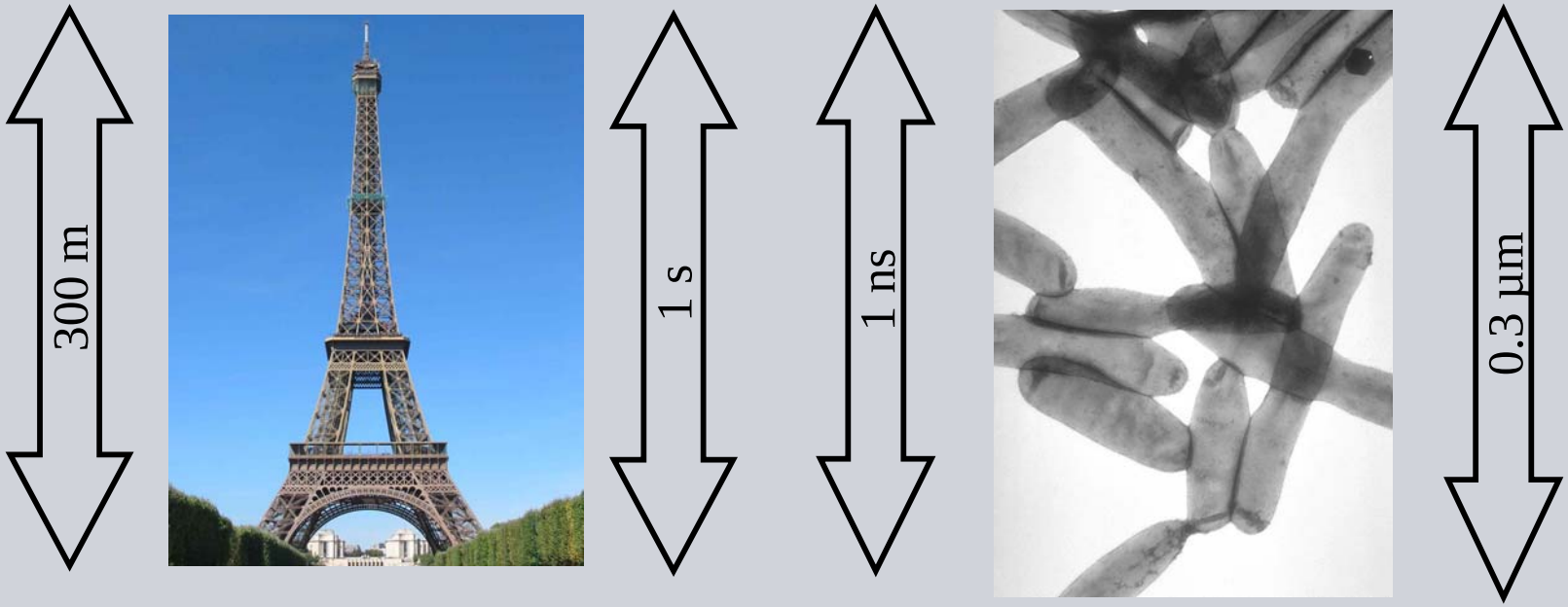
TT Systems are Operating at Physical and Mathematical Borderlines:

What is a nano second ?

if	1 second	is equivalent to the Eiffel tower height with	300 m
then	1 nanosecond	is equivalent to the length of a Legionella bacteria with	0.3 µm



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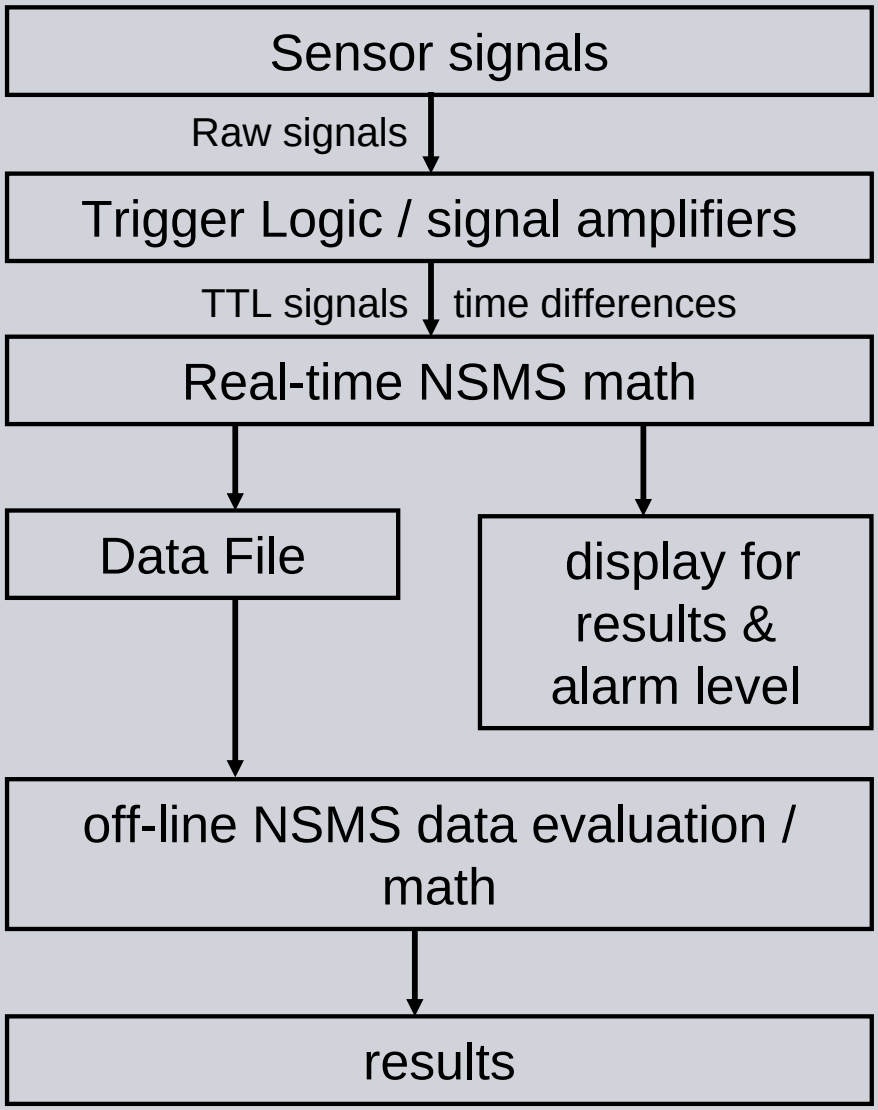
The TT Measurement Chain is Complex



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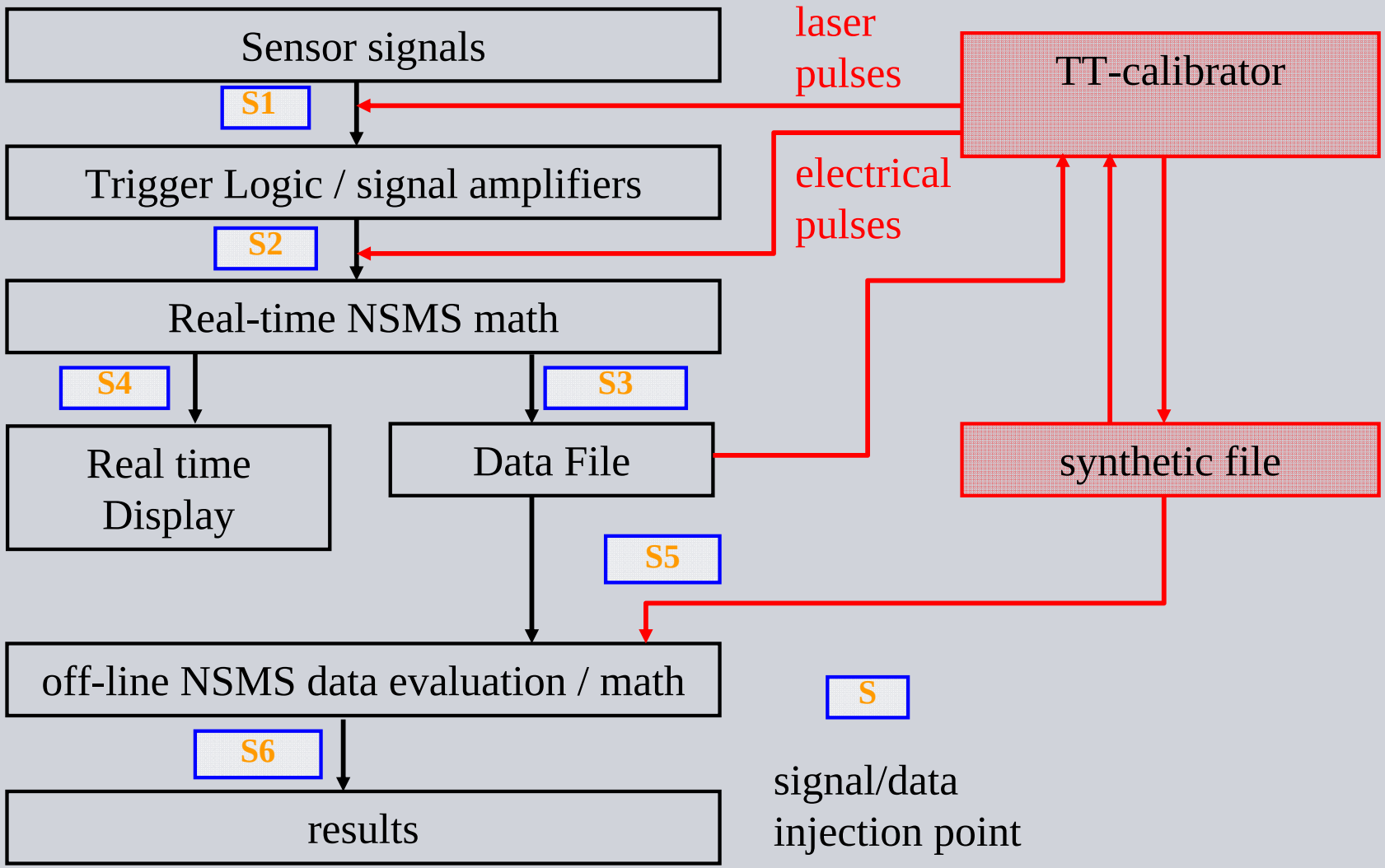
The TT-Calibrator is the Missing Link between Standards and Measurements



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Siemens UTT-Calibrator Milestones

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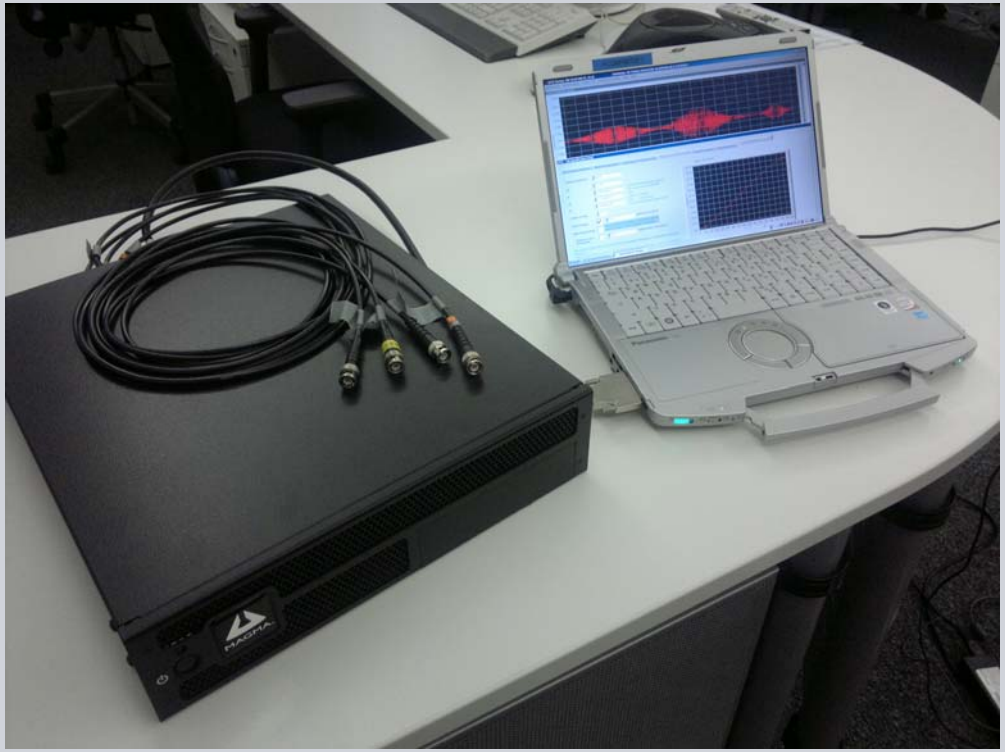
Siemens UTTC: Universal Tip Timing Calibrator

- first and world-unique TipTiming Calibrator
- Nano second precision
- Generation of complex synthetic simulation signals
- essential validation tool for turbine blade vibration measurements



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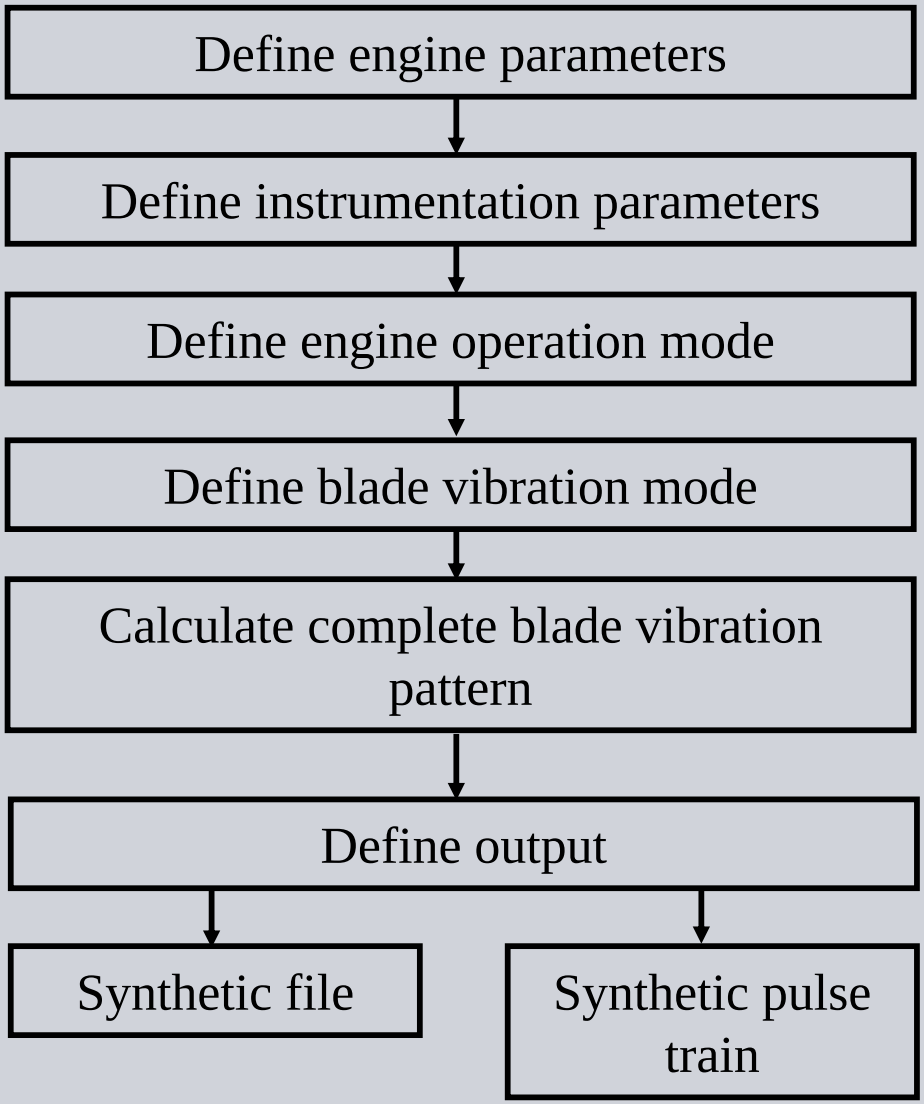
UTTC Software Concept: Work Flow



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UTTC Synthetic Signal Concept: Blade Disk Vibration Patterns for cw-Mode

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- 3 basic vibration pattern:

  - all blades same amplitude and frequency
  - all blades same frequency, blade individual phase
  - frequency, amplitude & phase blade individual

- up to 10 different vibration modes can be superimposed
  → Superheterodyne mode

- vibration noise level can be added

  - noise vibration level is mode individual for p1
  - noise vibration level is blade individual for p2 & p3

- simulation of sensor effects, bearing orbits, rotor bending modes and rotor drive train torsion vibrations

- all simulation parameters can be read/ stored from a prefabricated EXCEL worksheet

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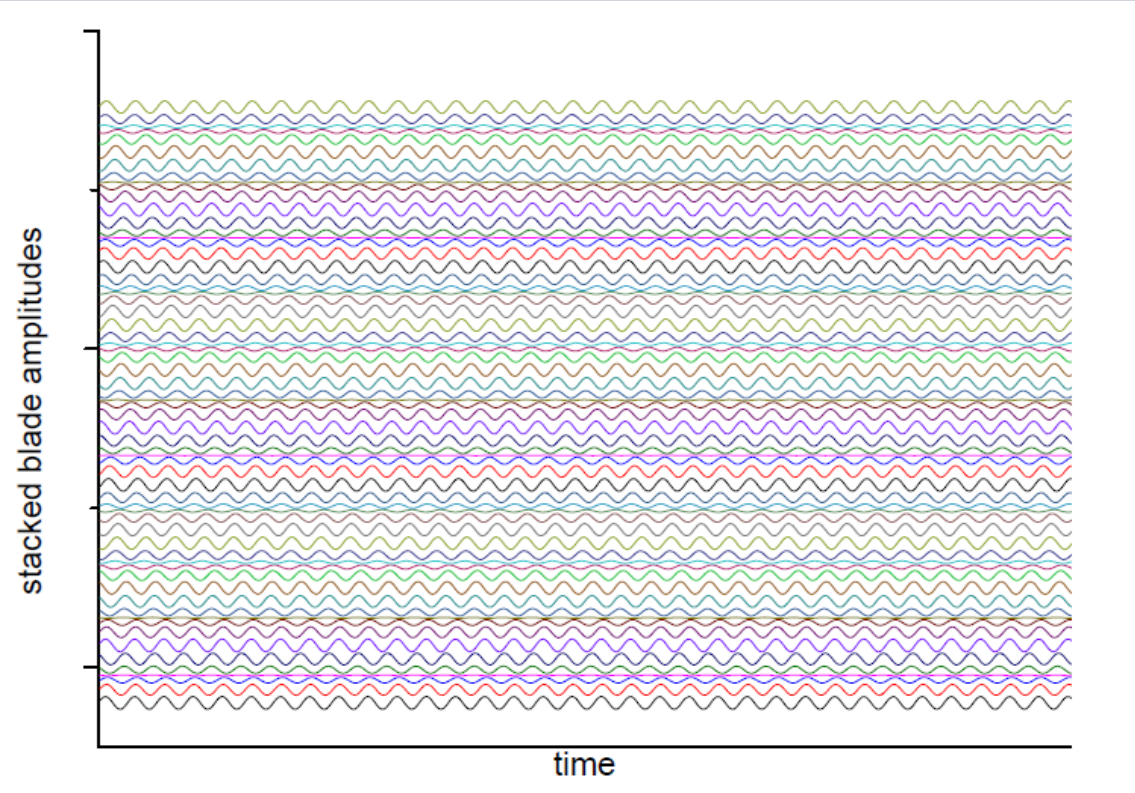
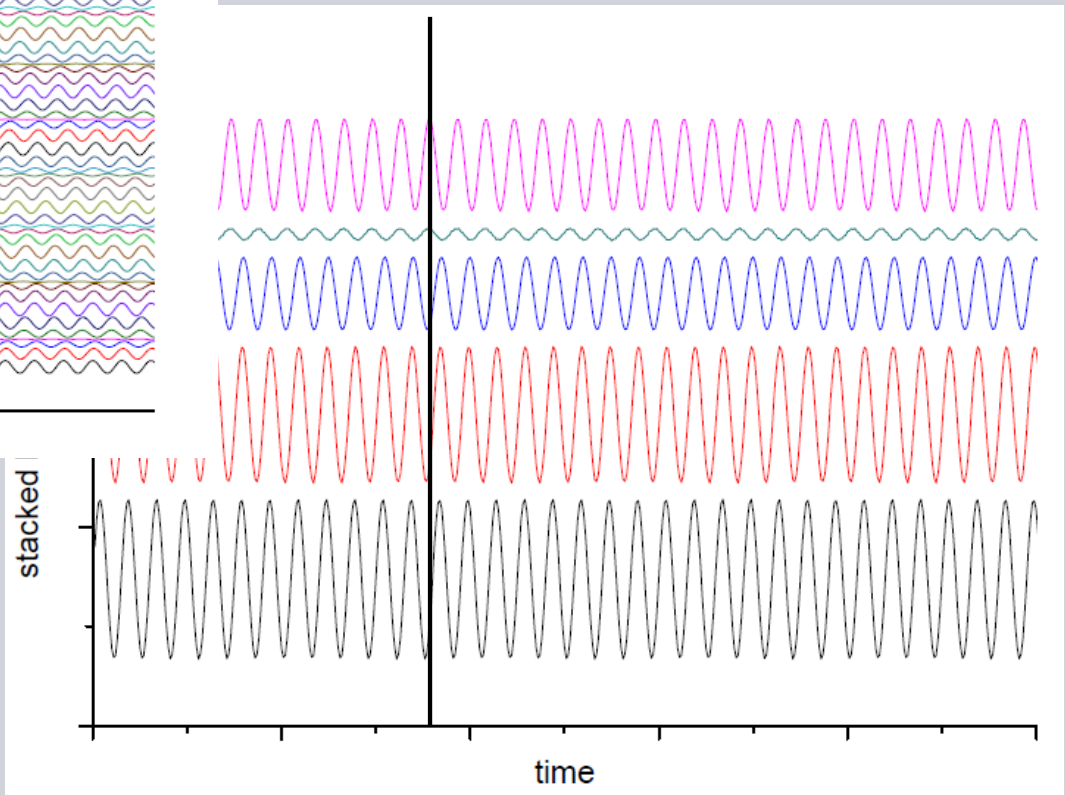
UTTC Synthetic Signal Concept: Blade Vibration Examples for cw-Mode





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UTTC Synthetic Signal Concept: Blade Vibration Examples for cw-Mode

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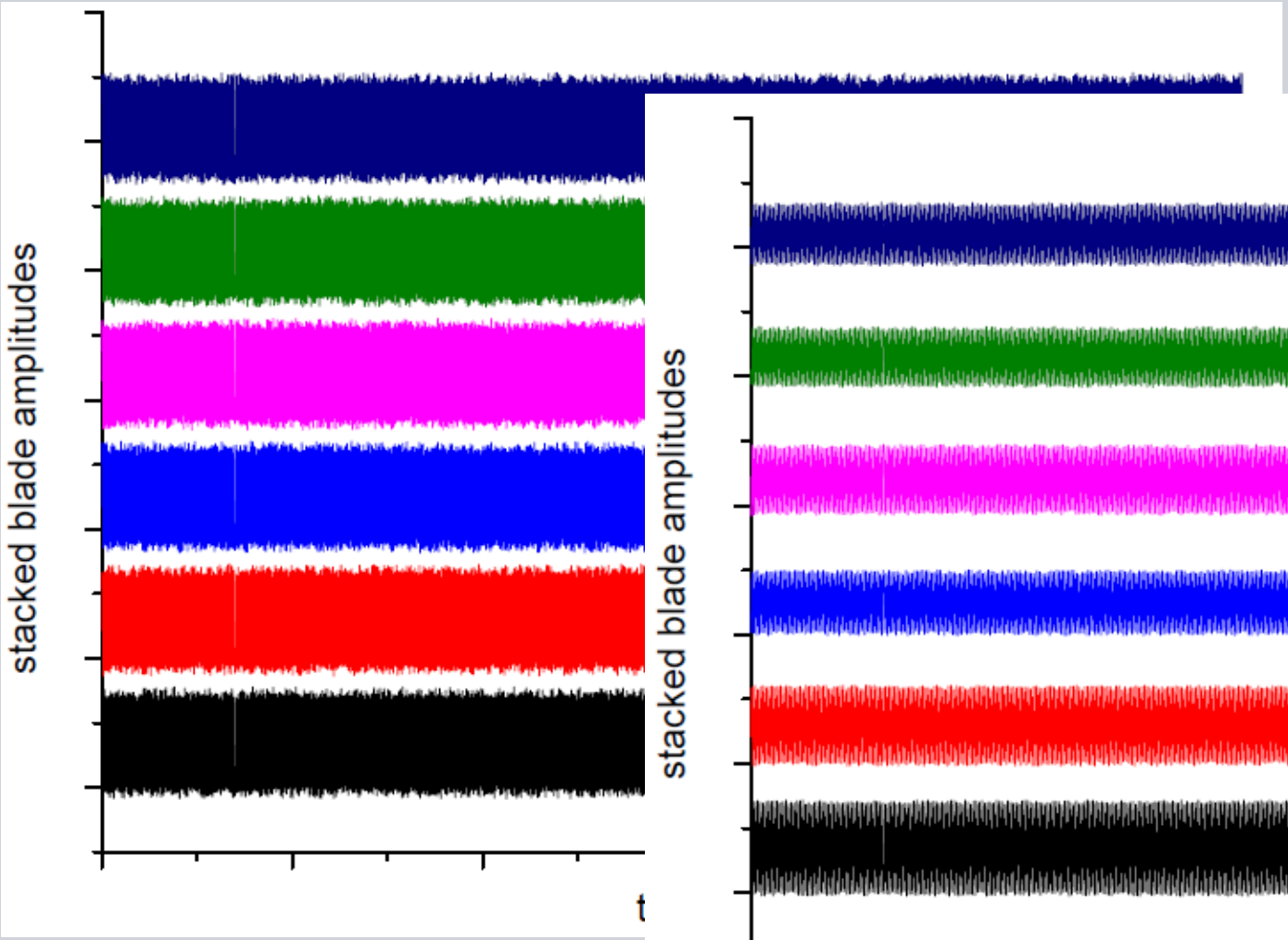
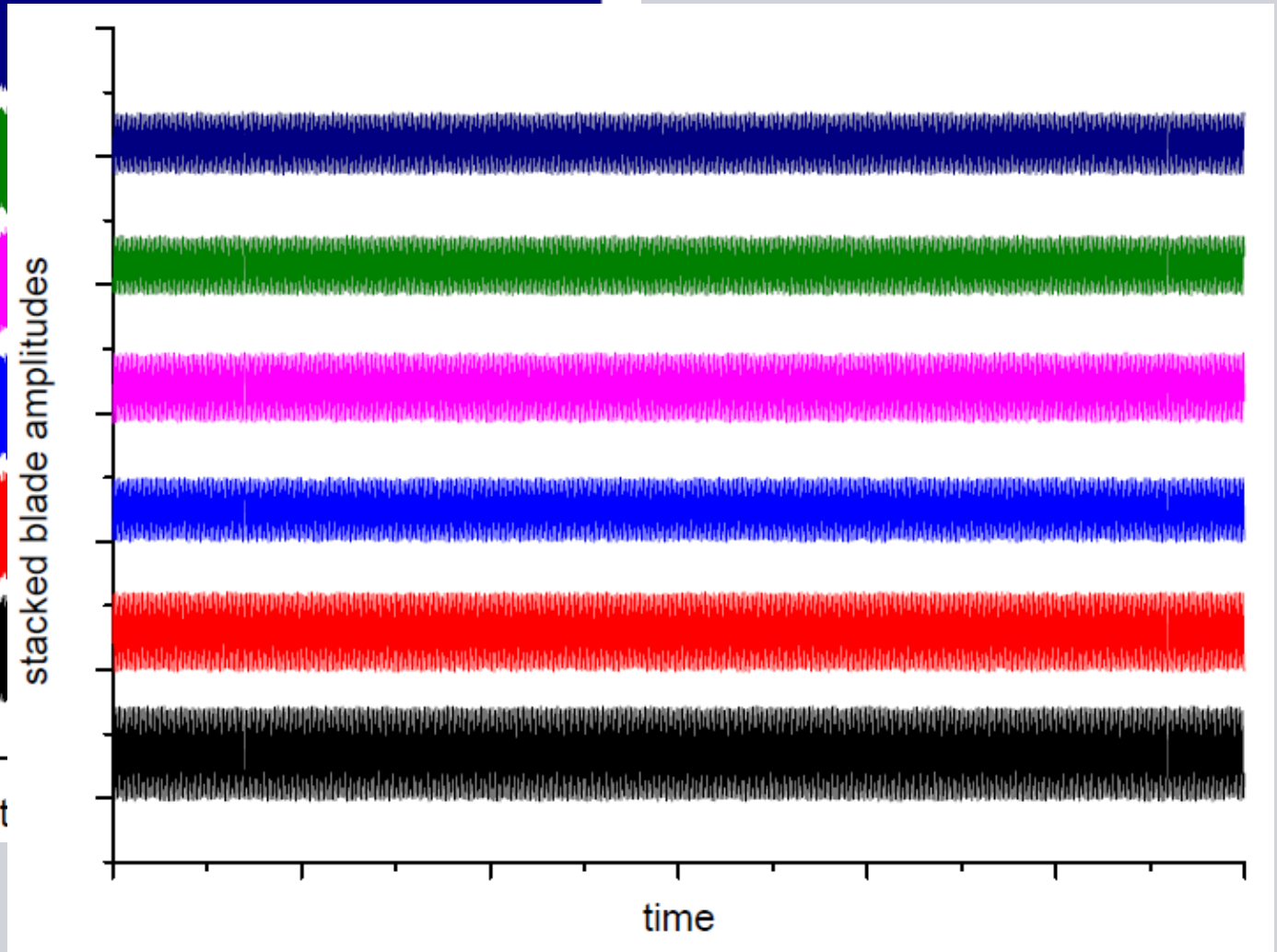


Noise Simulation

Individual Blade Amplitudes



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Synthetic Signal Concept: Blade Vibration Examples for cw-Mode Heterodyne (10) cw-Mode

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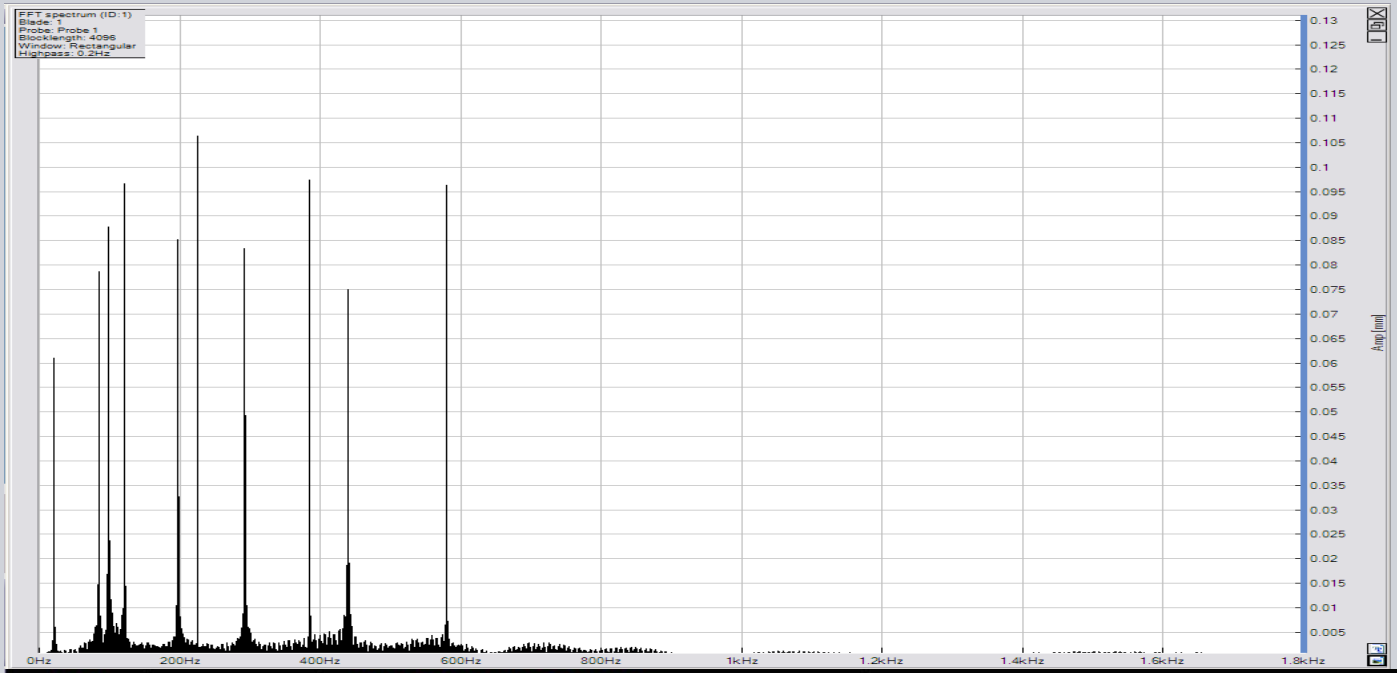
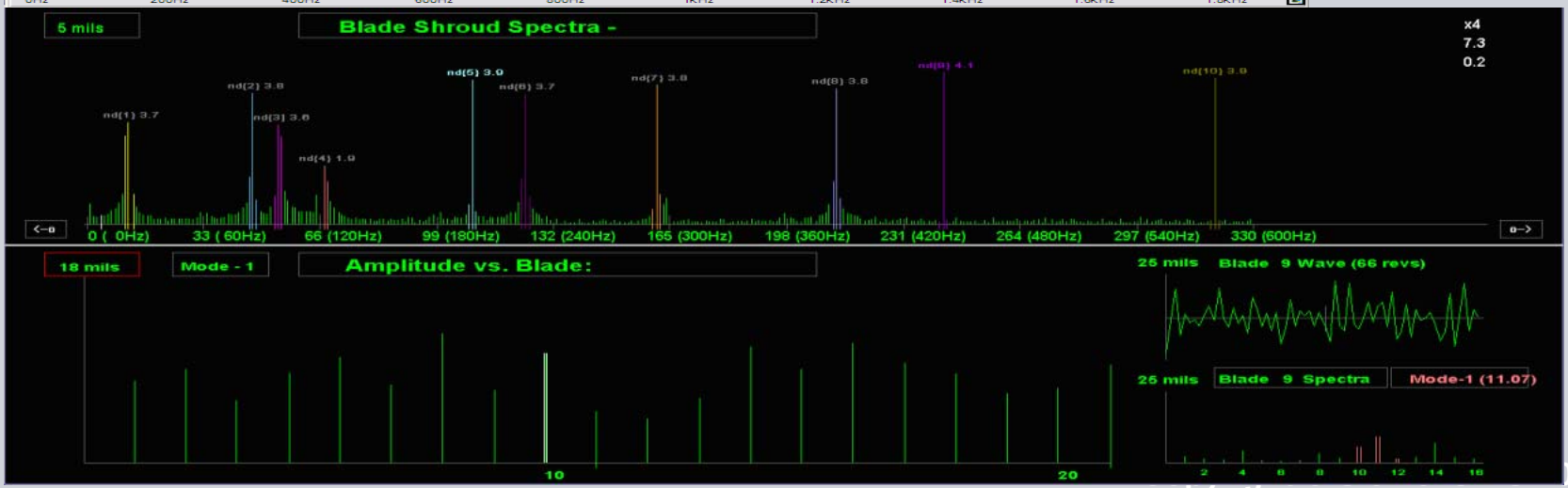


System 1 Response



System 2 Response

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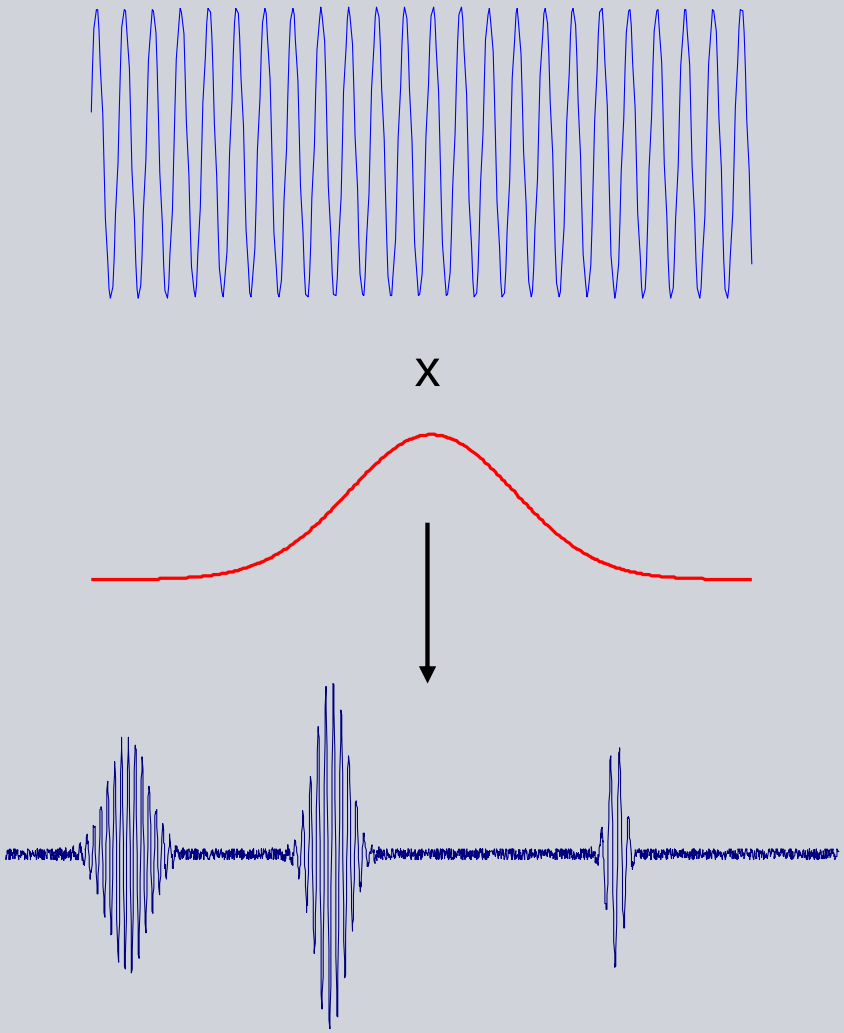
Synthetic Signal Concept: Blade Disk Vibration Pattern for Transient Mode



tr-engine operation mode
Blade disk vibration pattern

- max. 10 different excitation events
- excitation event characterized by
    - frequency
    - amplitude
    - phase
    - EO
    - envelope shape parameter
- blade individual
- vibration noise level can be added
- frequency lock-in feature
- all parameters can be r/w from/to a prefabricated EXCEL worksheet

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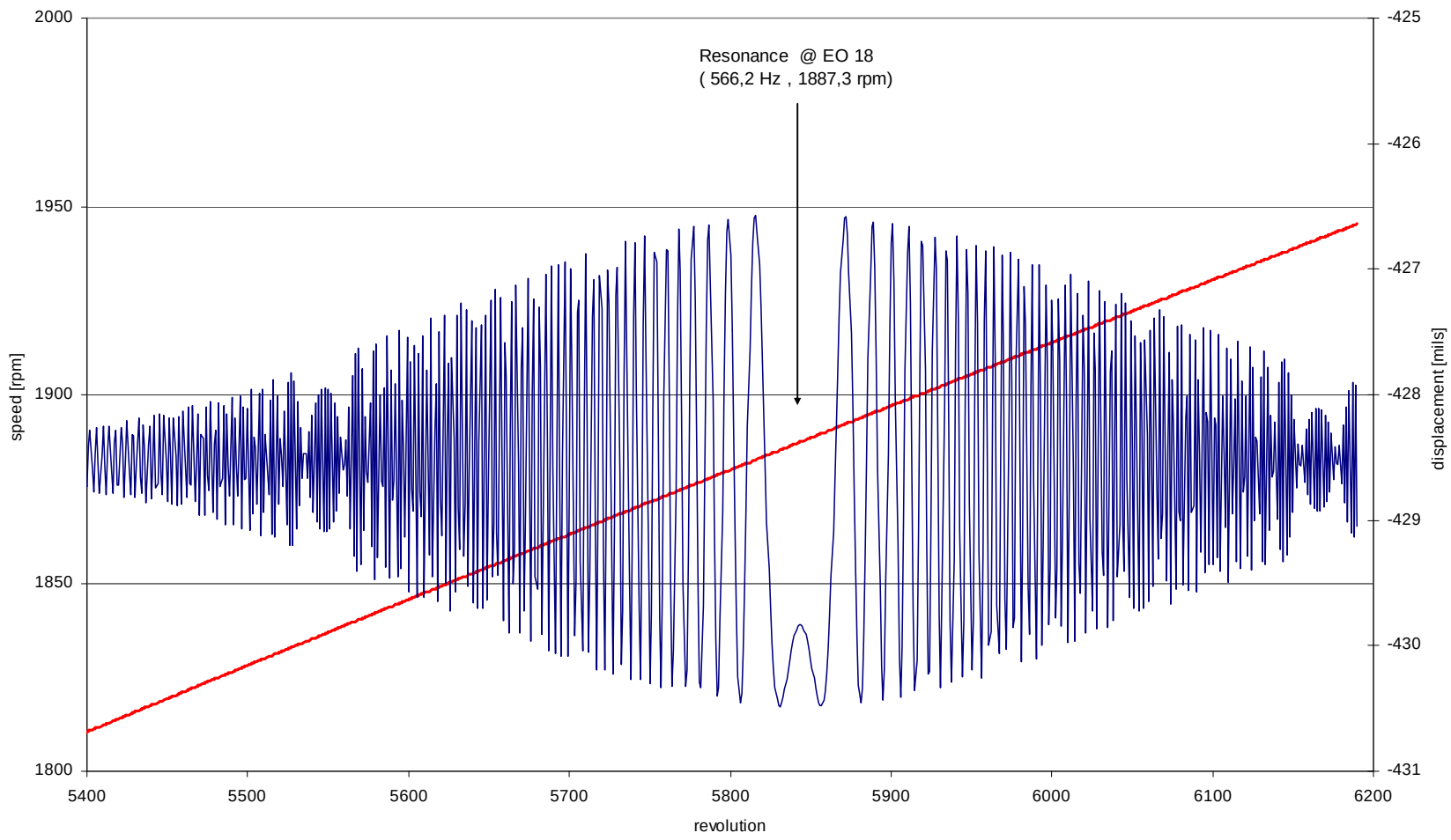
Synthetic Signal Concept: Single Excitation Events in Transient Engine Mode
Synthetic Signal



Low

Noise

Test

Case

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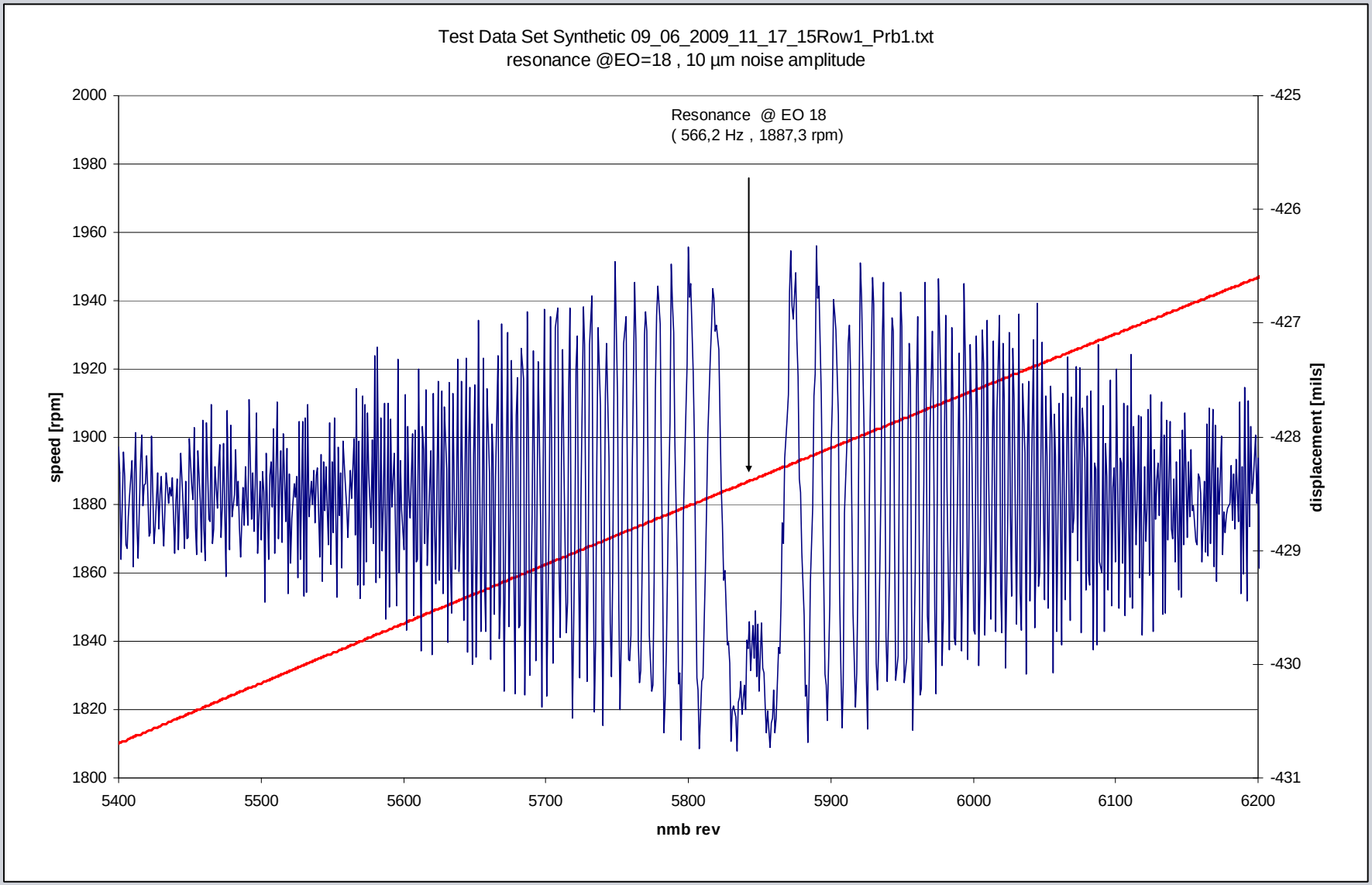
Synthetic Signal Concept: Single Excitation Events in Transient Engine Mode
Synthetic Signal



High

Noise

Test

Case

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Synthetic Signal Concept: Single Excitation Events in Transient Engine Mode Tip Timing System Response

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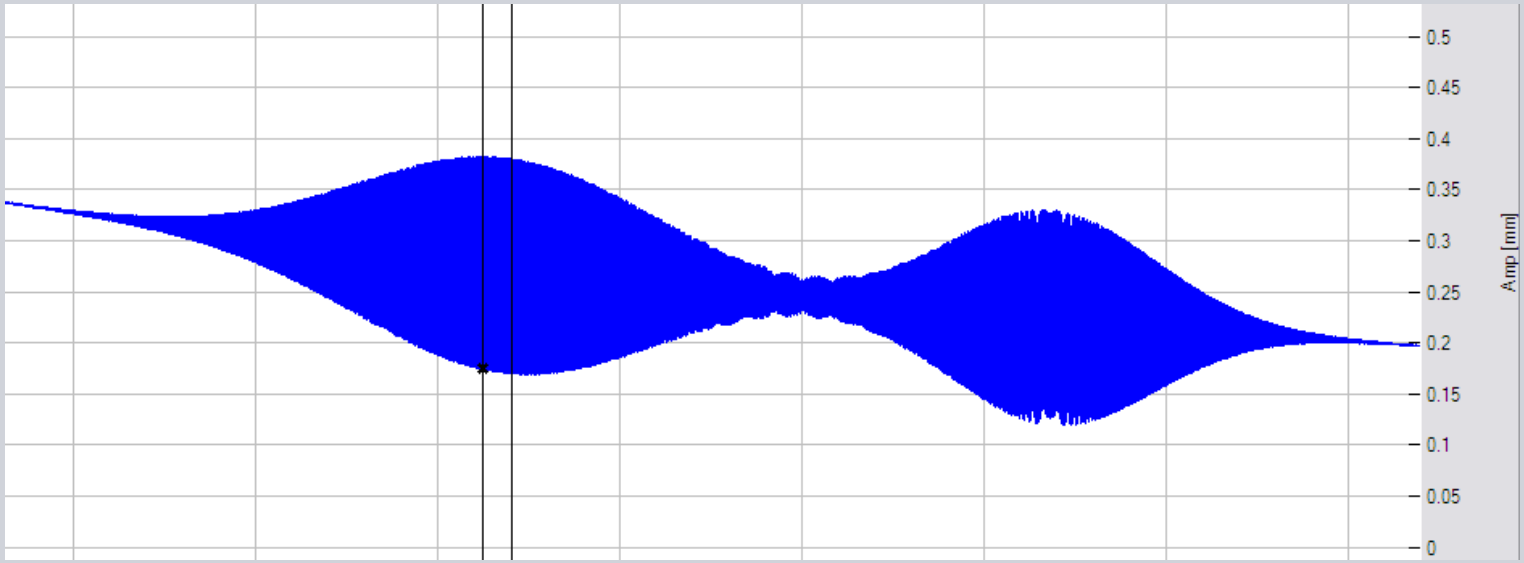
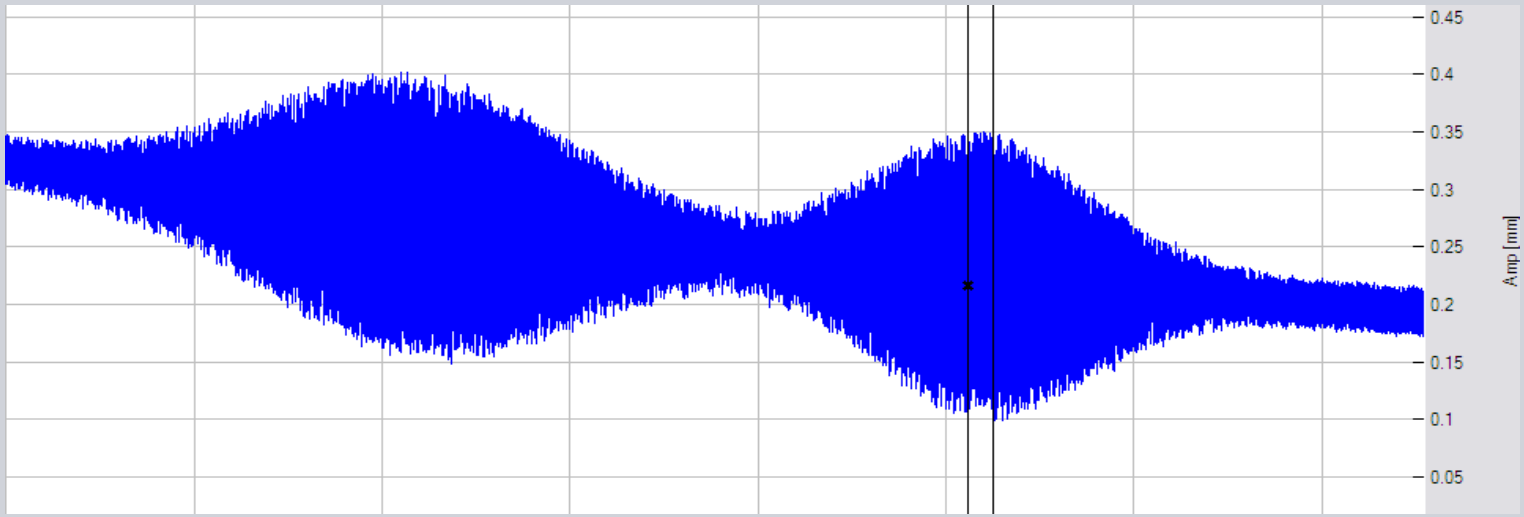


no noise



20 µm noise

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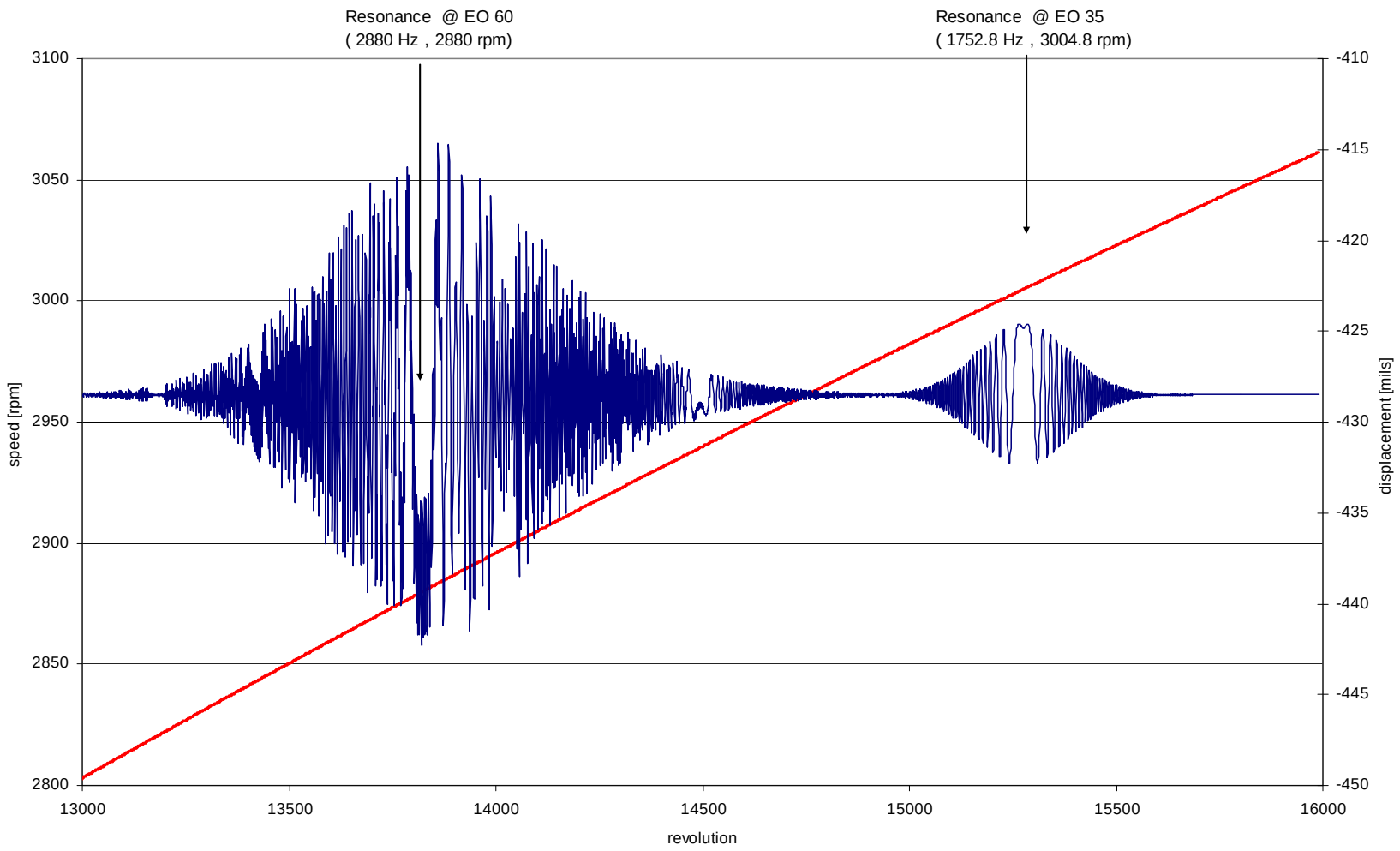
Synthetic Signal Concept: Multiple Excitation Events with/without Noise
Synthetic Signal



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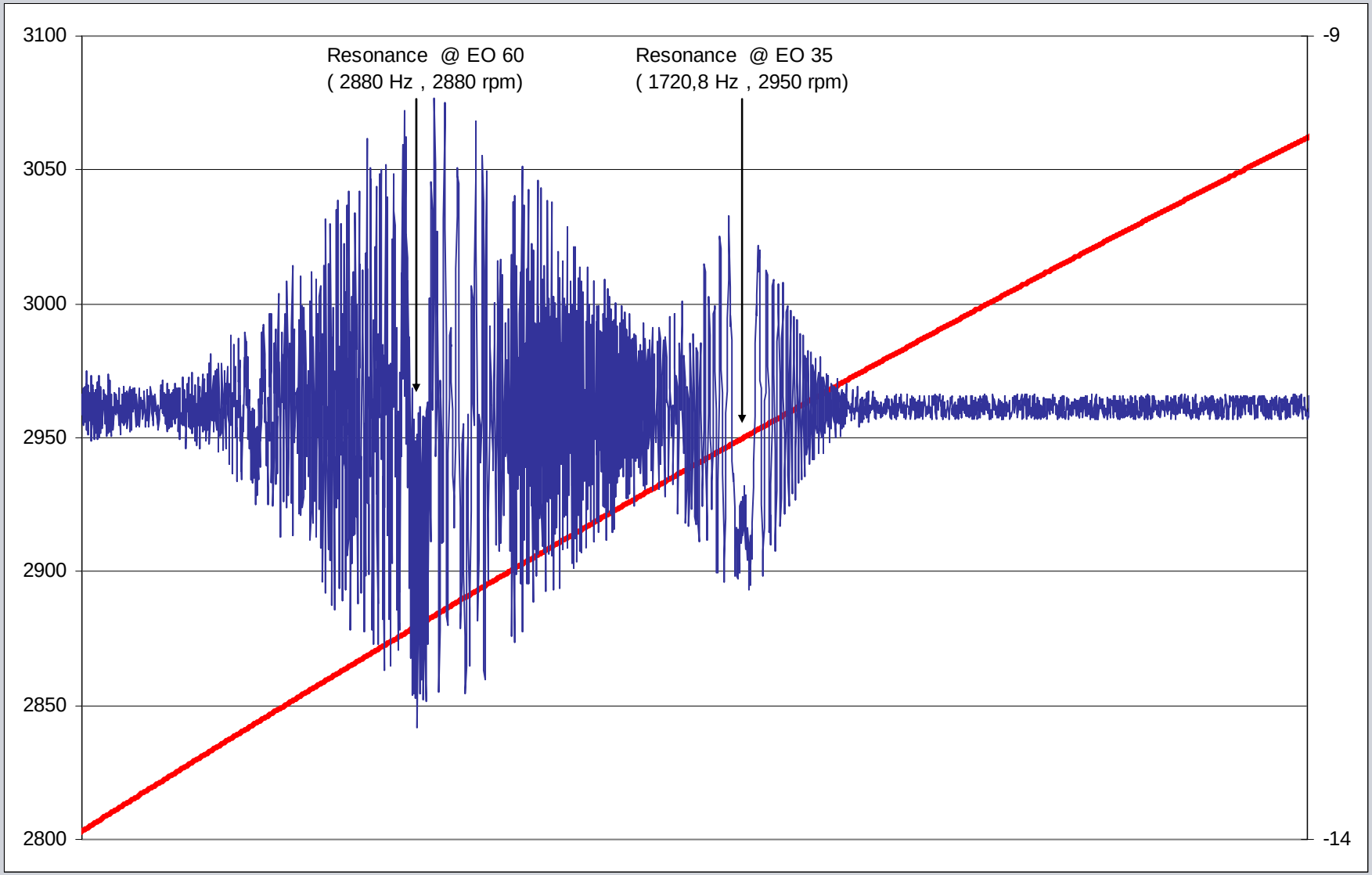
Synthetic Signal Concept: Multiple Excitation Events with/without Noise

Synthetic Signal



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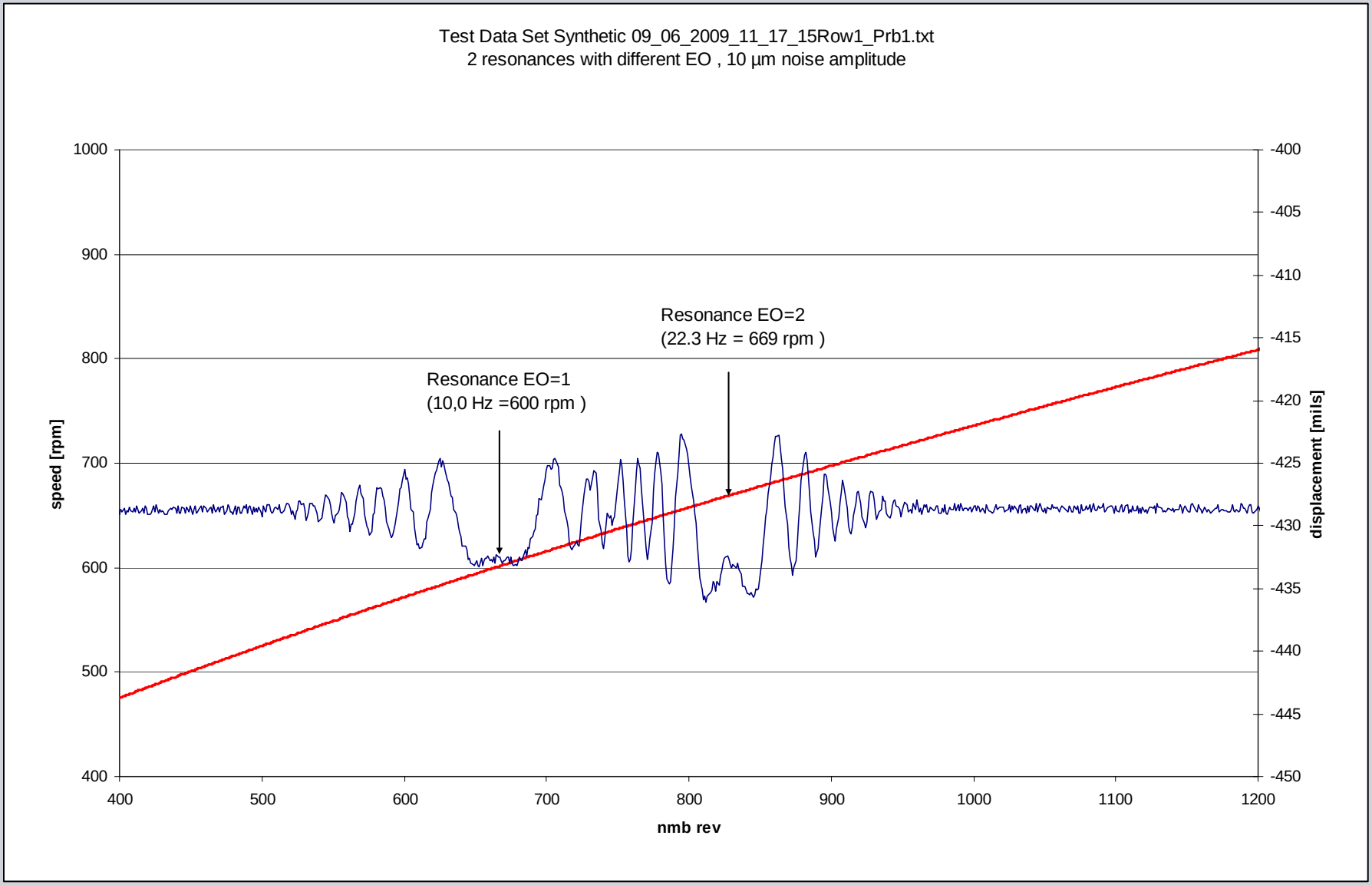
Synthetic Signal Concept: Overlapped Excitation Events with Noise

Synthetic Signal



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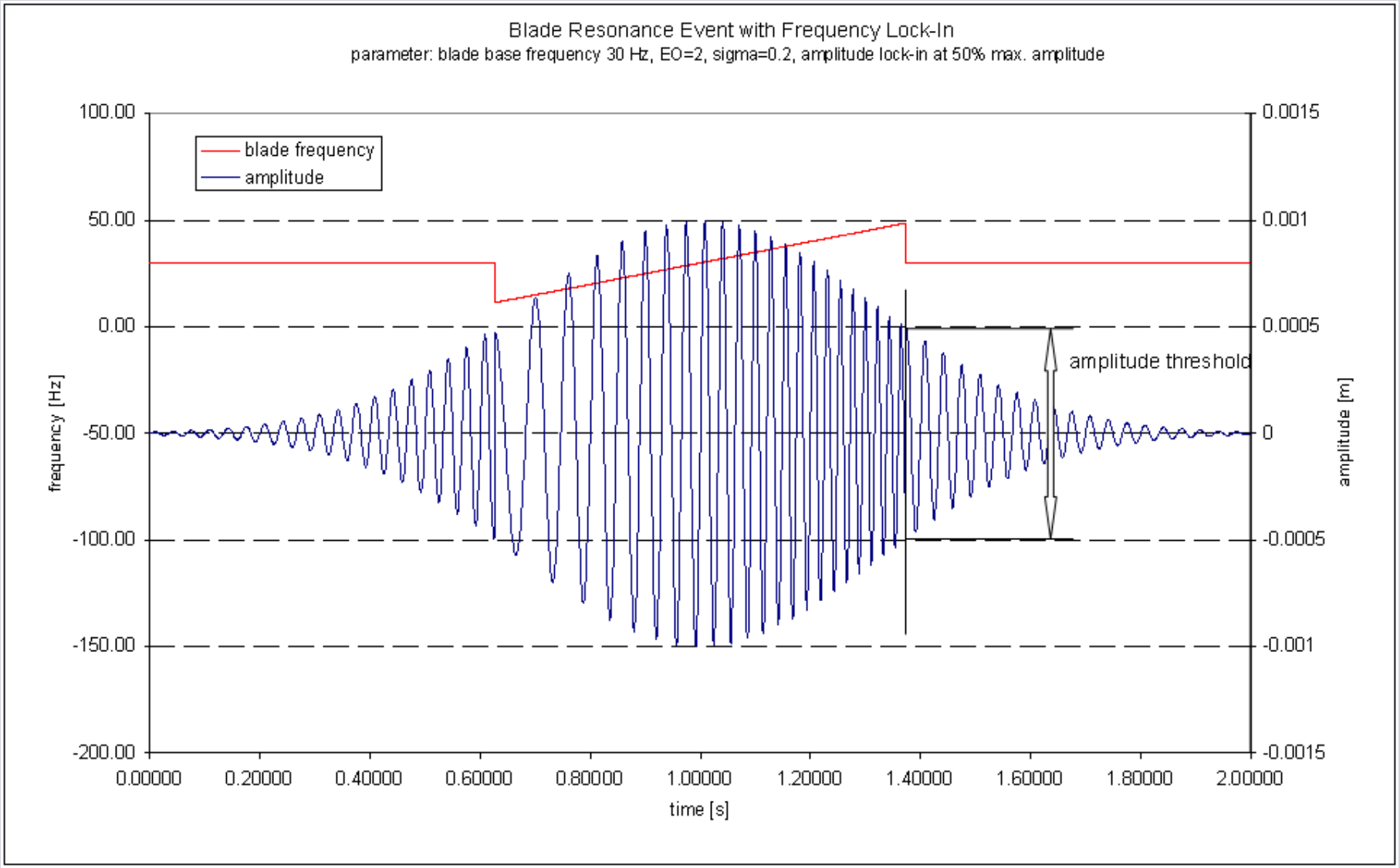
Synthetic Signal Concept: Frequency Lock-In



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Simulation Lab Test Setup for UTTC and TT-System 1 & 2 Test

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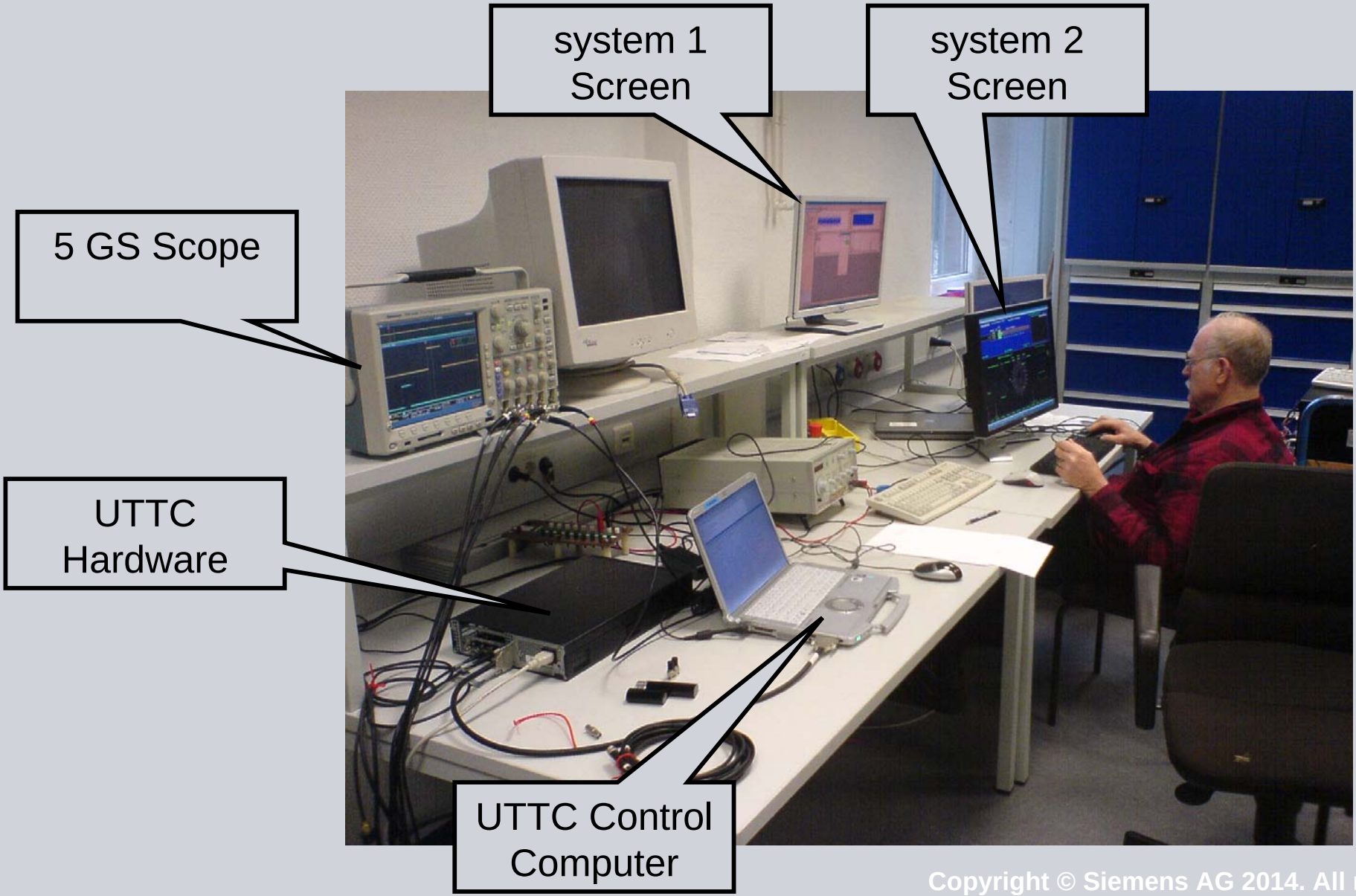

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UTTC and System 2 Monitor Display Example
UTTC cw-Mode: Synchronous Vibration with Combined Phase Modulation

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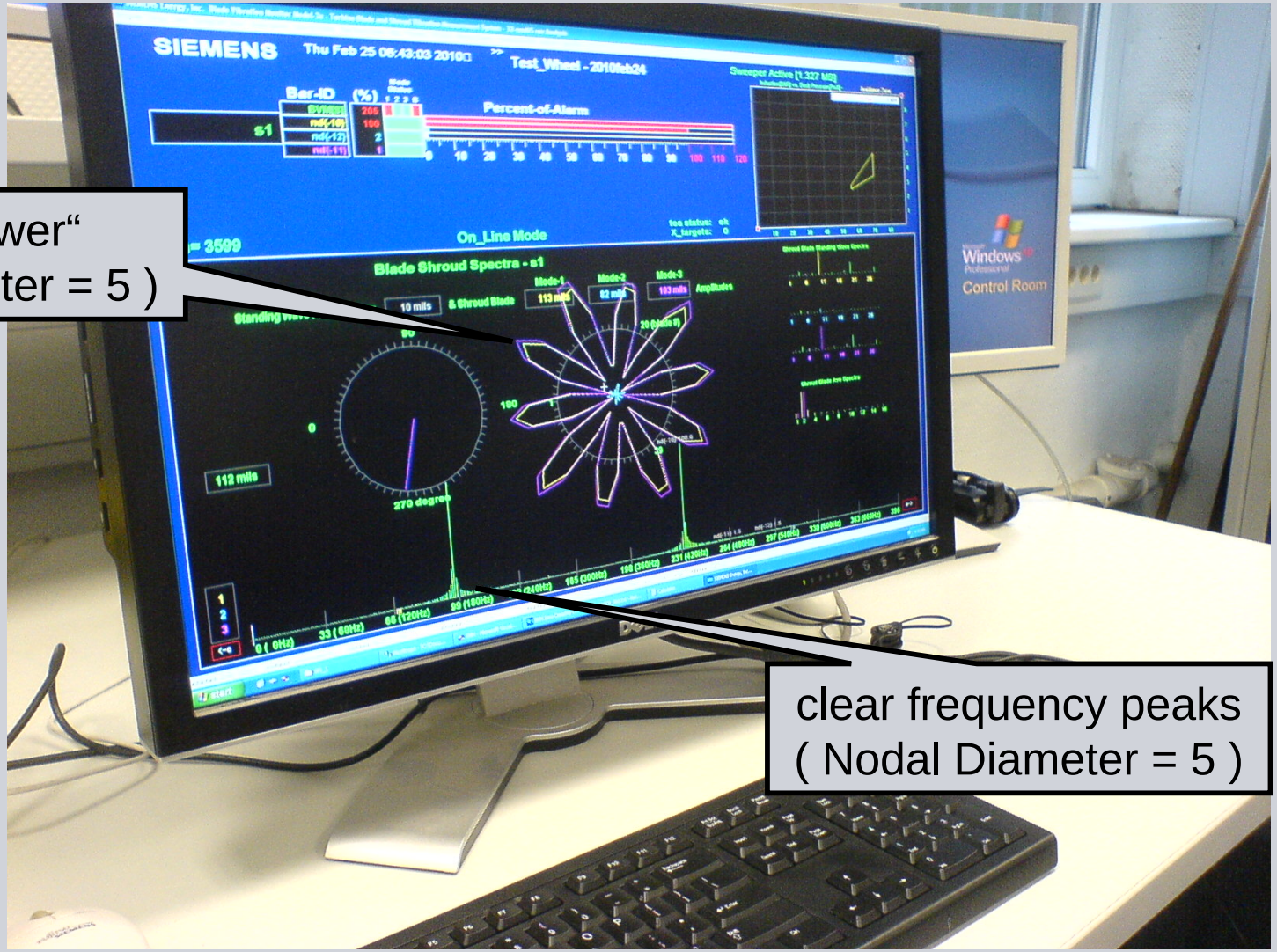

„Daisy Flower“
(Nodal Diameter = 5)

clear frequency peaks
(Nodal Diameter = 5)

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Summary

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Validation of TT-systems with synthetic signals:

- is an essential, powerful and effective method
- is used to generate live sensor signals with simple and very complex vibration patterns
- can be used in prior of test campaigns to check a particular instrumentation setup and to check correct mode identification
- can be used to optimize the setup of TT-systems without having a real running engine
- can be used to generate synthetic signal data files in various formats
- synthetic data files are used for evaluation and validation of off-line analysis software

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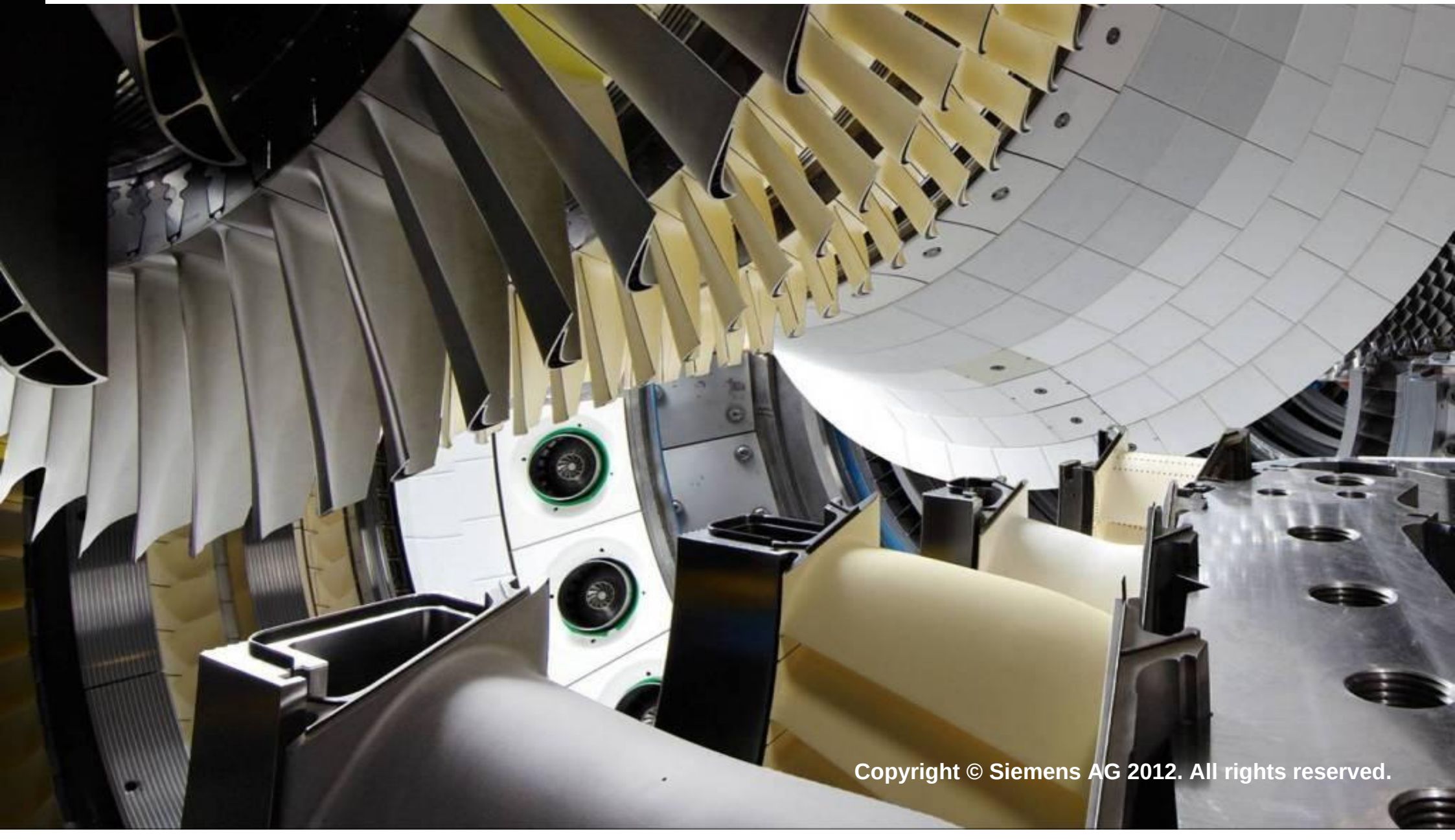

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