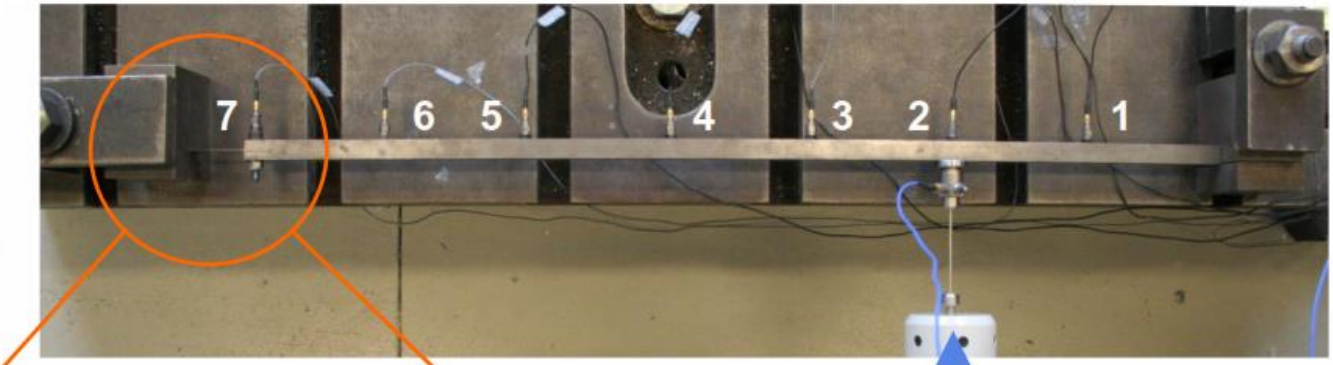
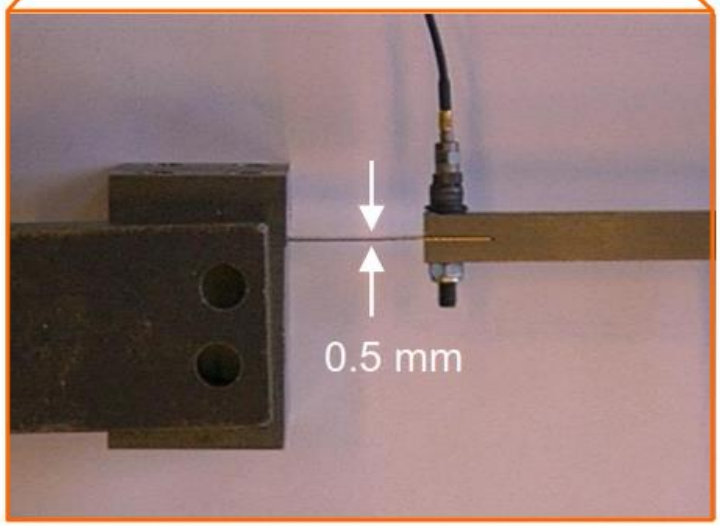
Nonlinear Vibrations of Aerospace Structures

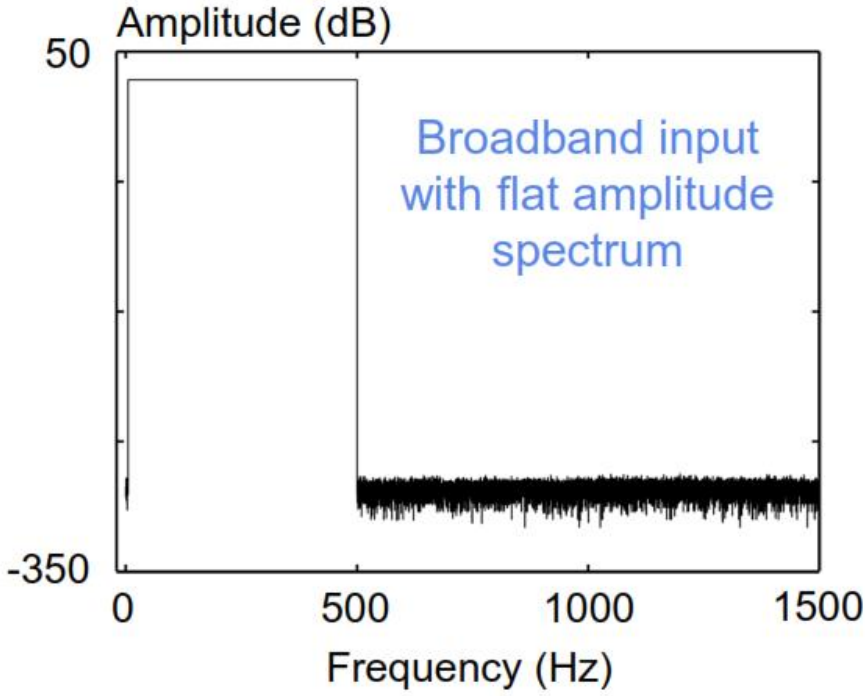
Tutorial 09

Estimating Parameters using FNSI

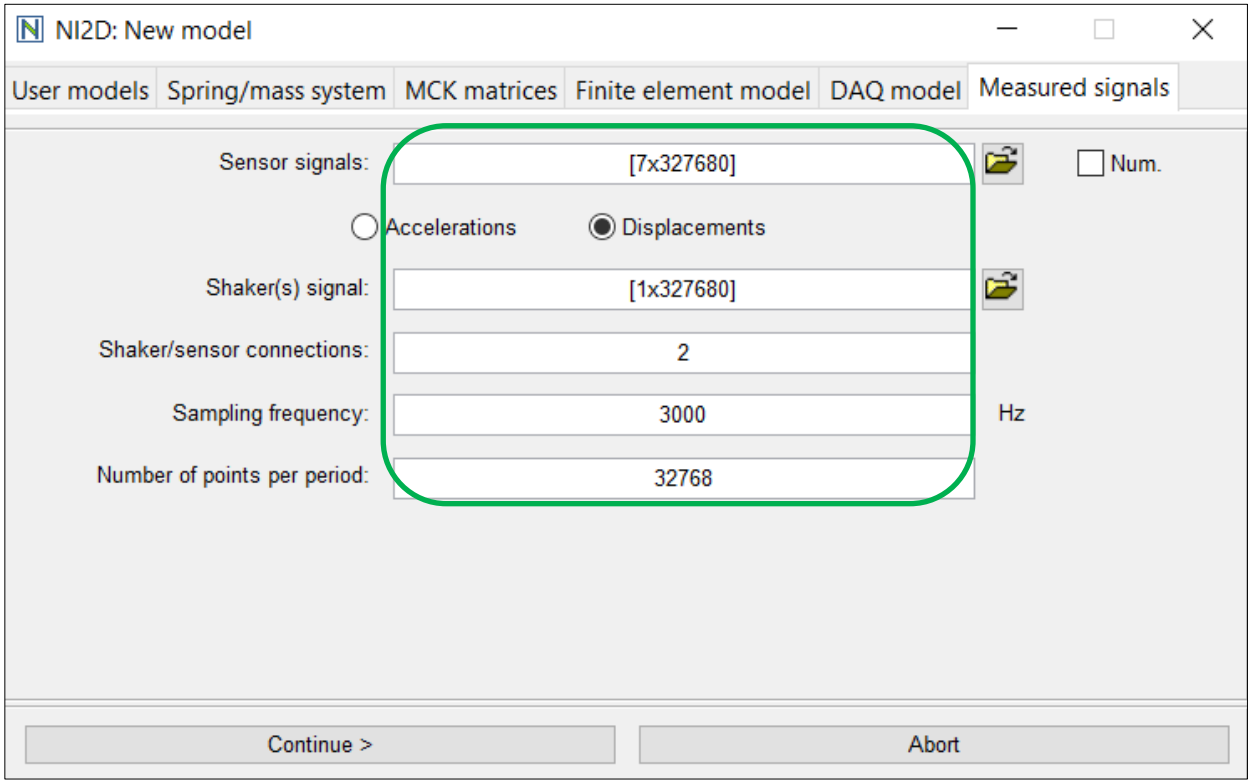
A Numerical Beam with a Geometric Nonlinearity





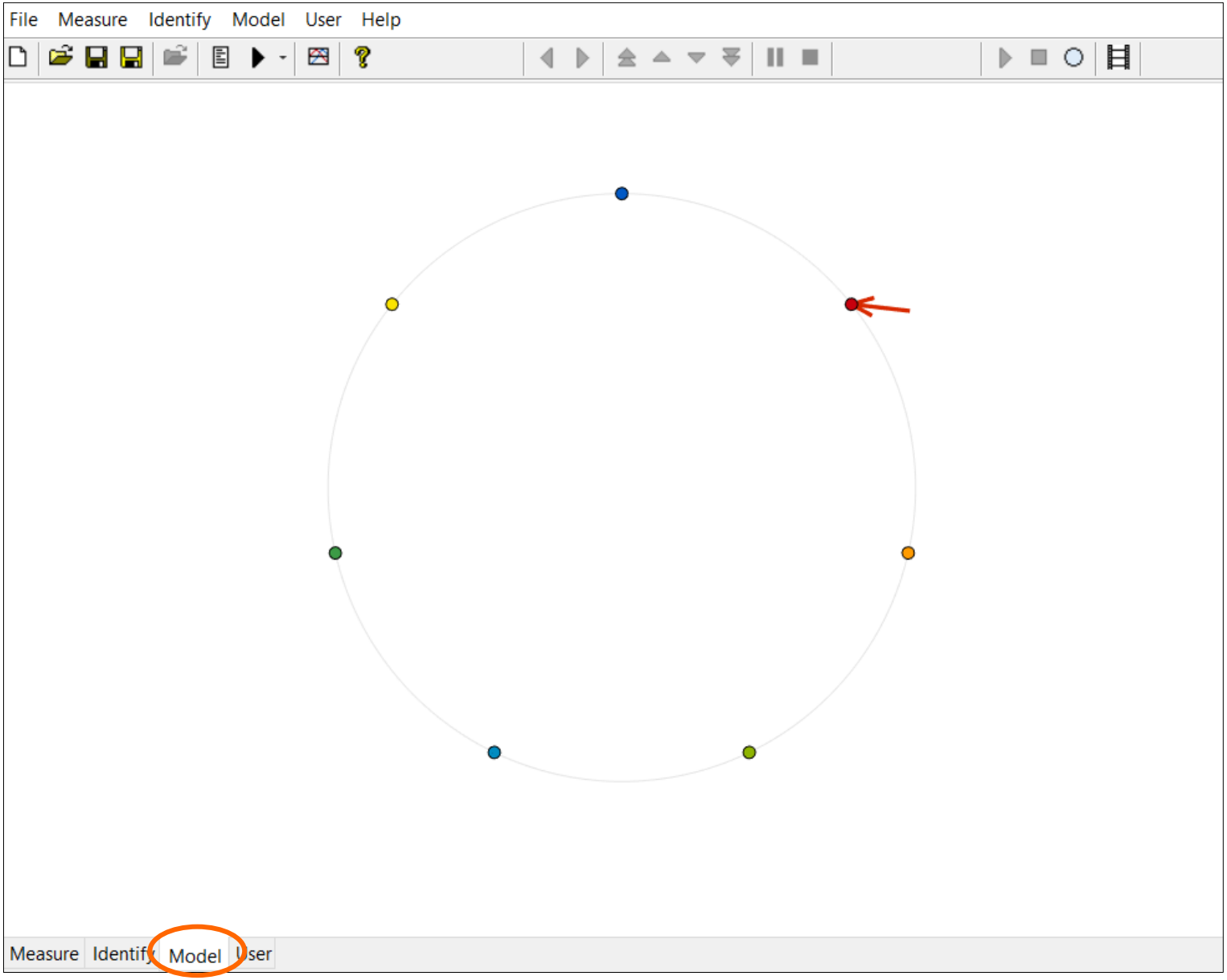


Create a New Model at 0.1 N based on Measured Signals



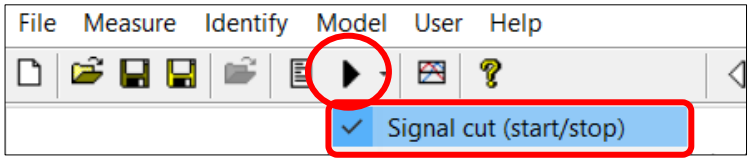
Use the FNSI data for this. *Y* includes the sensor signals while the shaker signal is saved in *u*.

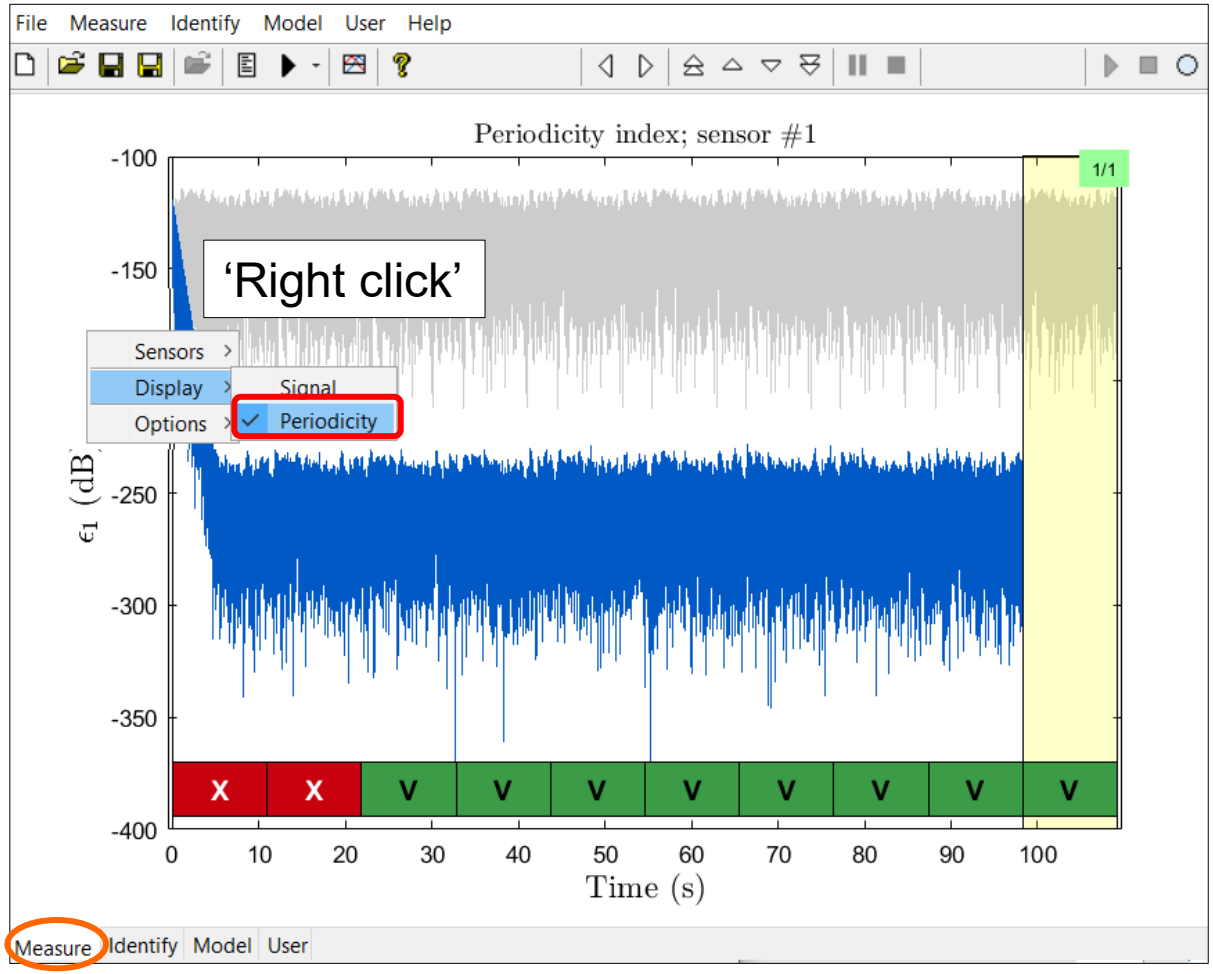
7 Displacements and 1 Shaker are Represented



Transient Analysis to Avoid Leakage in FD Identification

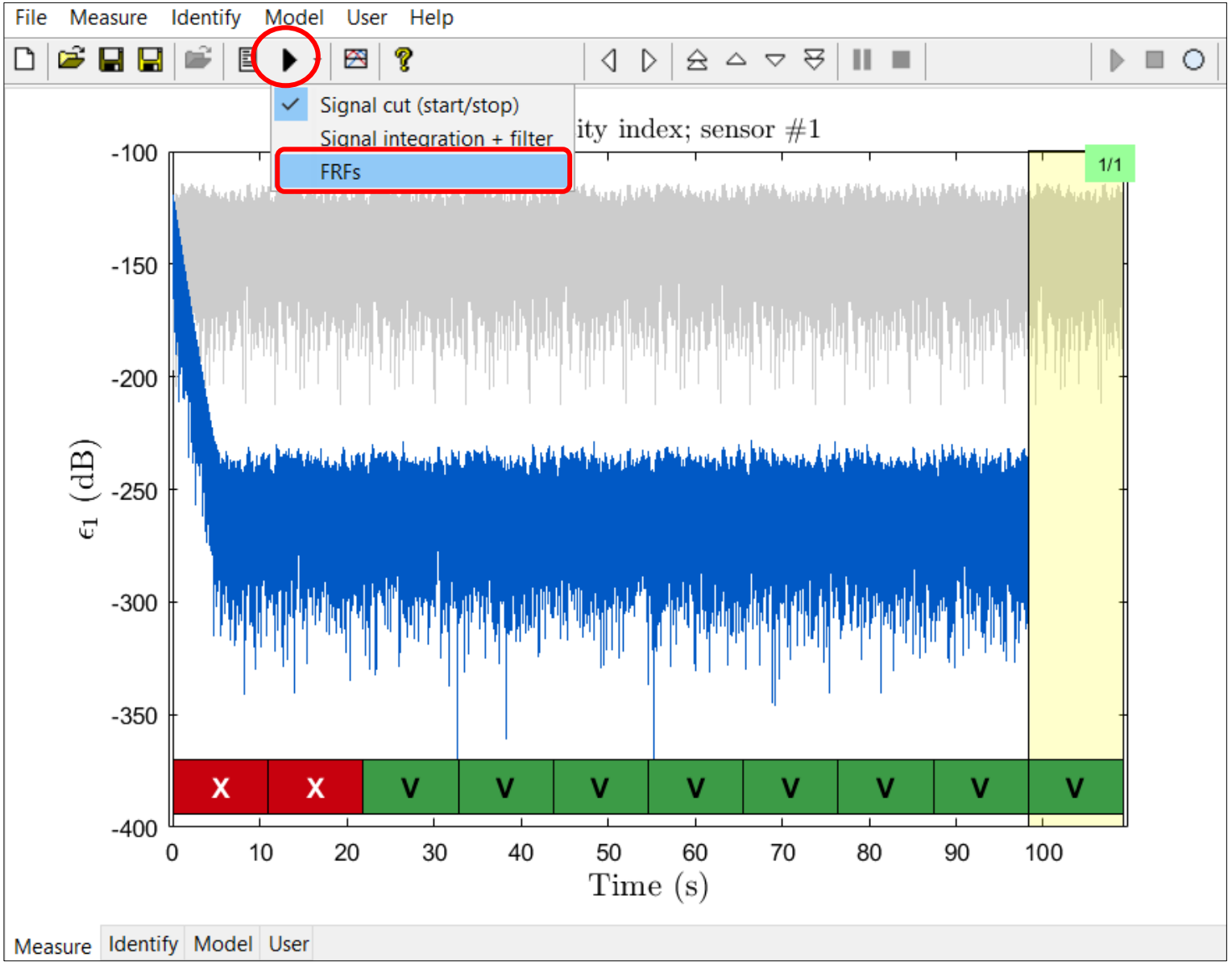
1. Go to the ‘Measure’ tab and play ‘Signal cut’



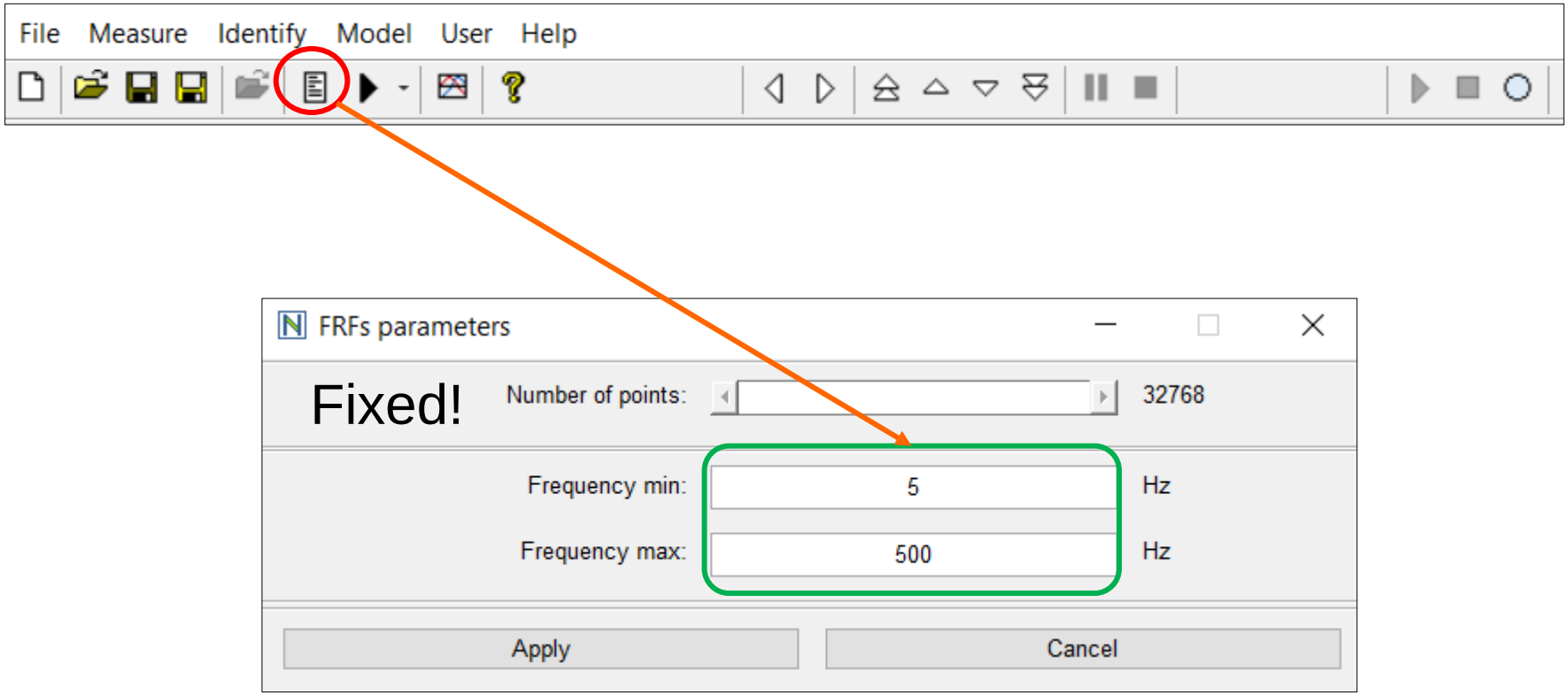


2. Display the Periodicity of the signal

Nonparametric FRF Analysis Before Estimating Parameters

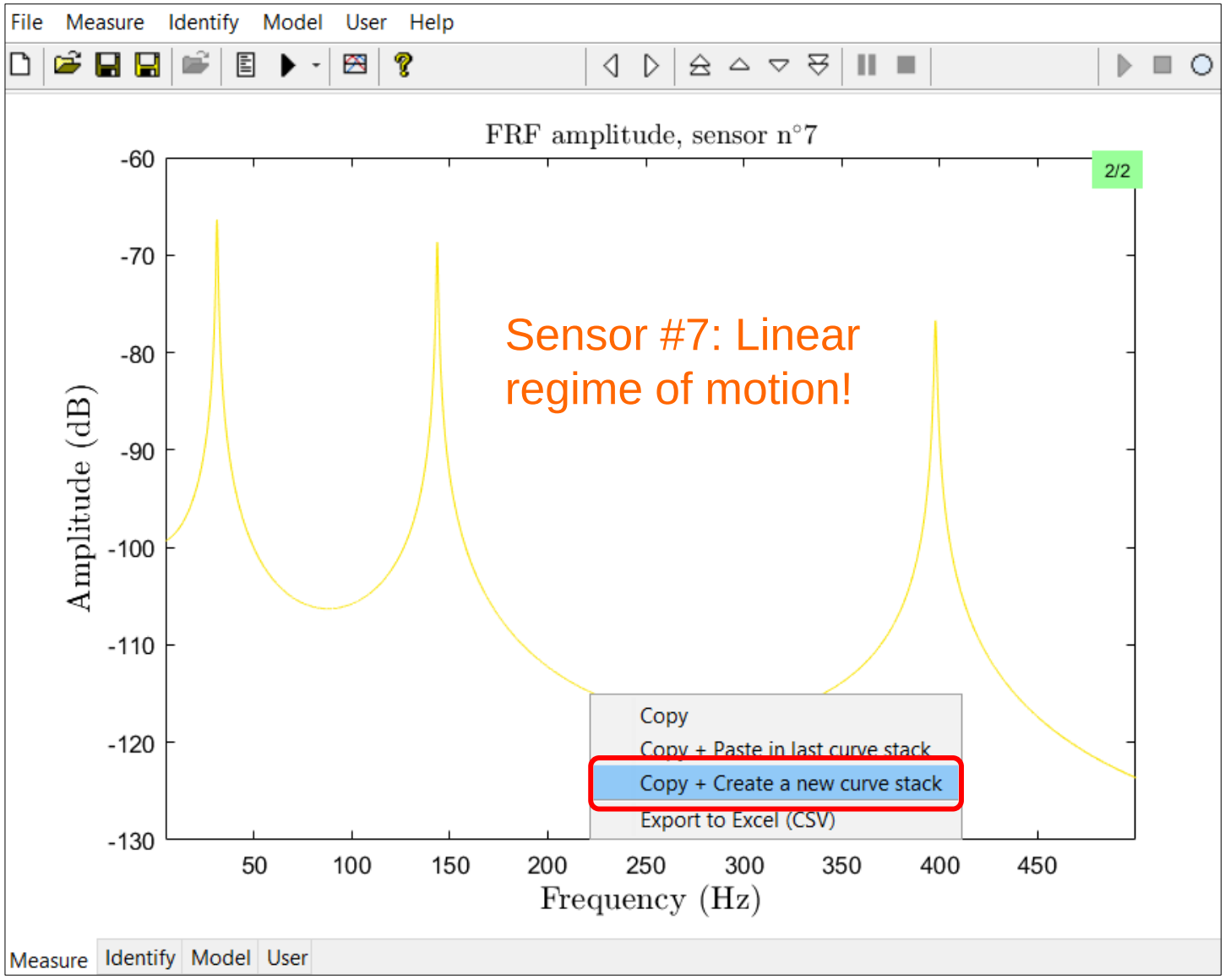


Calculation over the Input Band (Number of Points Is Fixed)

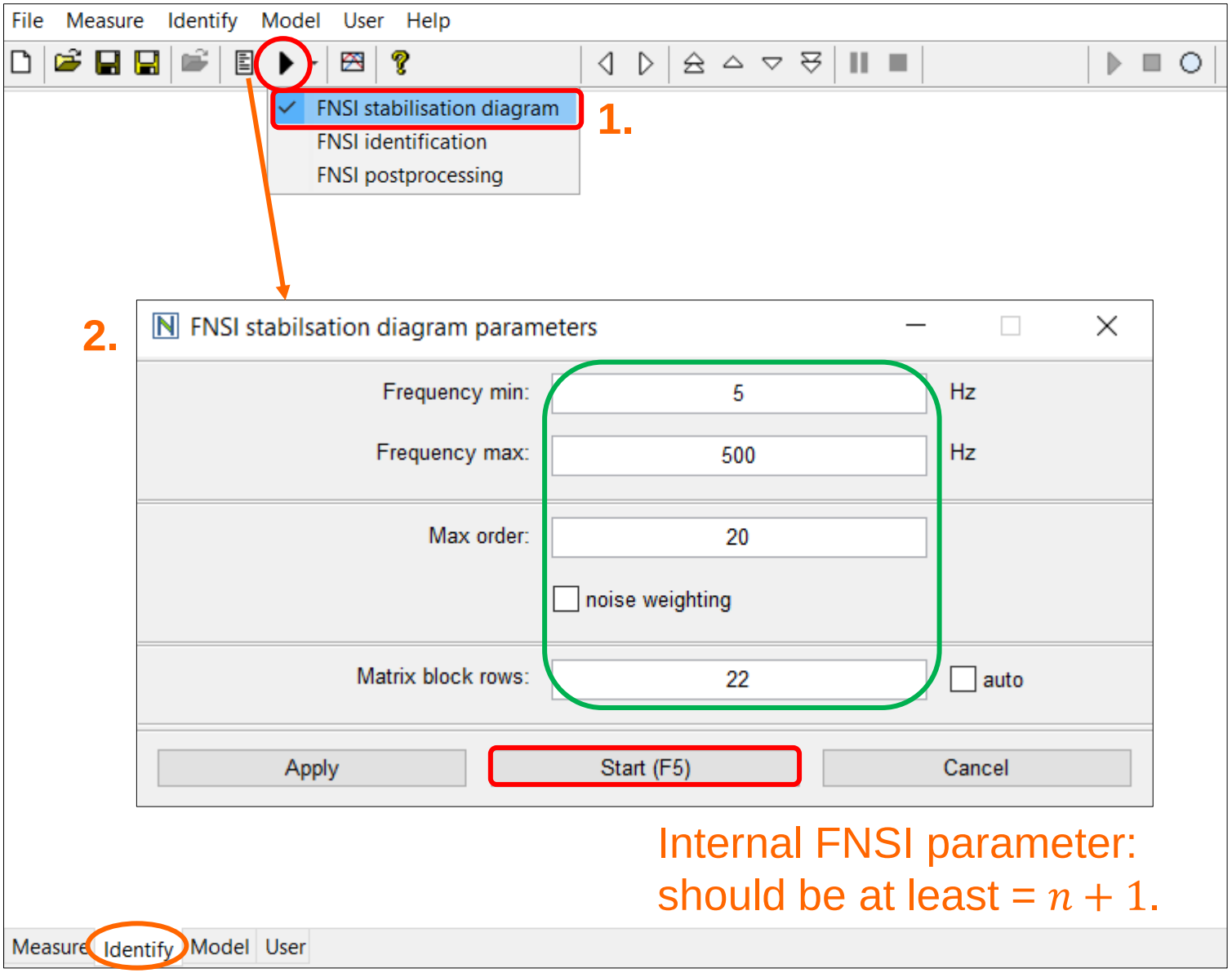


Choose the frequency range of interest and compute the FRFs.

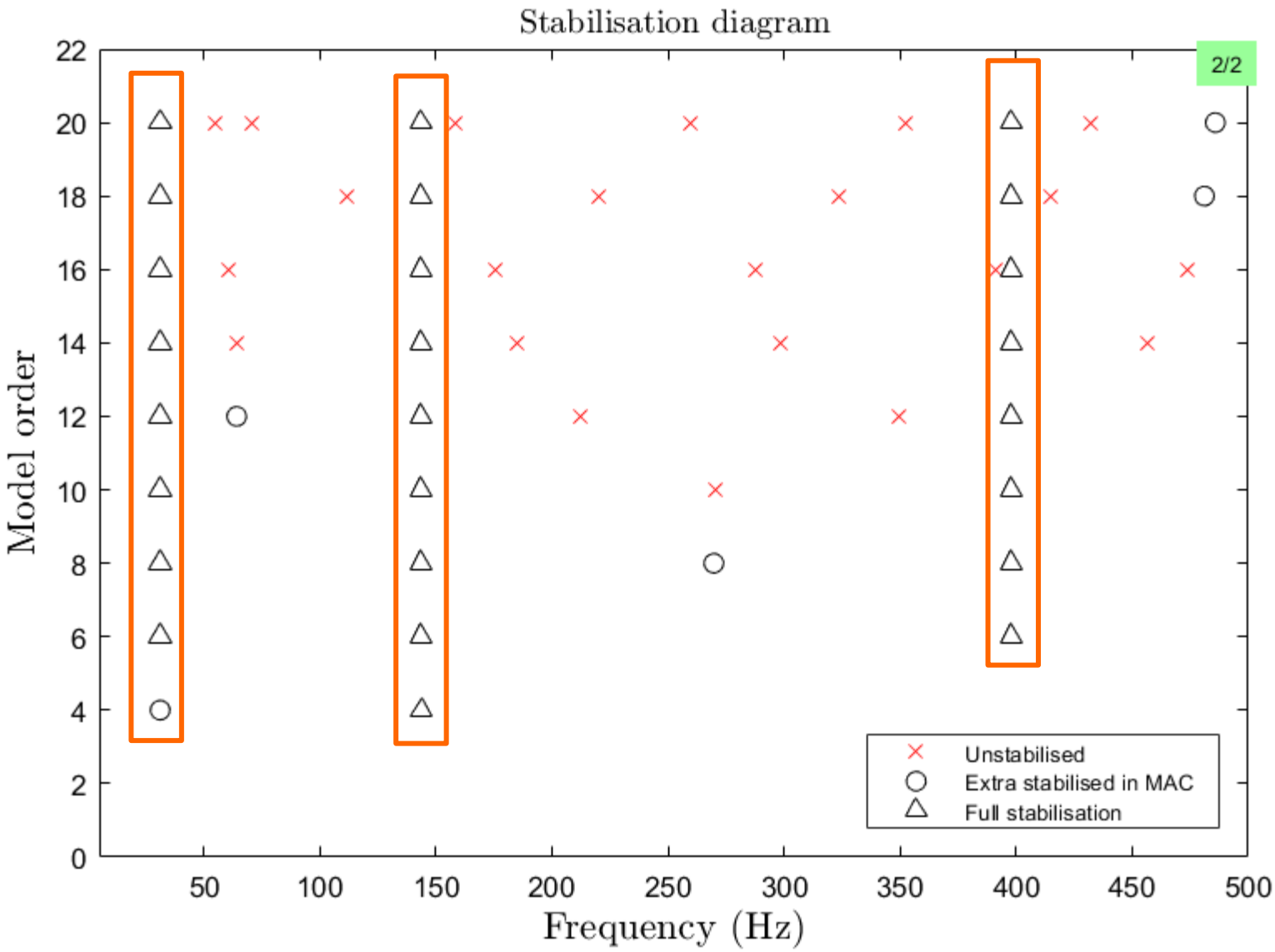
The Input Band Encompasses the First Three Beam Modes



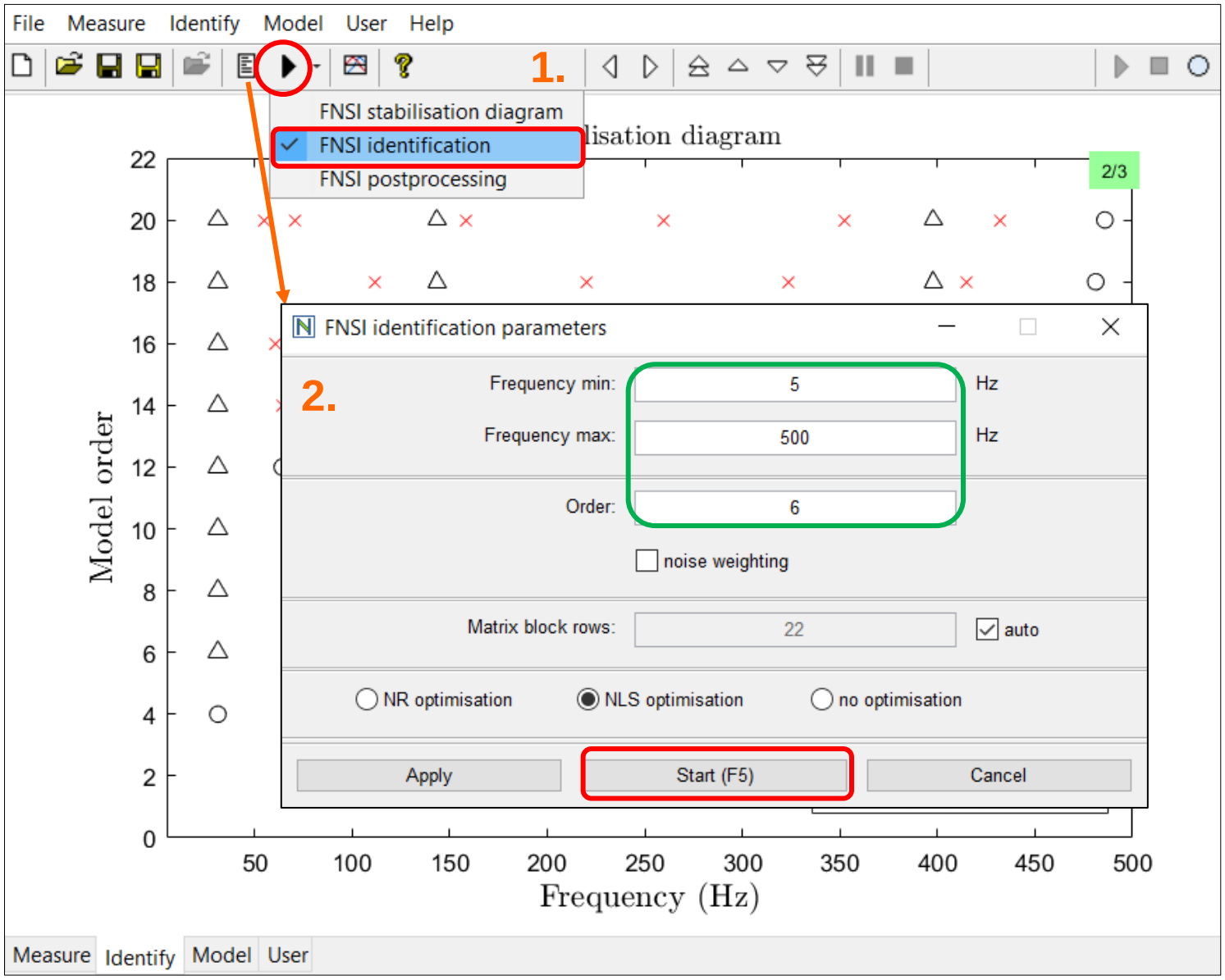
FNSI Can Be Used for Linear System Identification!



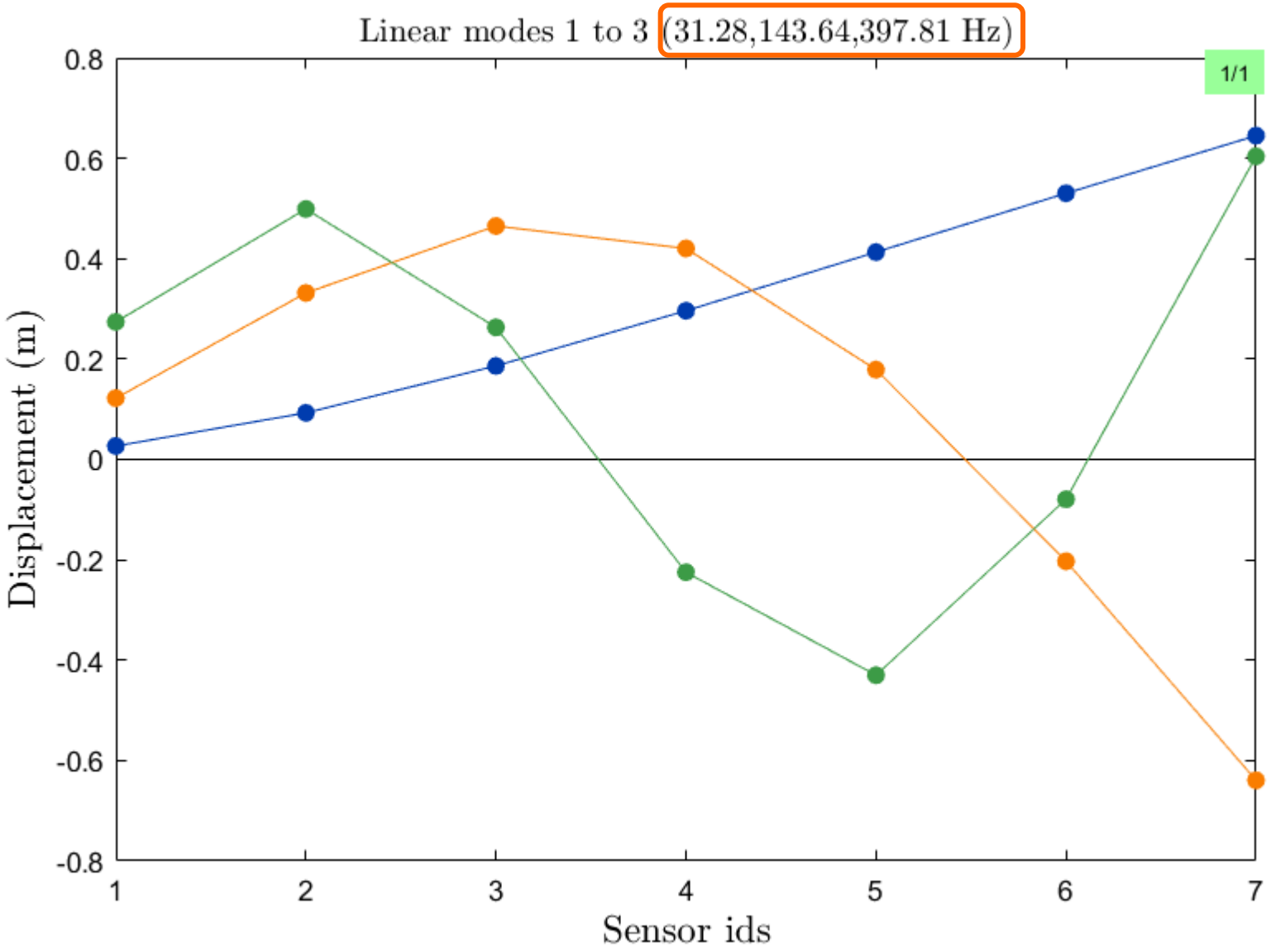
The Three Beam Modes Are Clearly Distinguished



Identification: Select Model Order 6 and Parameter Estimation

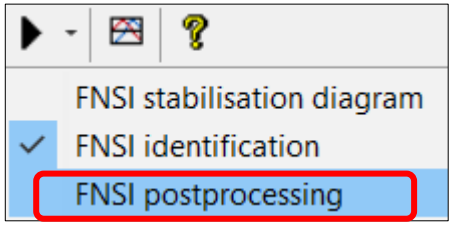


Modal Properties are Accurately Estimated

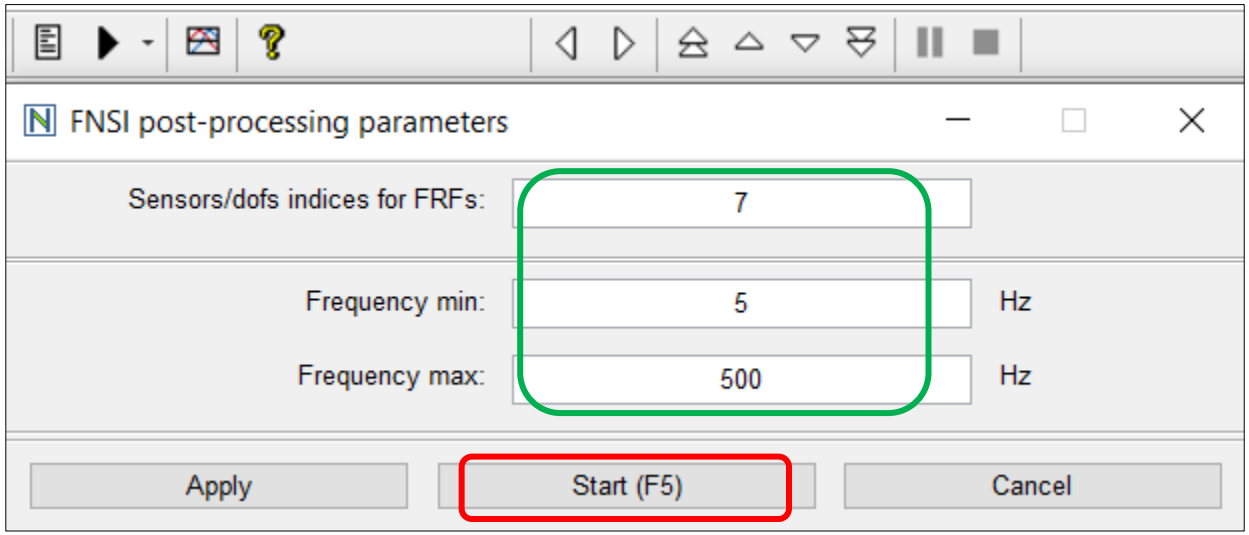


FRF Calculation based on the Identified State-space Model

1.

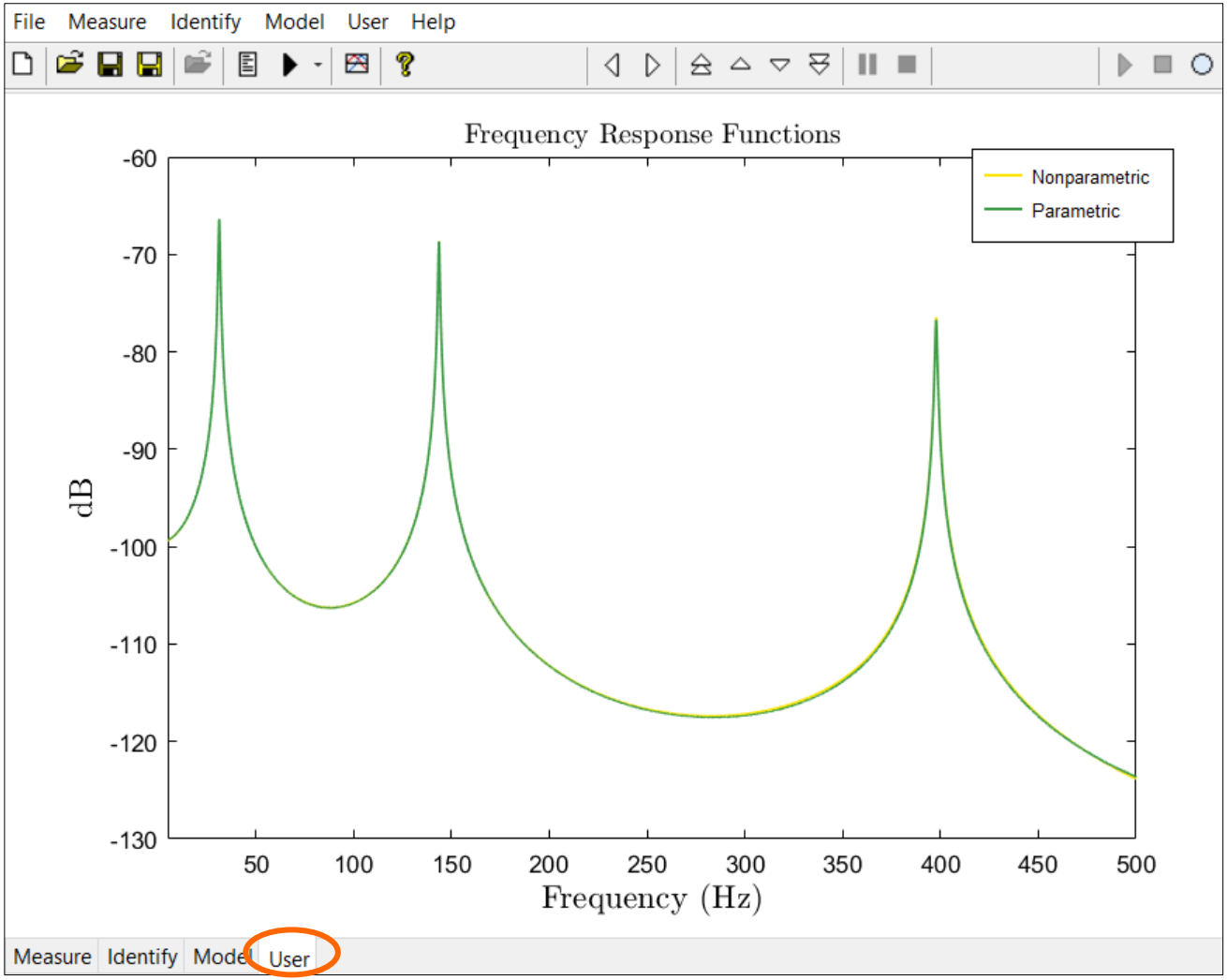


2.



Compare the computed FRFS in a curve stack

Nonparametric and parametric FRFs match very well!



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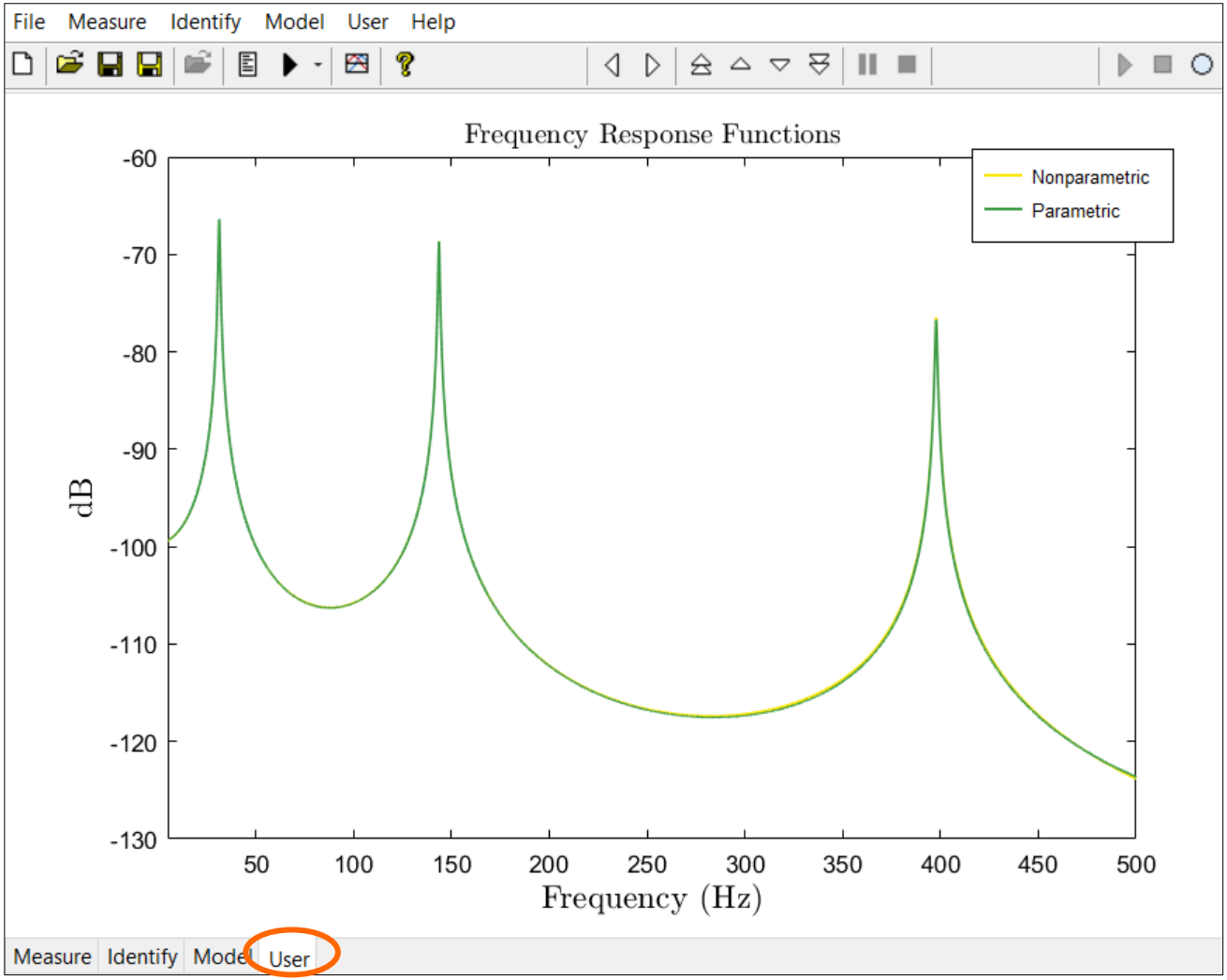
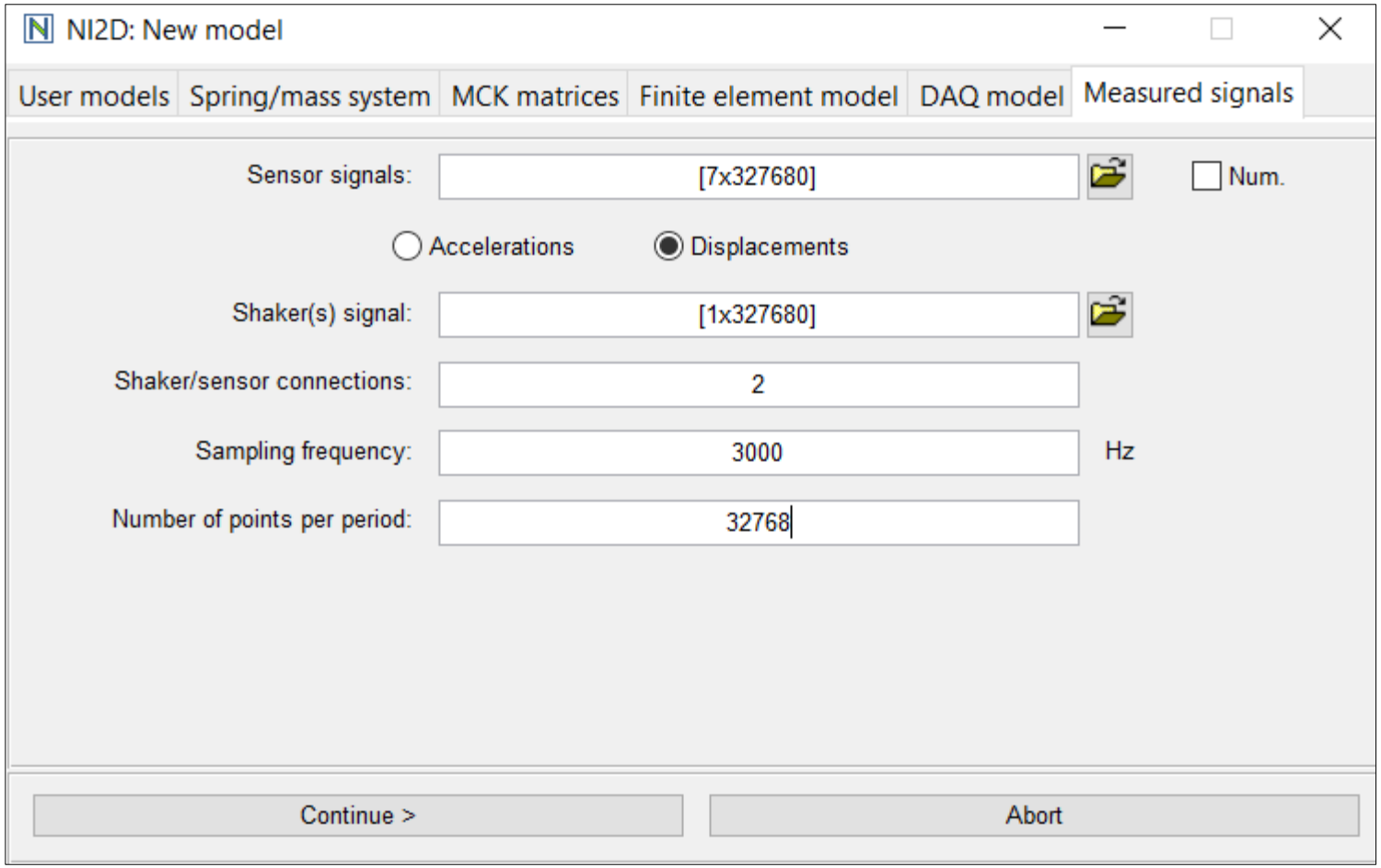
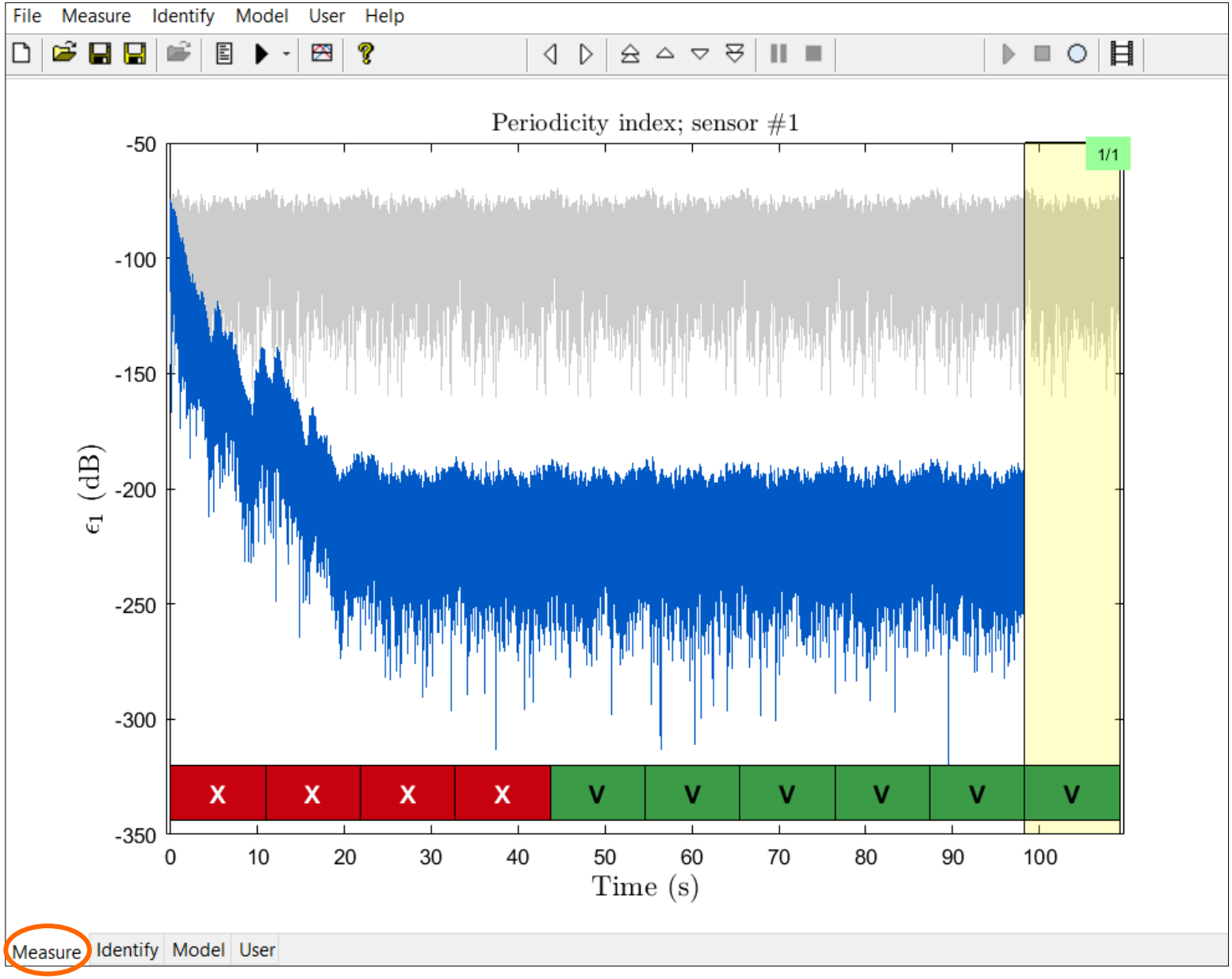


Nonlinear Identification at High Level (15 N)

Create a new model with the displacement series obtained using a higher forcing amplitude.

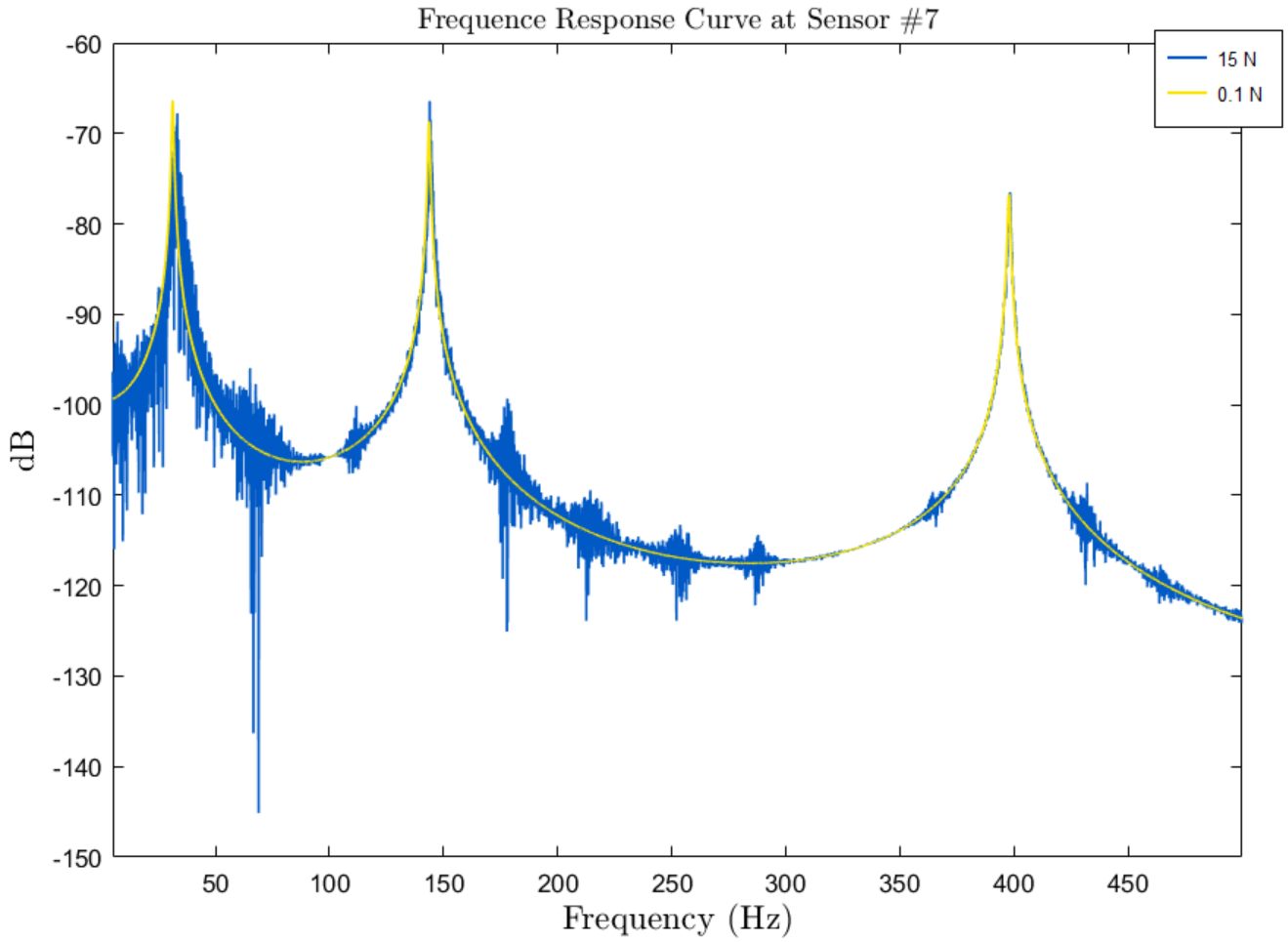


Get Rid of Transients



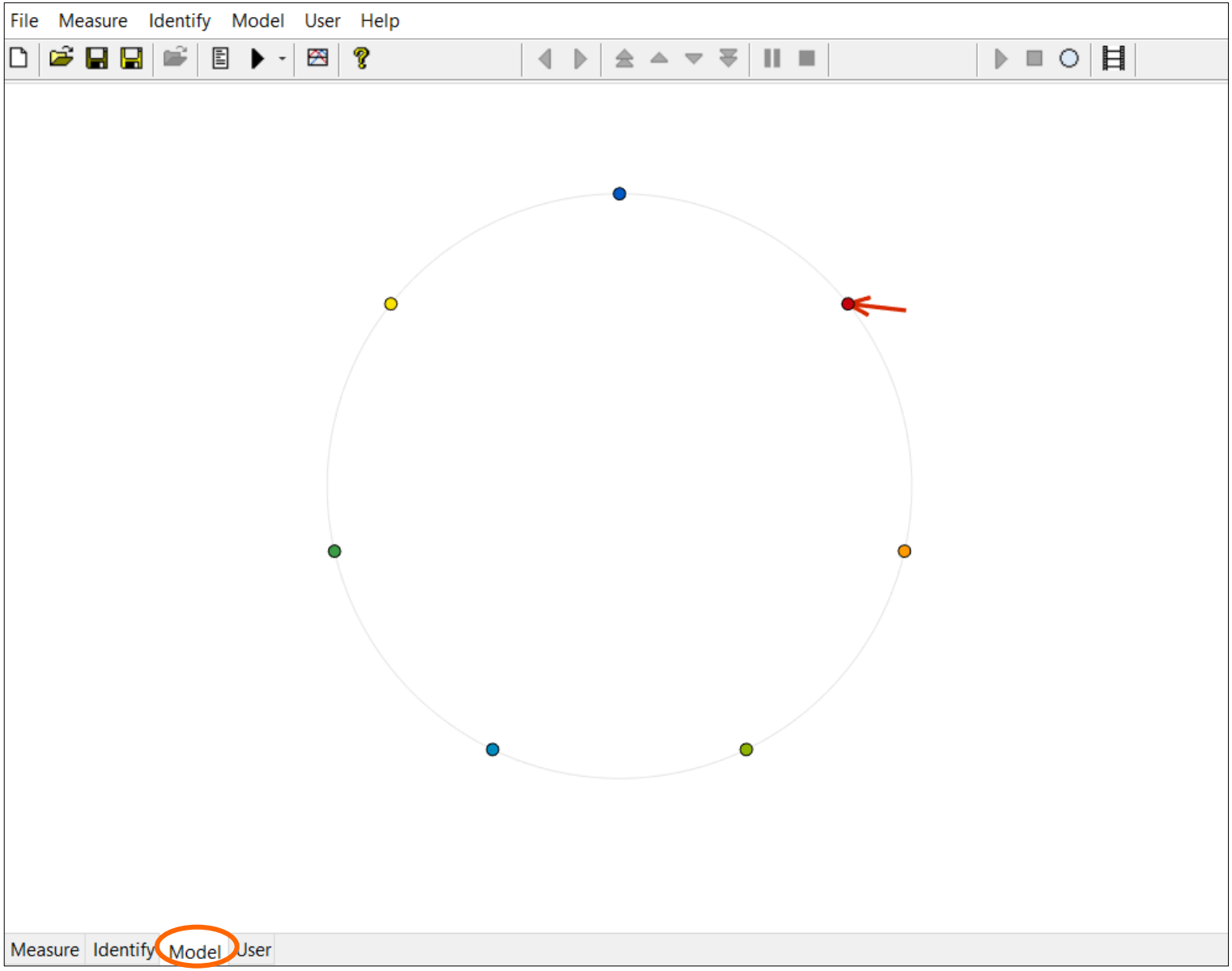
And Compute the FRF

Compare the FRF to the FRF for a forcing amplitude of 0.1 N by saving them in the same curve stack. You can copy data from one curve stack to another by ‘right click’ and ‘copy’.



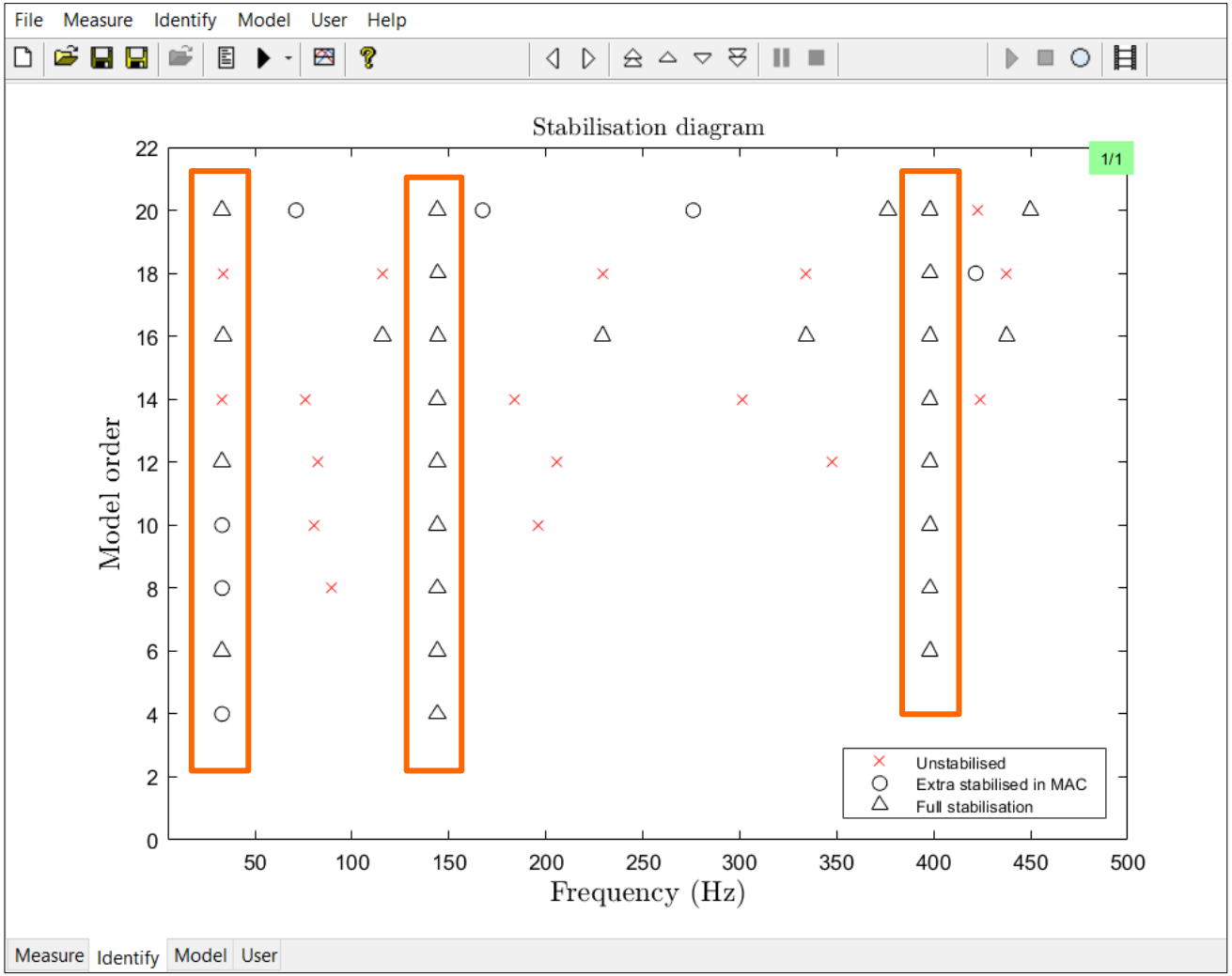
Substantial nonlinear distortions are detected in FRF Plots.

Fitting a Linear Model to Nonlinear Data

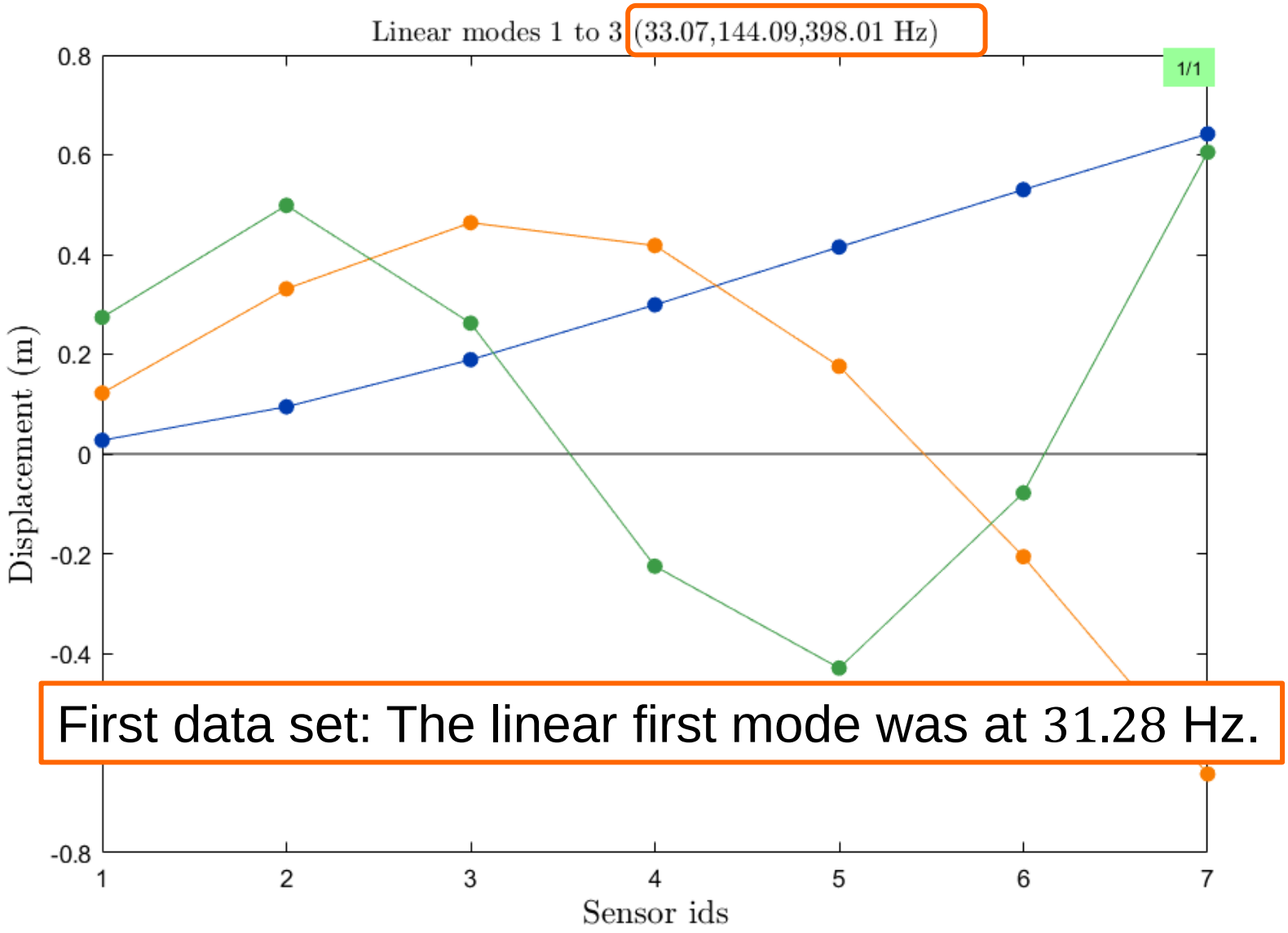


Accurate Stabilisation of Linearised Modal Properties

Go to the ‘Identify’ tab and compute the stabilisation diagram, using the same parameters as before.

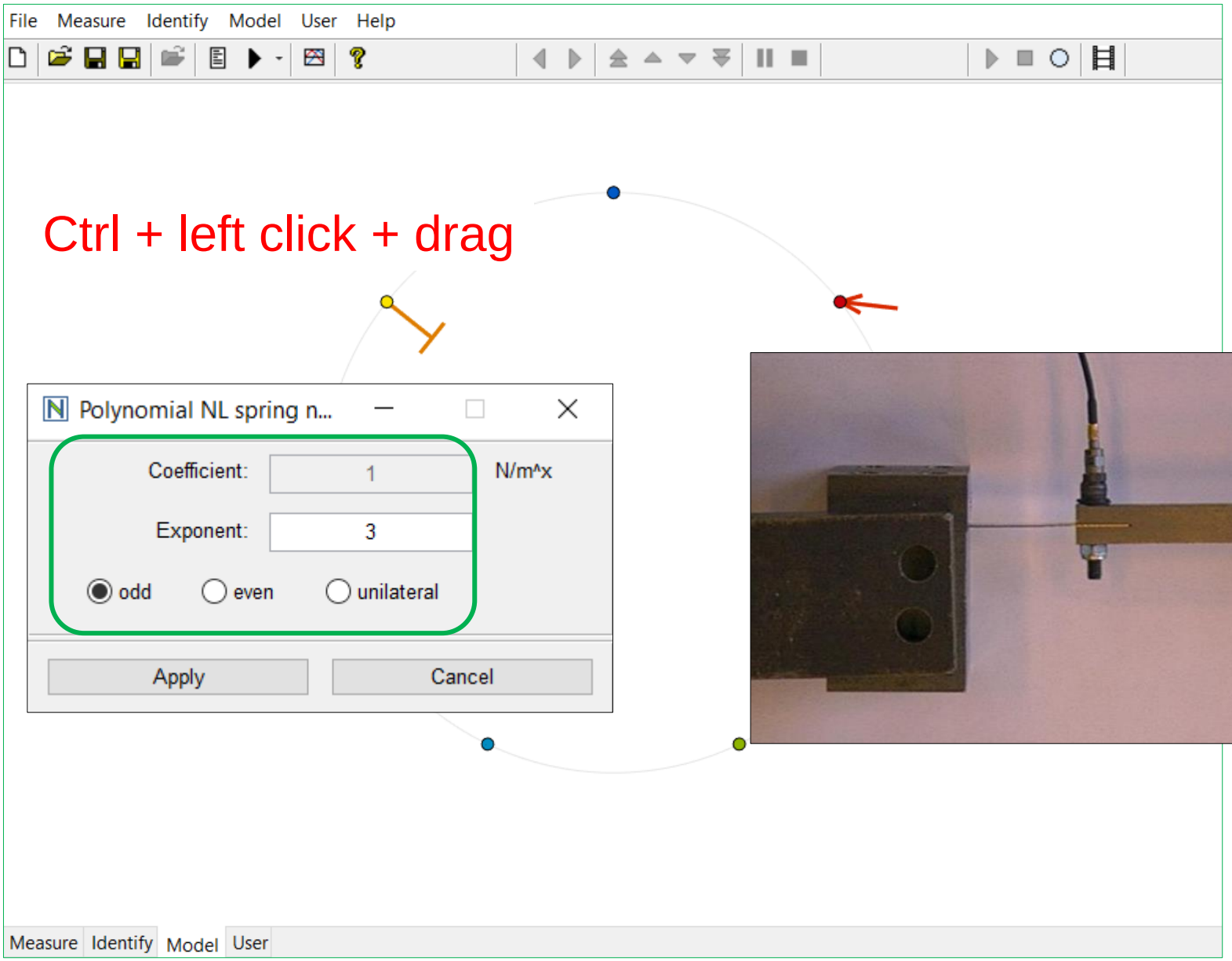


The First Mode Exhibits an Important Hardening



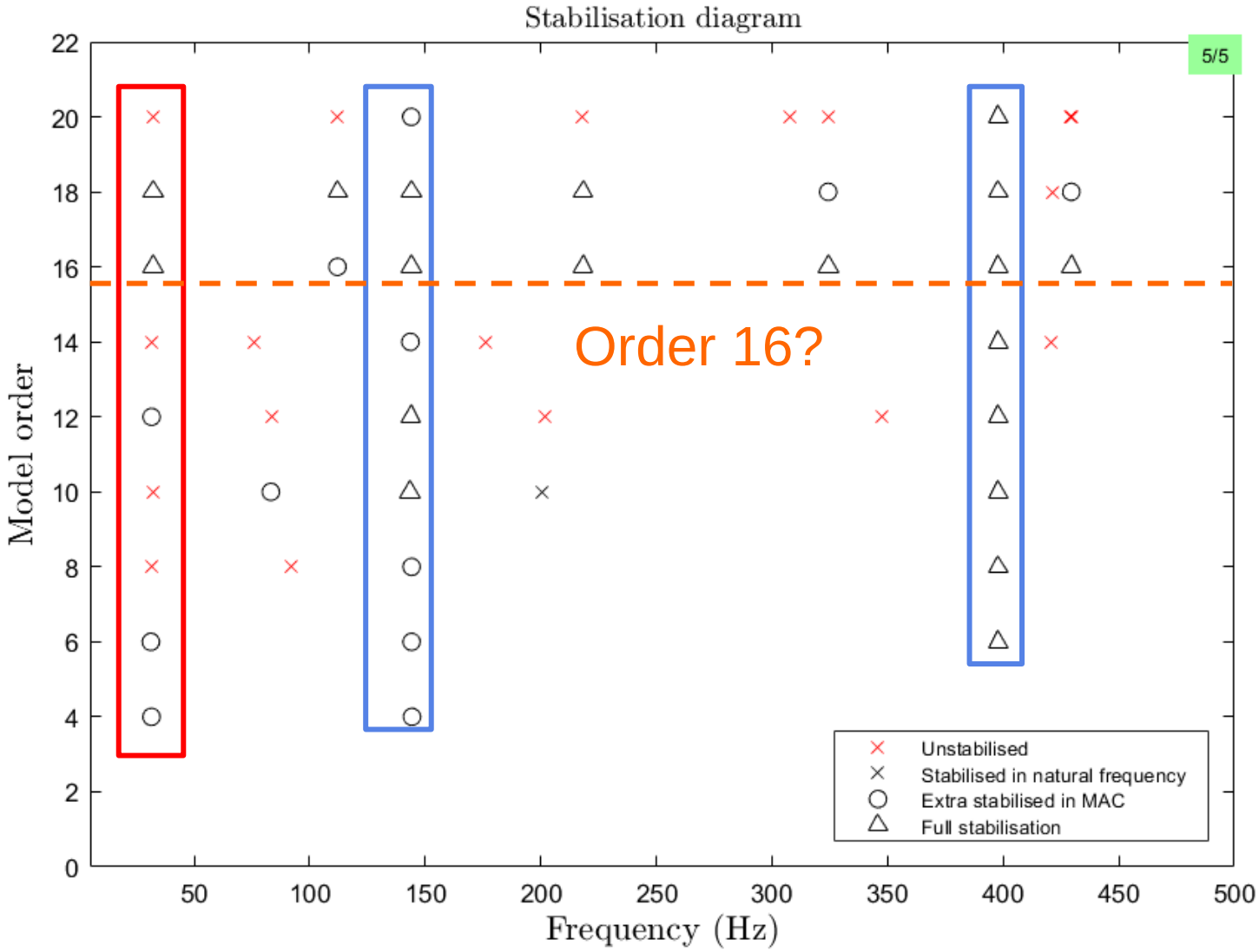
First data set: The linear first mode was at 31.28 Hz.

Physical Reasoning Suggests a Cubic Nonlinearity

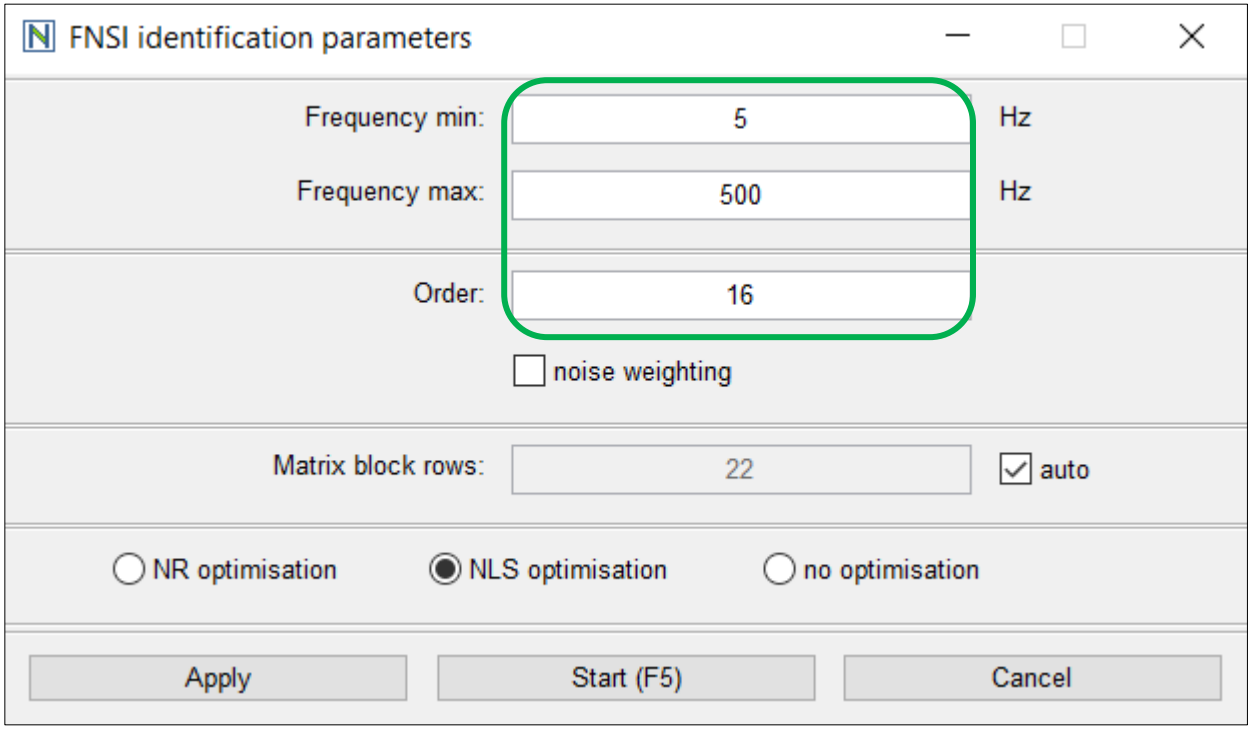


Compute the Stabilisation Diagram Again.

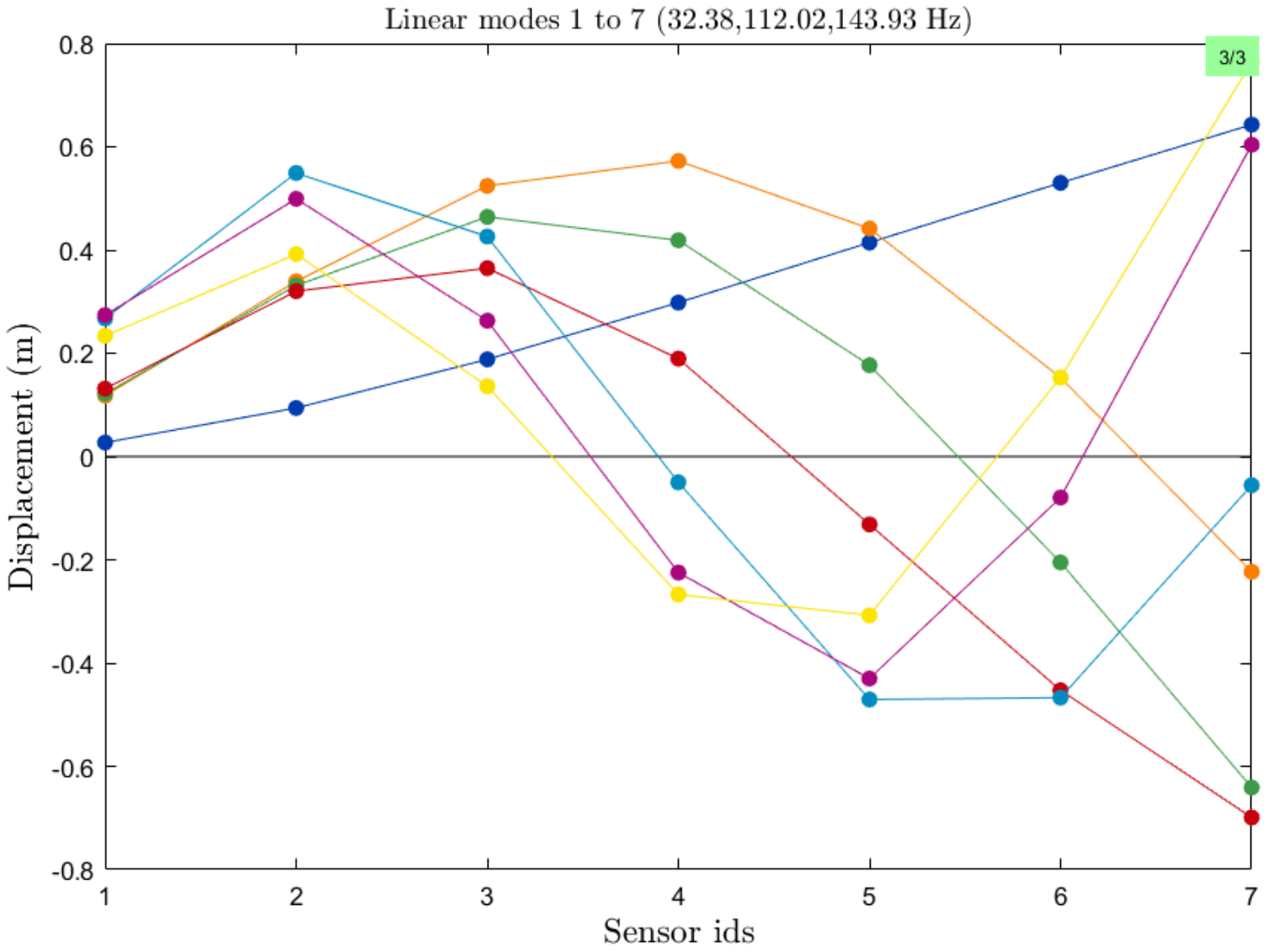
Inaccurate Stabilisation of Mode 1.



Set the FNSI Identification Parameters

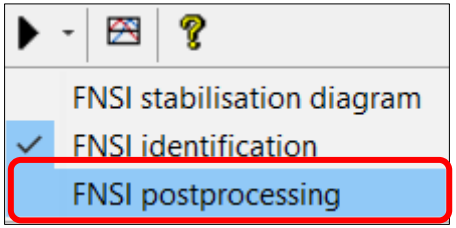


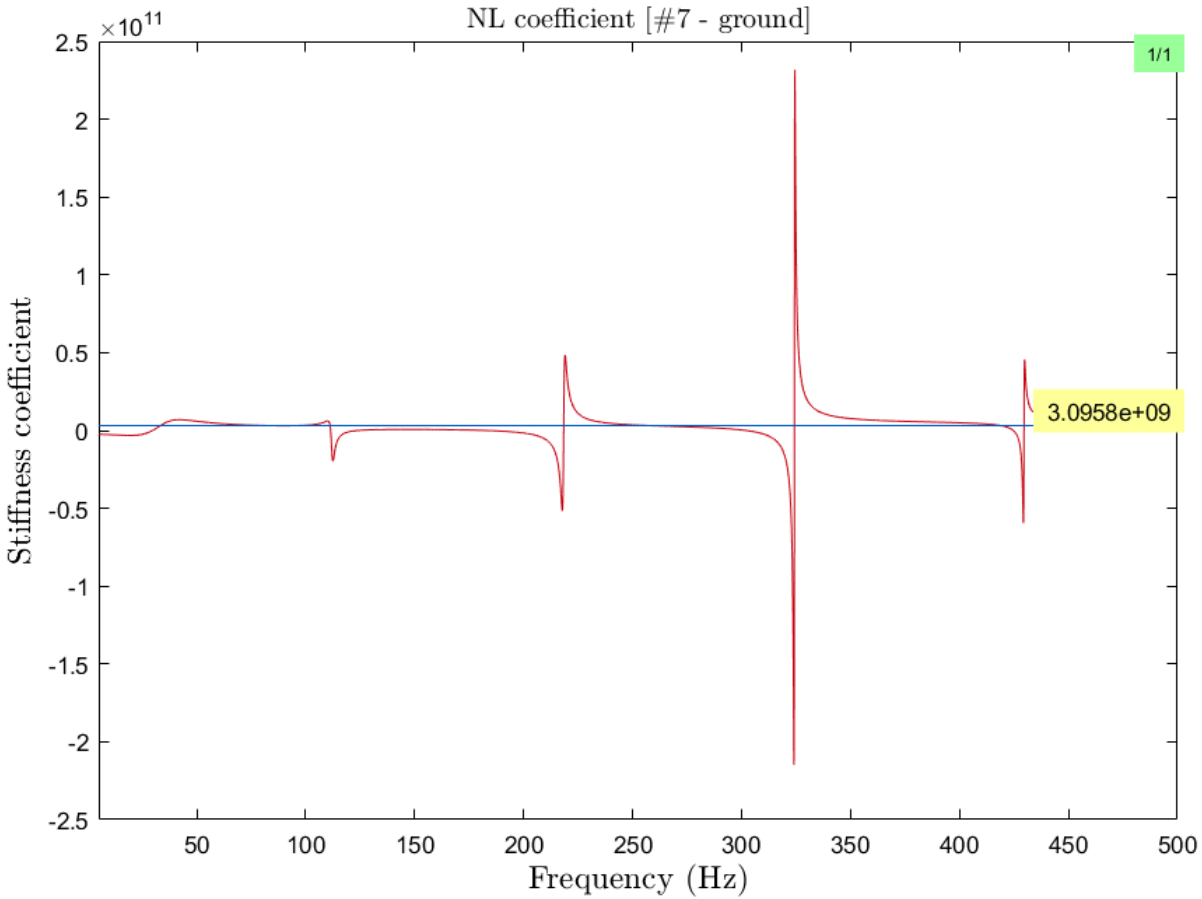
More than Three Modes Are Identified



The Nonlinear Coefficient

1. Go to the FNSI postprocessing





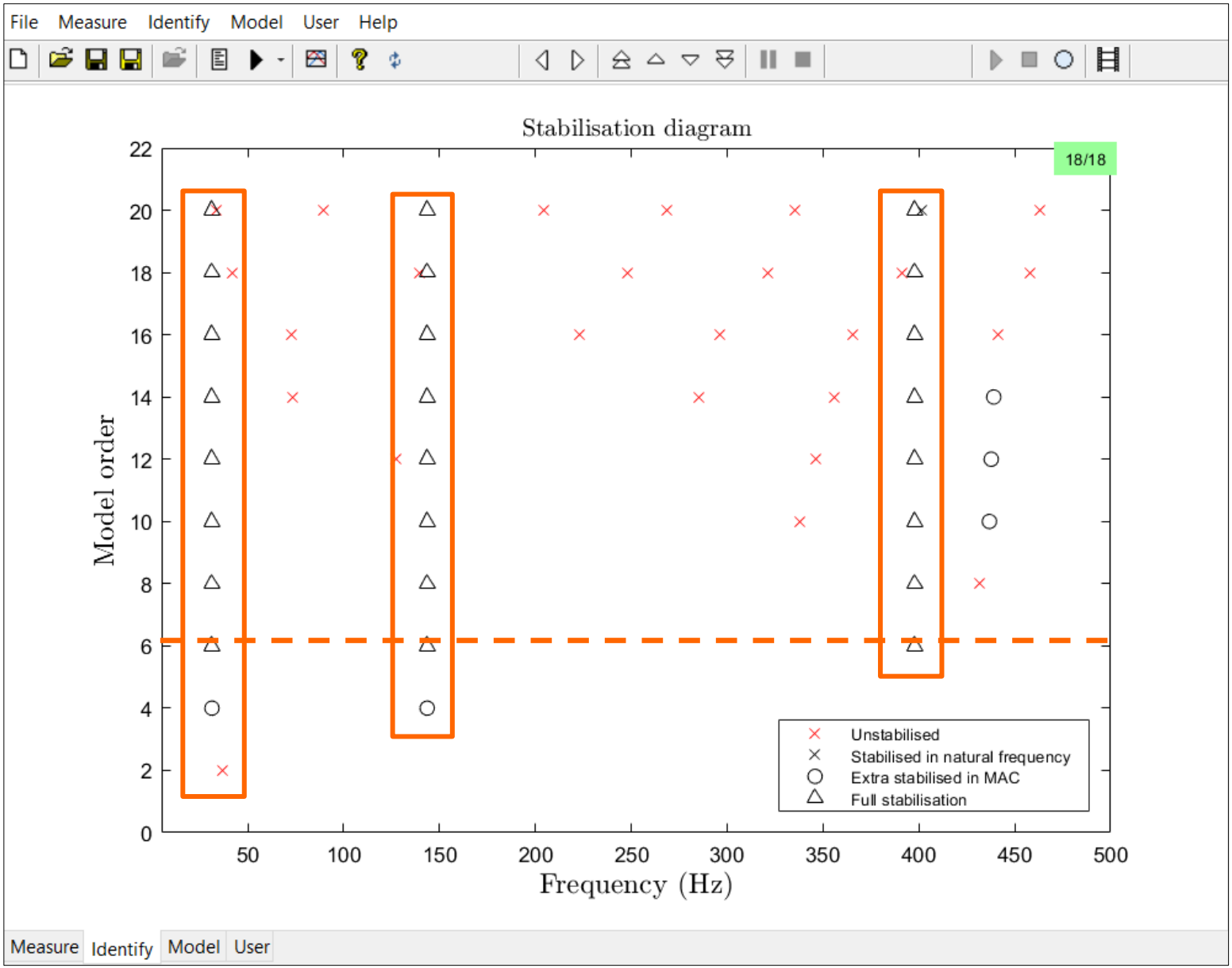
2. Multiple spurious poles appear in the nonlinear coefficient

Can You Guess the Exact Nonlinearity at Beam Tip?

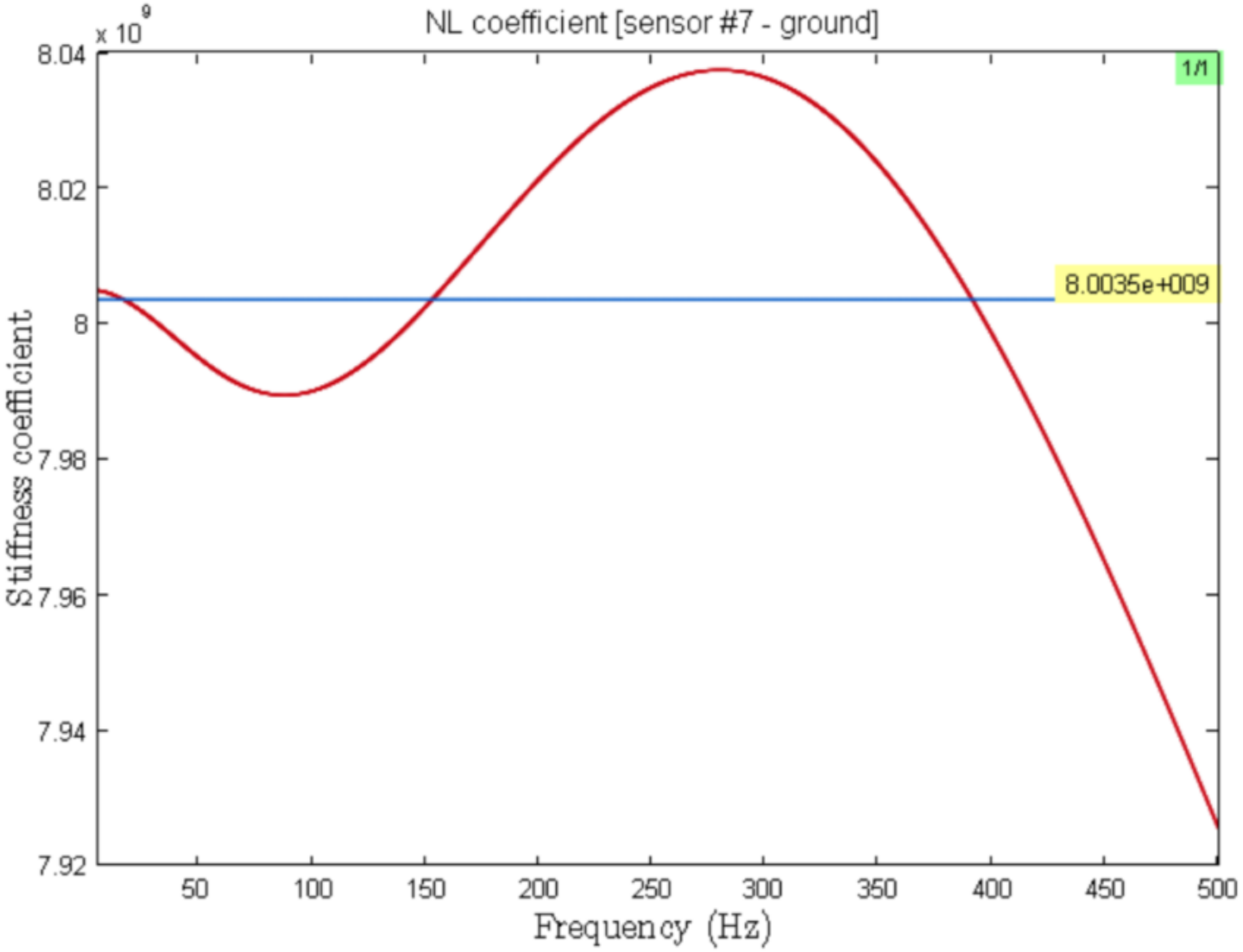
A few hints:

- Check the stabilisation of the first mode.
- Check the modal parameters compared to linear identification.
- Check the stability of the nonlinear coefficients versus frequency.
- Check the magnitude of the imaginary parts of the coefficients.

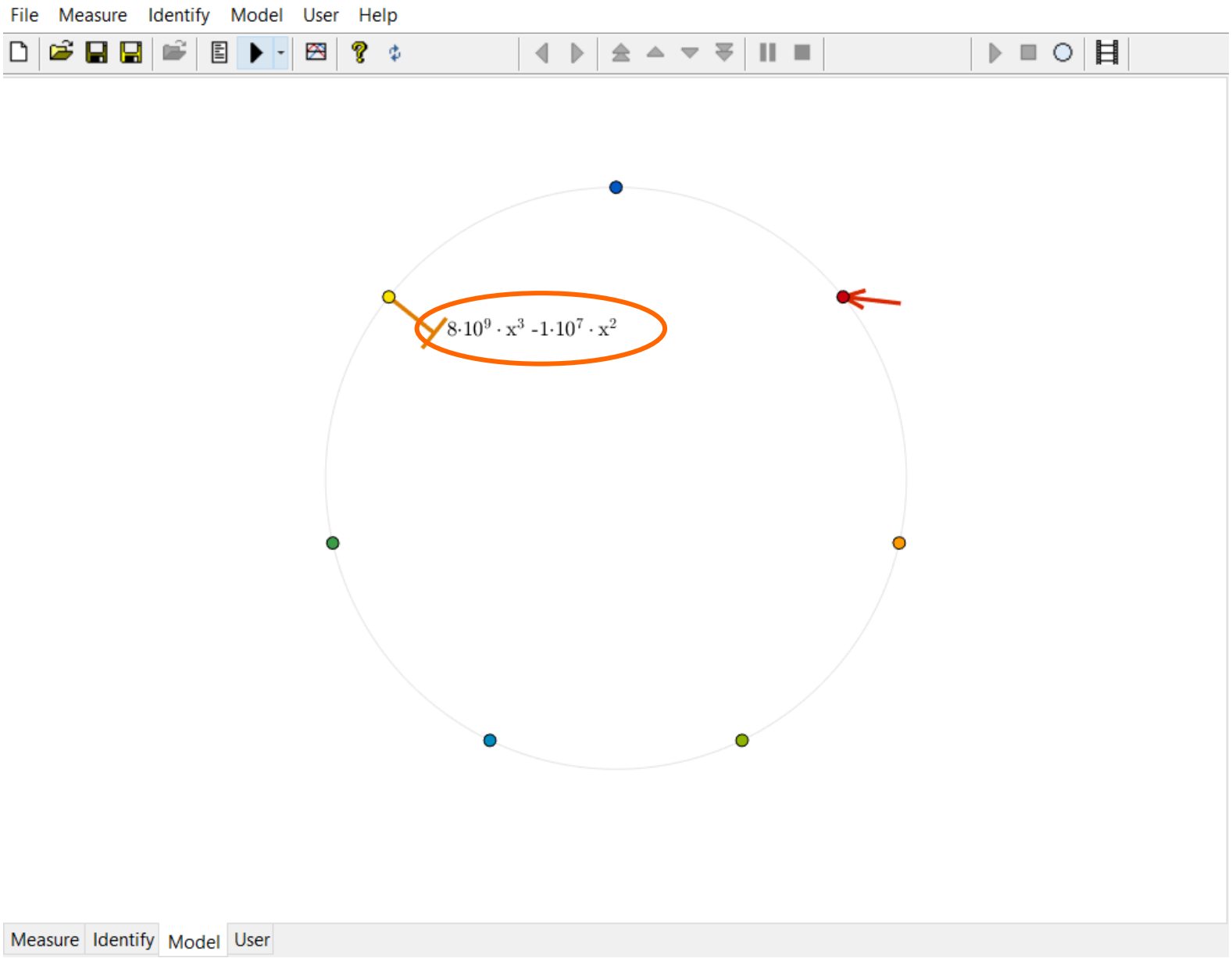
Accurate Nonlinear Stabilisation



Nonlinear Coefficient with Virtually no Frequency Dependence



Successful Identification of the Nonlinear Coefficients



Concluding Remarks and Learning Outcomes

- NI2D software makes the use of FNSI intuitive and effective (selection of nonlinear basis functions, stabilisation diagram, ...).
- Similar steps are followed to apply FNSI to linear and NL data.
- A successful characterisation remains of utmost importance towards accurately estimating model parameters.