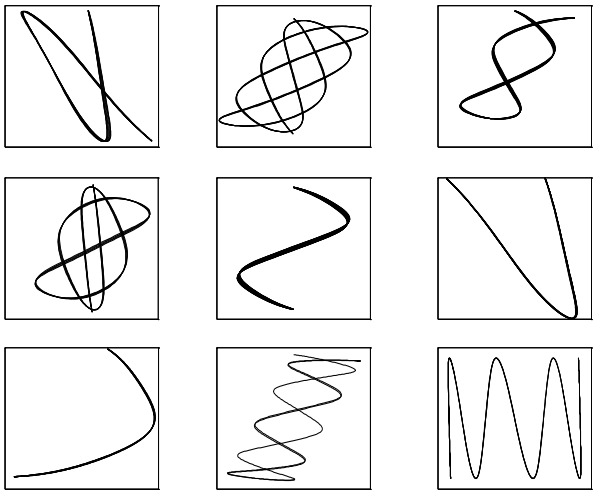
Nonlinear Vibrations of Aerospace Structures

T03 | **Nonlinear modal analysis**

Nonlinear normal modes

Frequency-energy plot

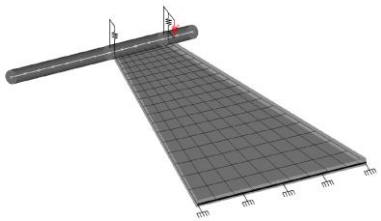


NI2D Philosophy

From measurements to design

VIBRATION MEASUREMENTS

LINEAR FINITE ELEMENT MODEL



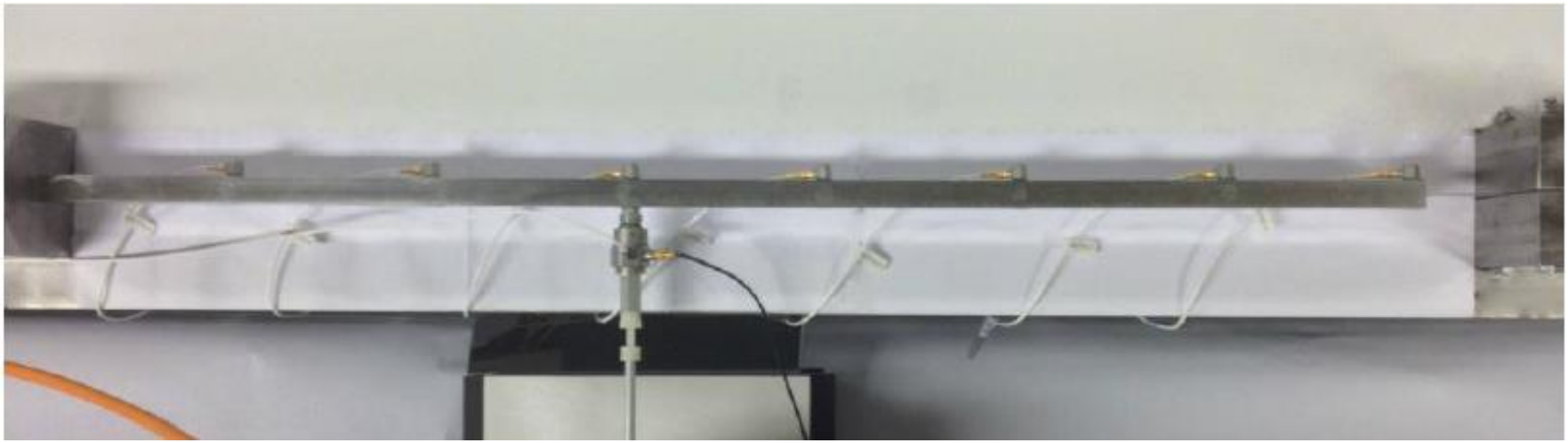
MEASURE → IDENTIFY → **HYBRID MODELING** → UNDERSTAND → DESIGN

A priori knowledge about the nonlinearities is available:

Load the linear FEM into NI2D and implement the nonlinearities using NI2D elements library.

Tutorial 1: The First Mode of the Nonlinear Beam

The Nonlinear Beam



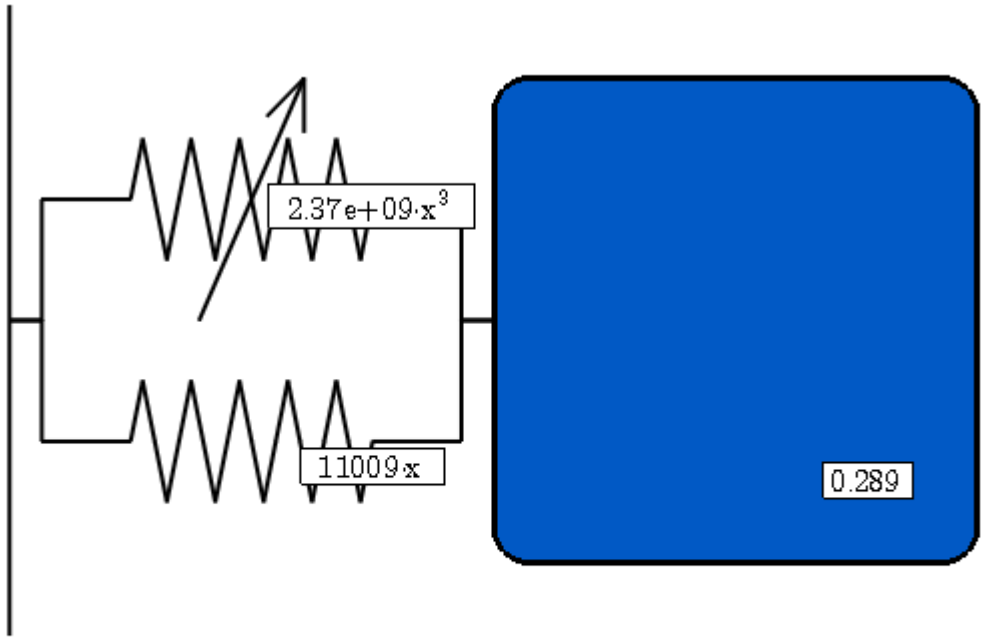
Linear model identified at low level (31 Hz, 0.12%):

$$0.289\ddot{x} + 0.1357\dot{x} + 11009x = Fsin\omega t$$

Nonlinearity identified at high level: $2.37.10^9\, x^3$

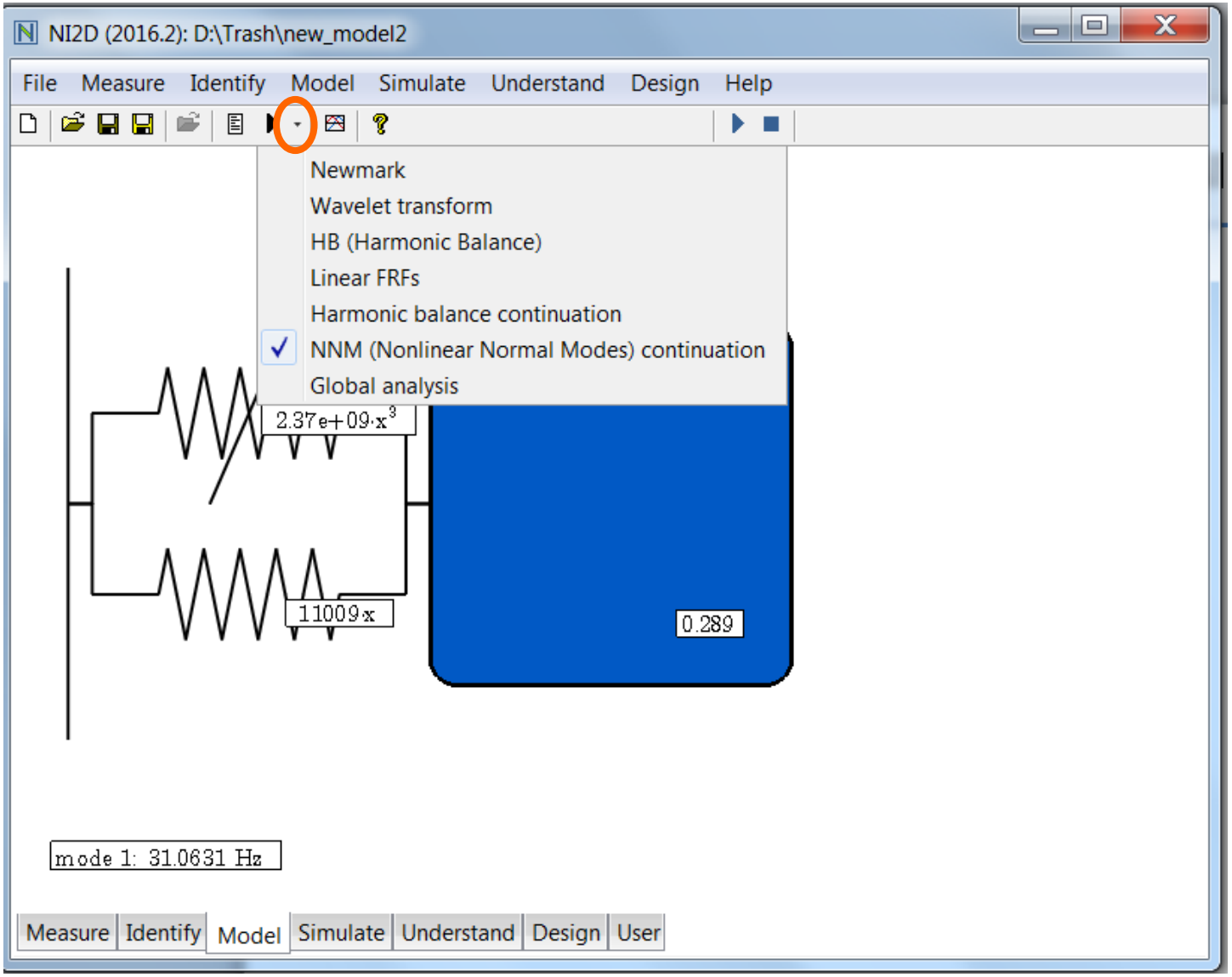
The Nonlinear Beam

No forcing, no damping

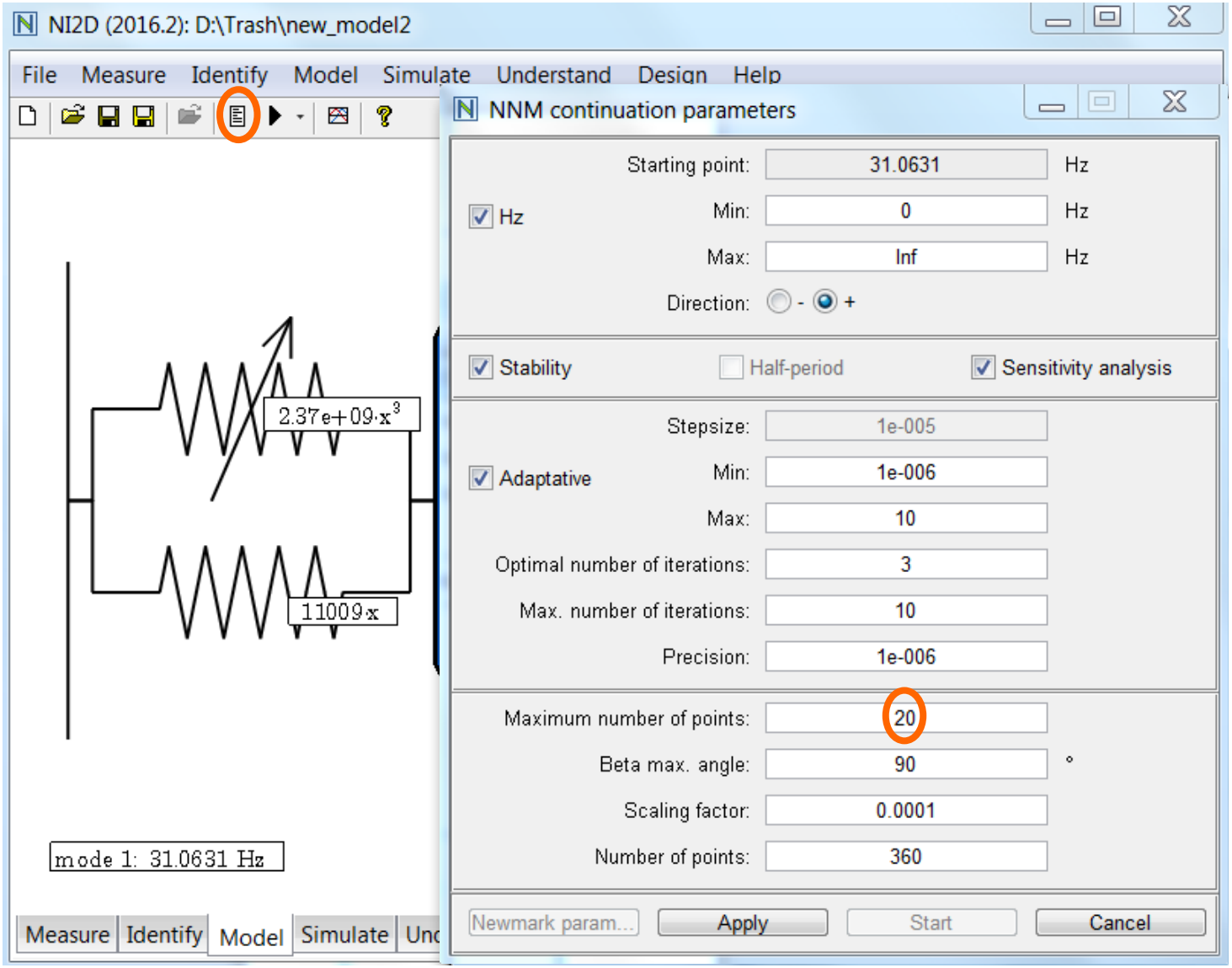


mode 1: 31.0631 Hz

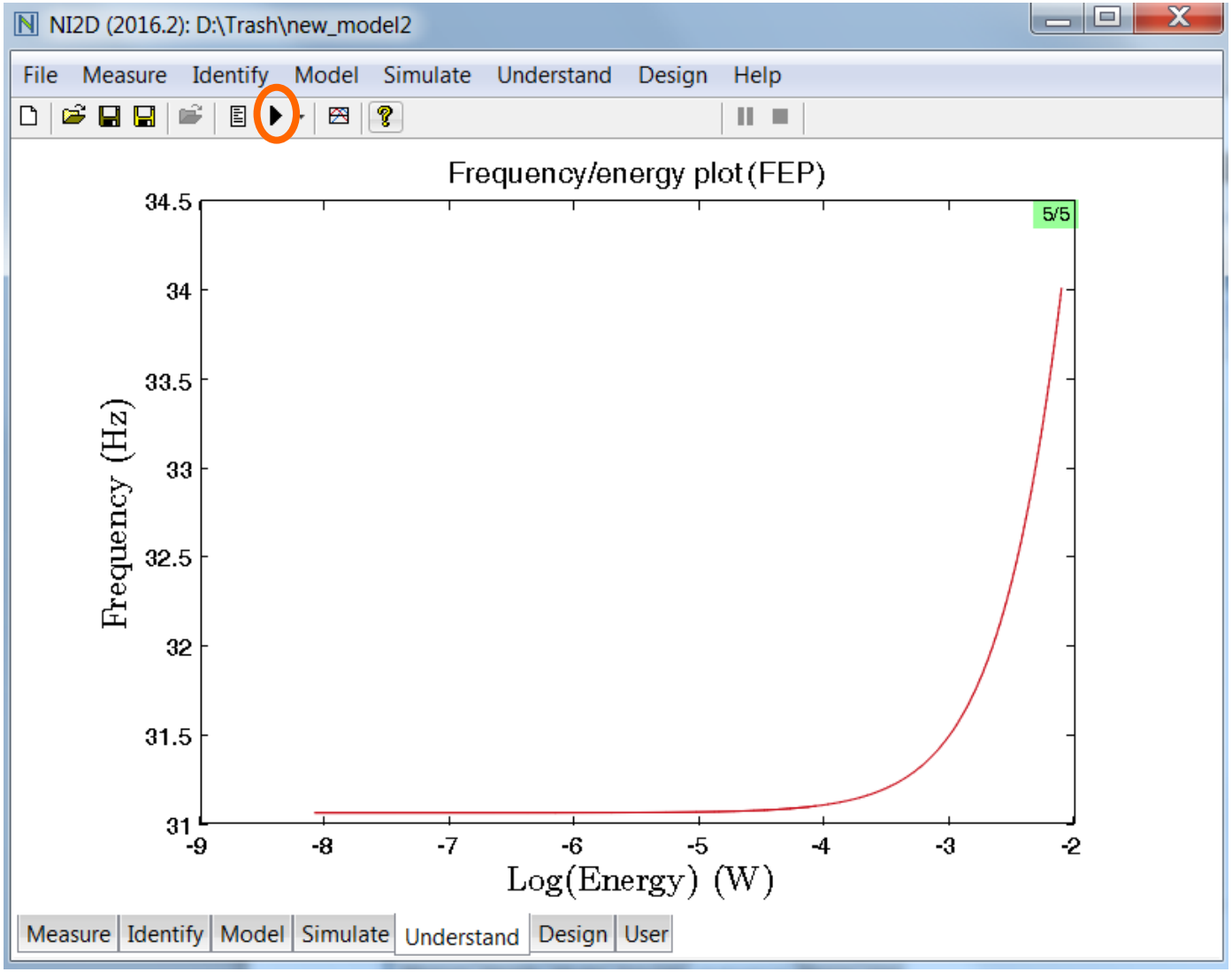
The NNM Solver



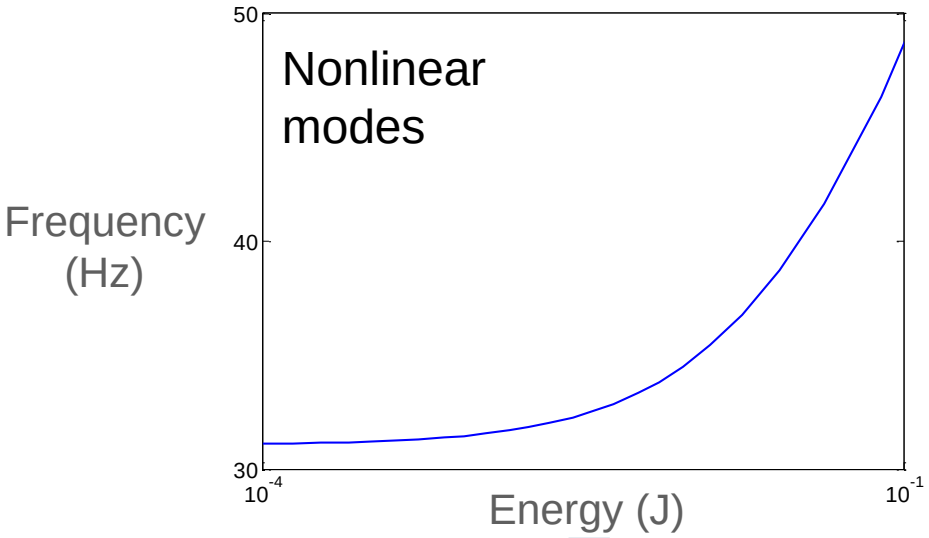
Set Appropriate Parameters

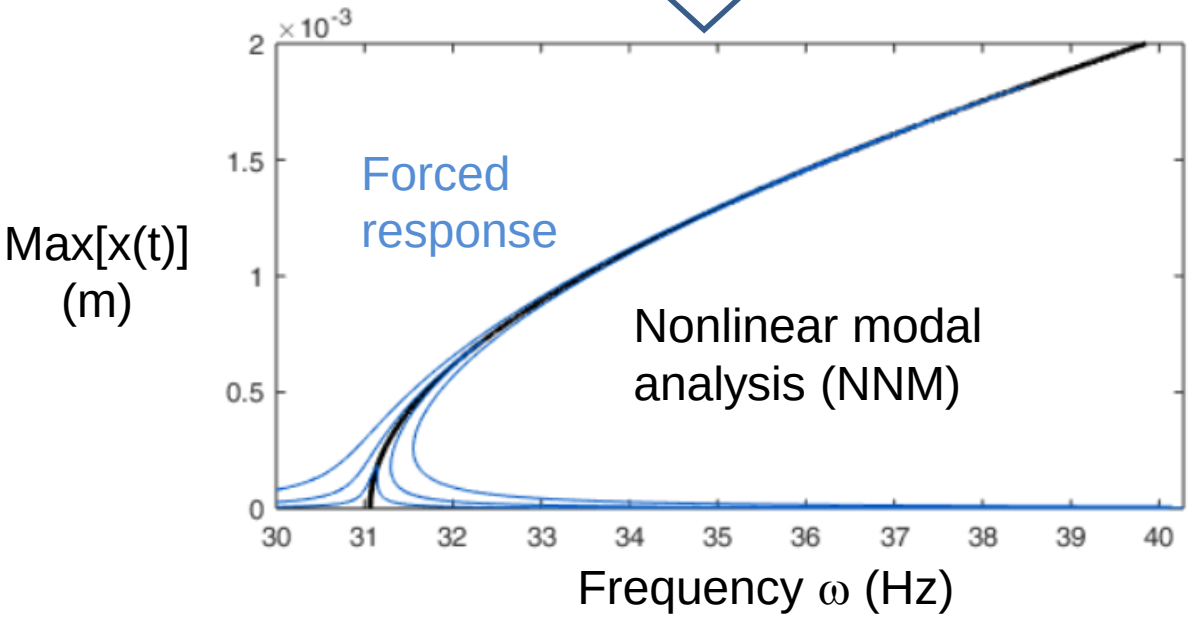


Compute The First Nonlinear Mode



The Link Between Nonlinear Modes and FRFs

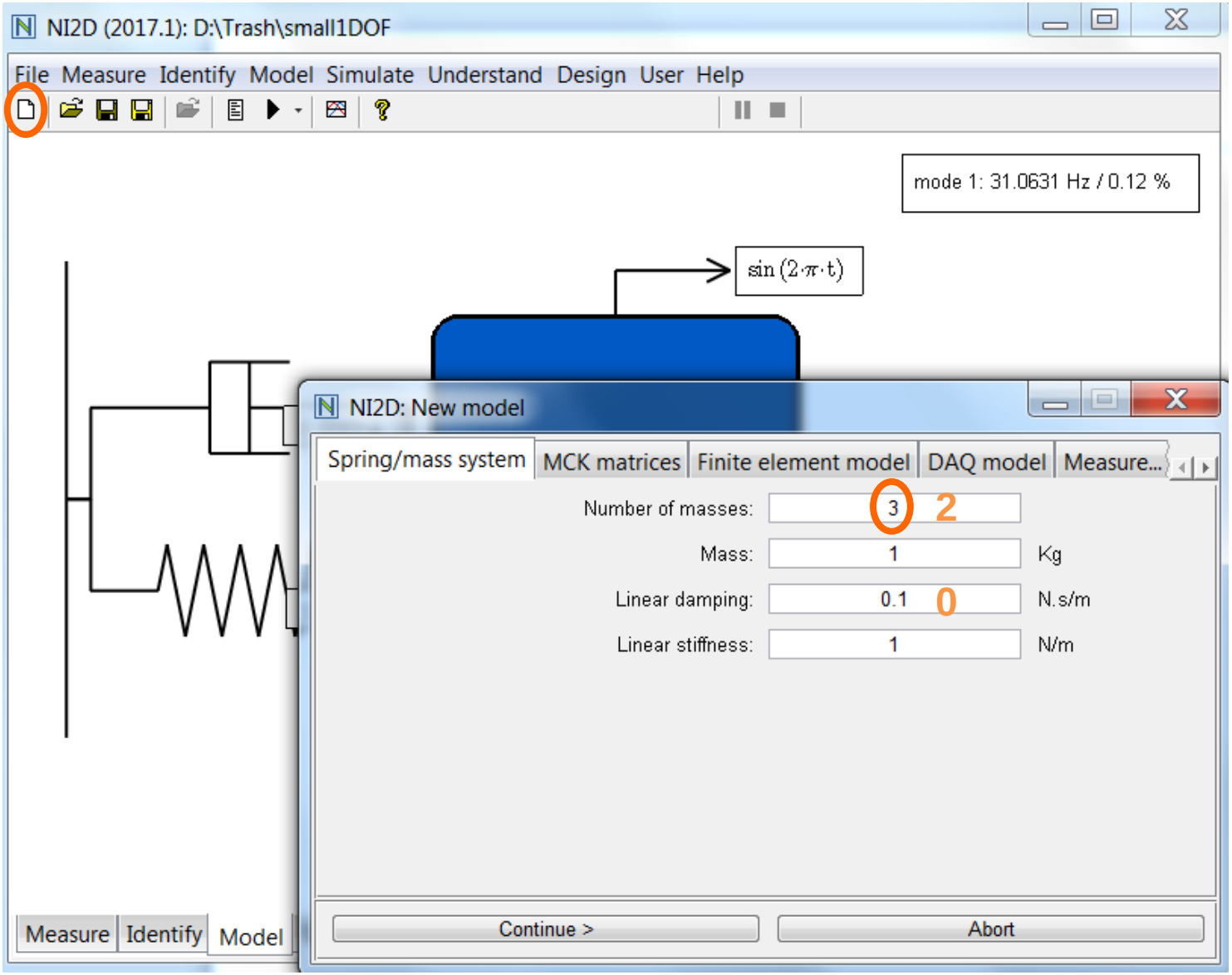




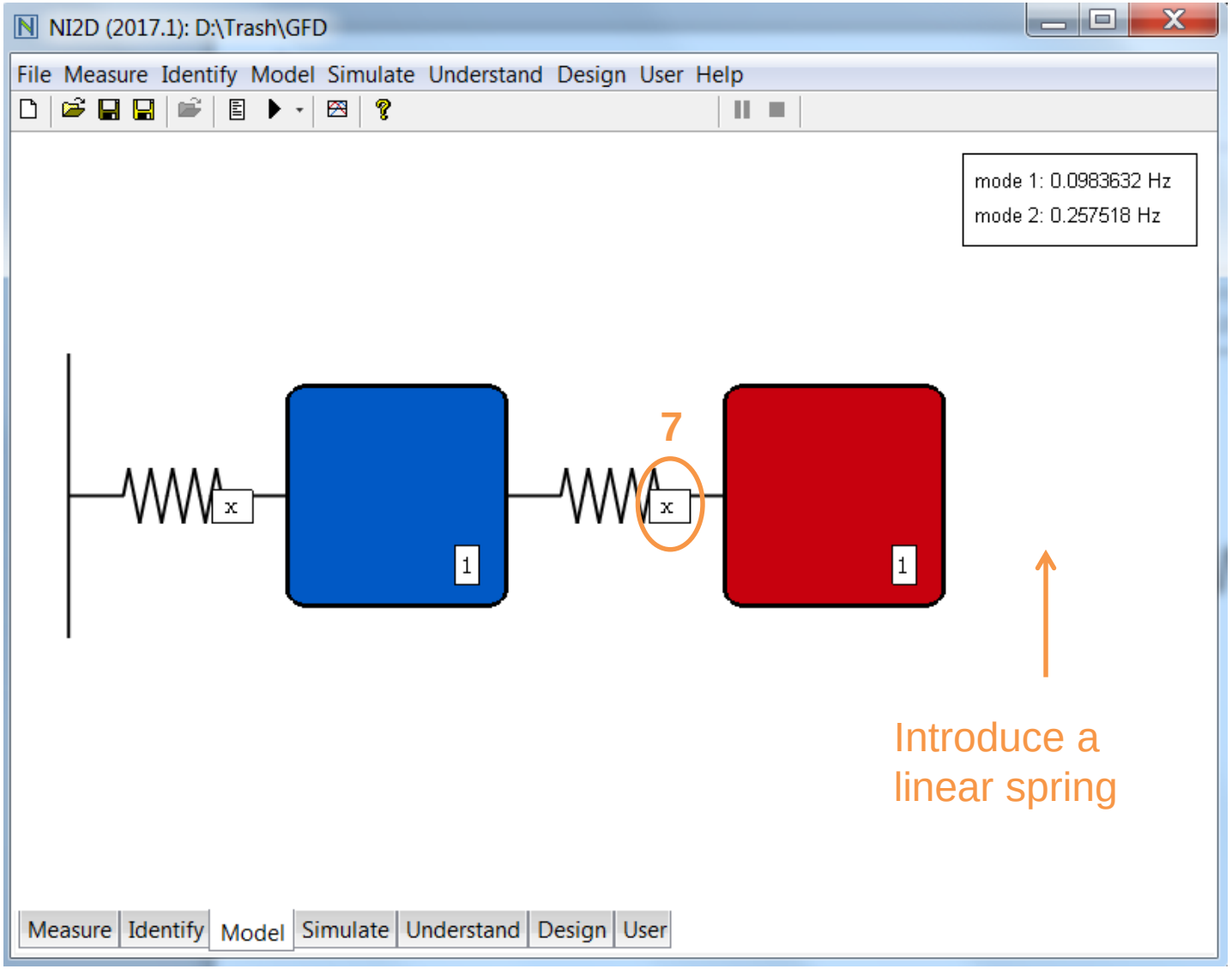
Concept of backbone curve !

Tutorial 2: The Modes of a Multi-DOF System

Create a 2-DOF Model

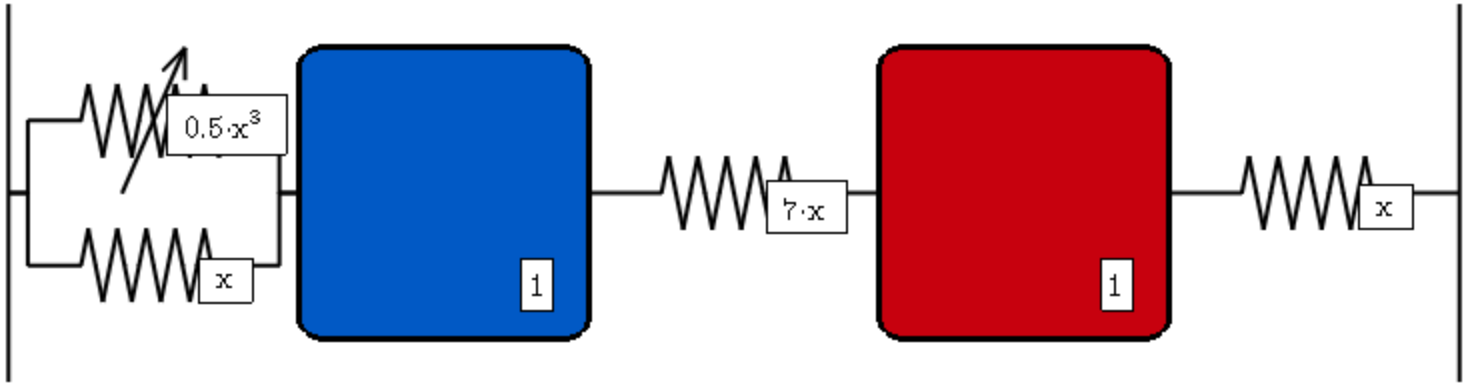


Modify the 2-DOF Model

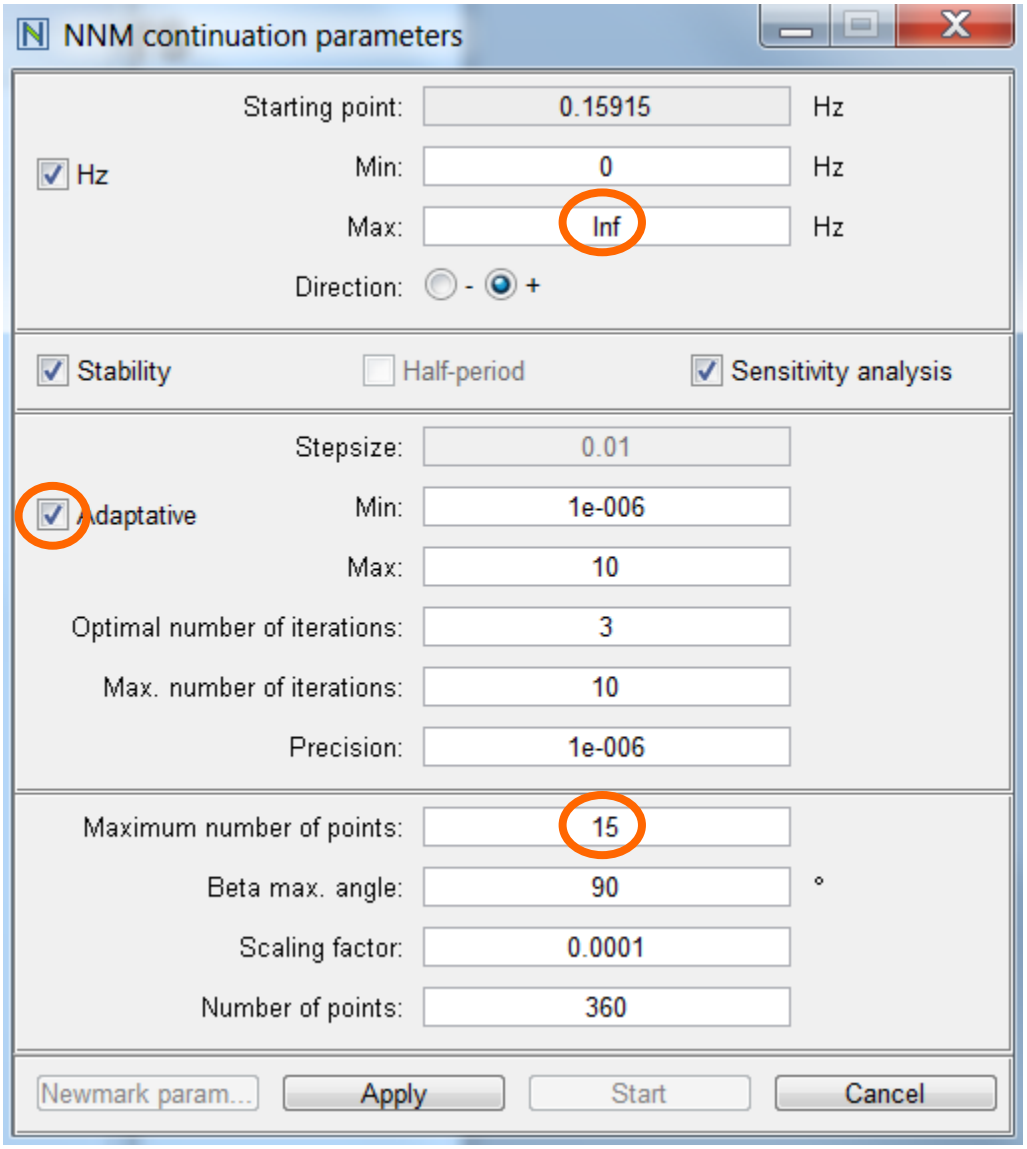


The Final Model

mode 1: 0.159155 Hz
mode 2: 0.616404 Hz



In-Phase Mode: Set Appropriate Parameters



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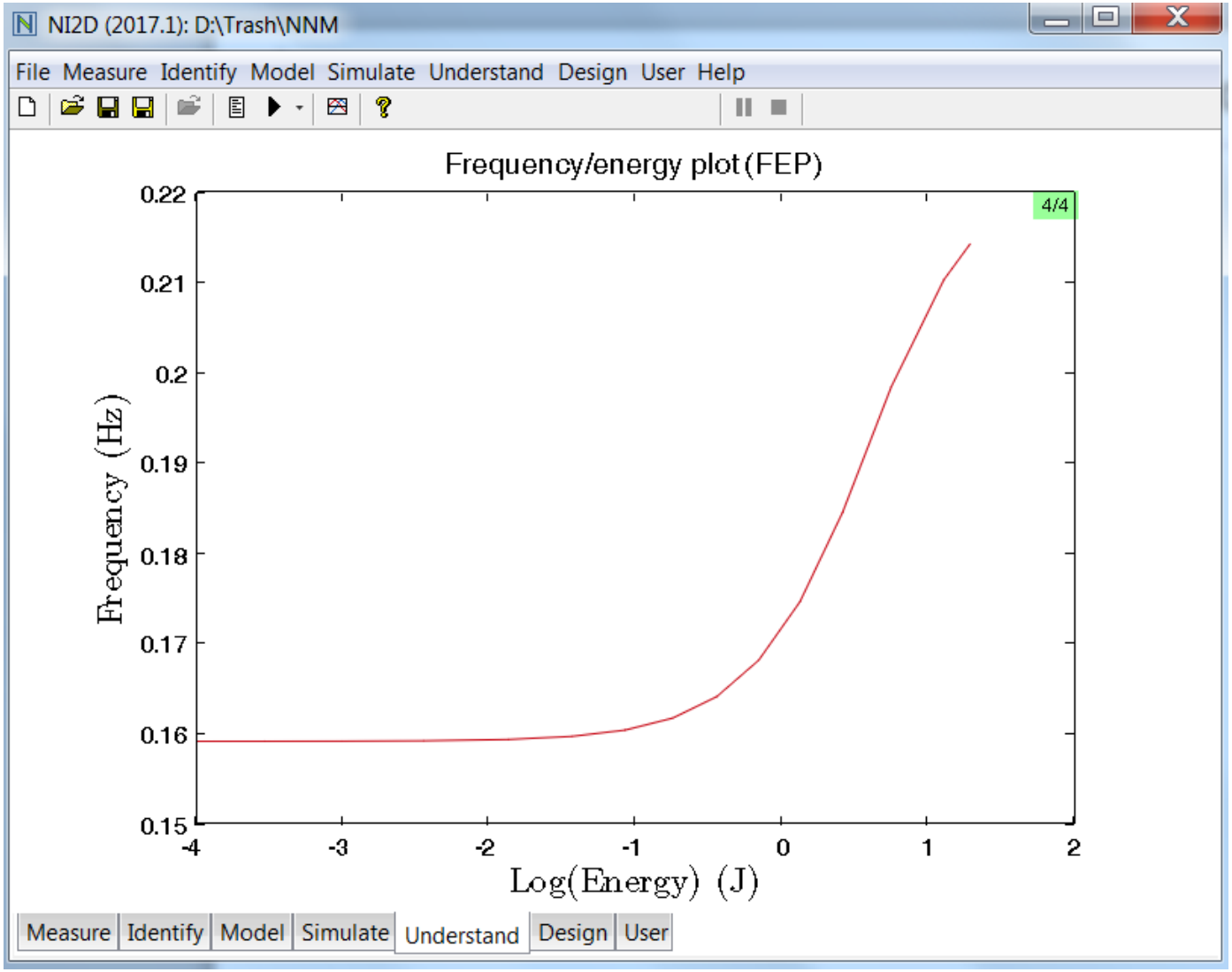
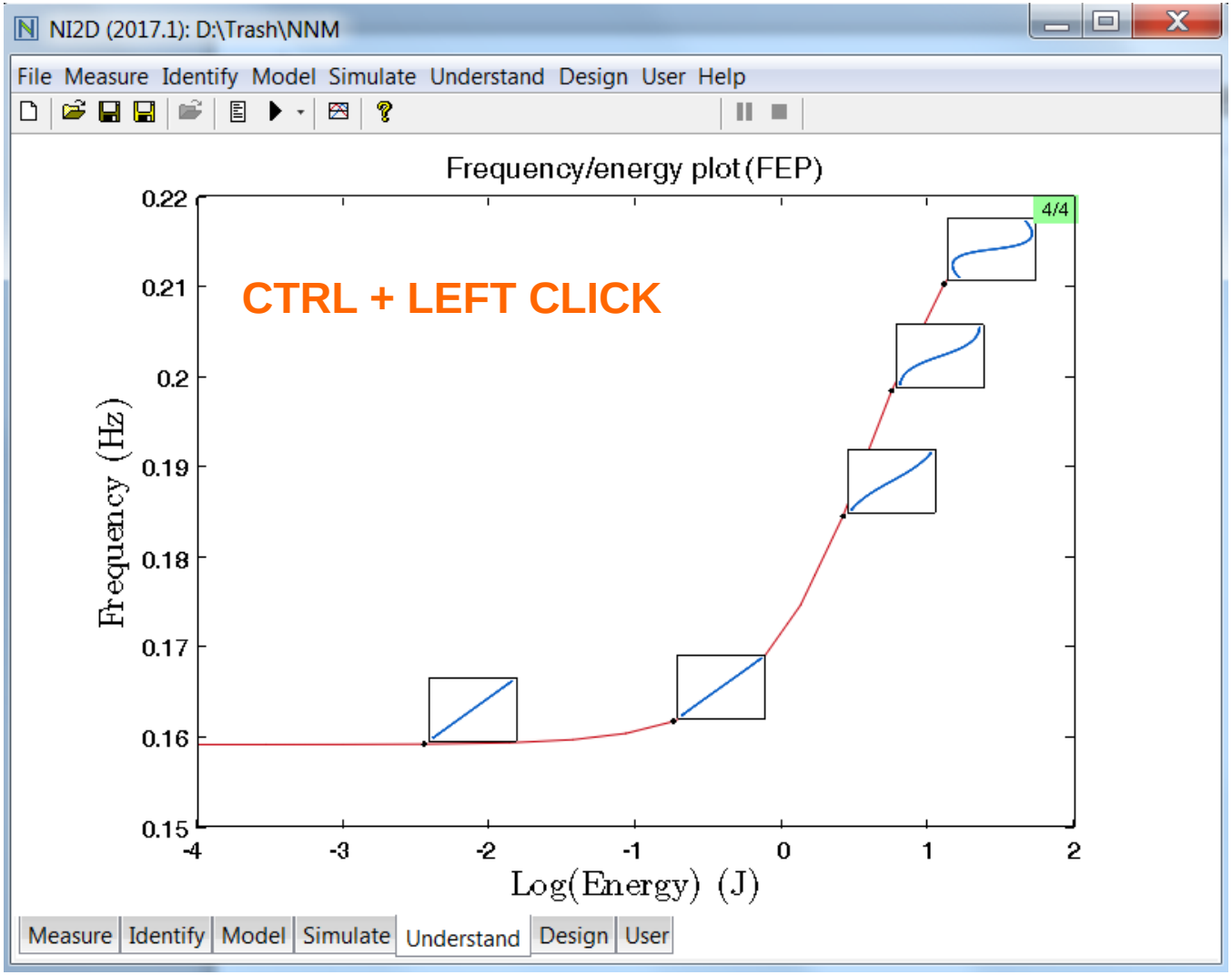
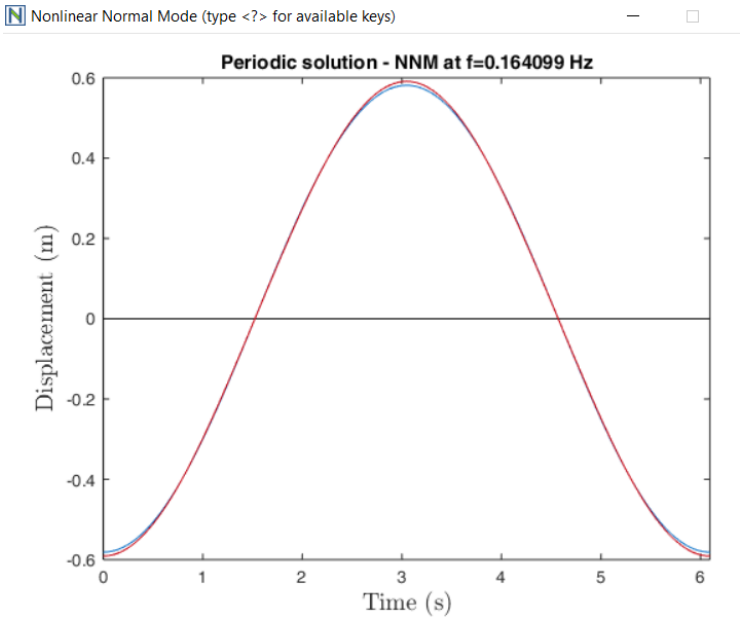
In-Phase Mode: The Resonance Frequencies

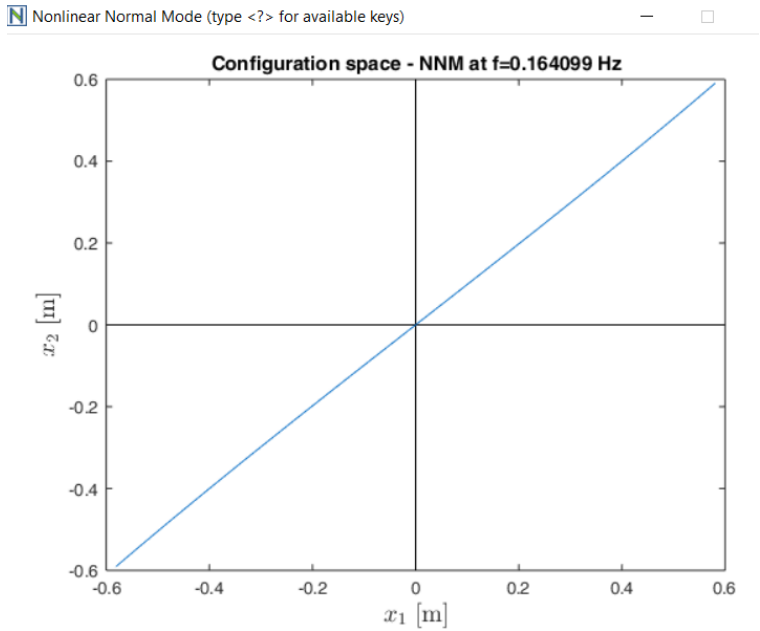


In-Phase Mode: The Modal Shapes



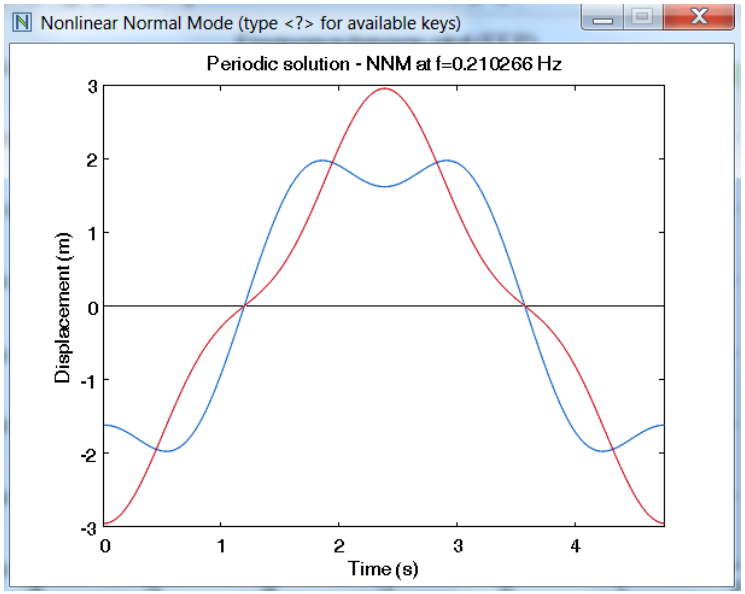
In-Phase Mode @ Low Energies

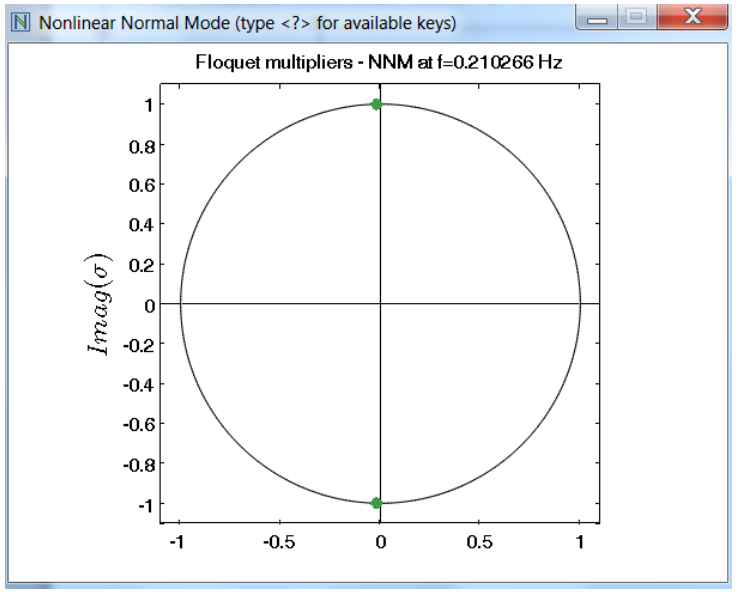




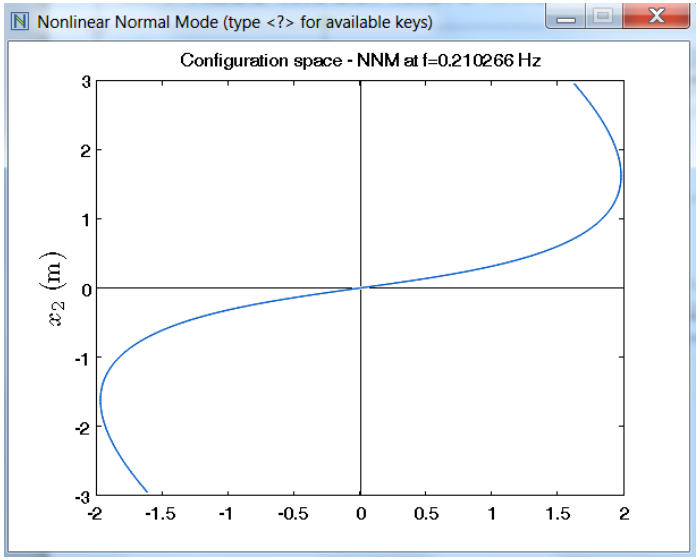
Double click + A

In-Phase Mode @ High Energies



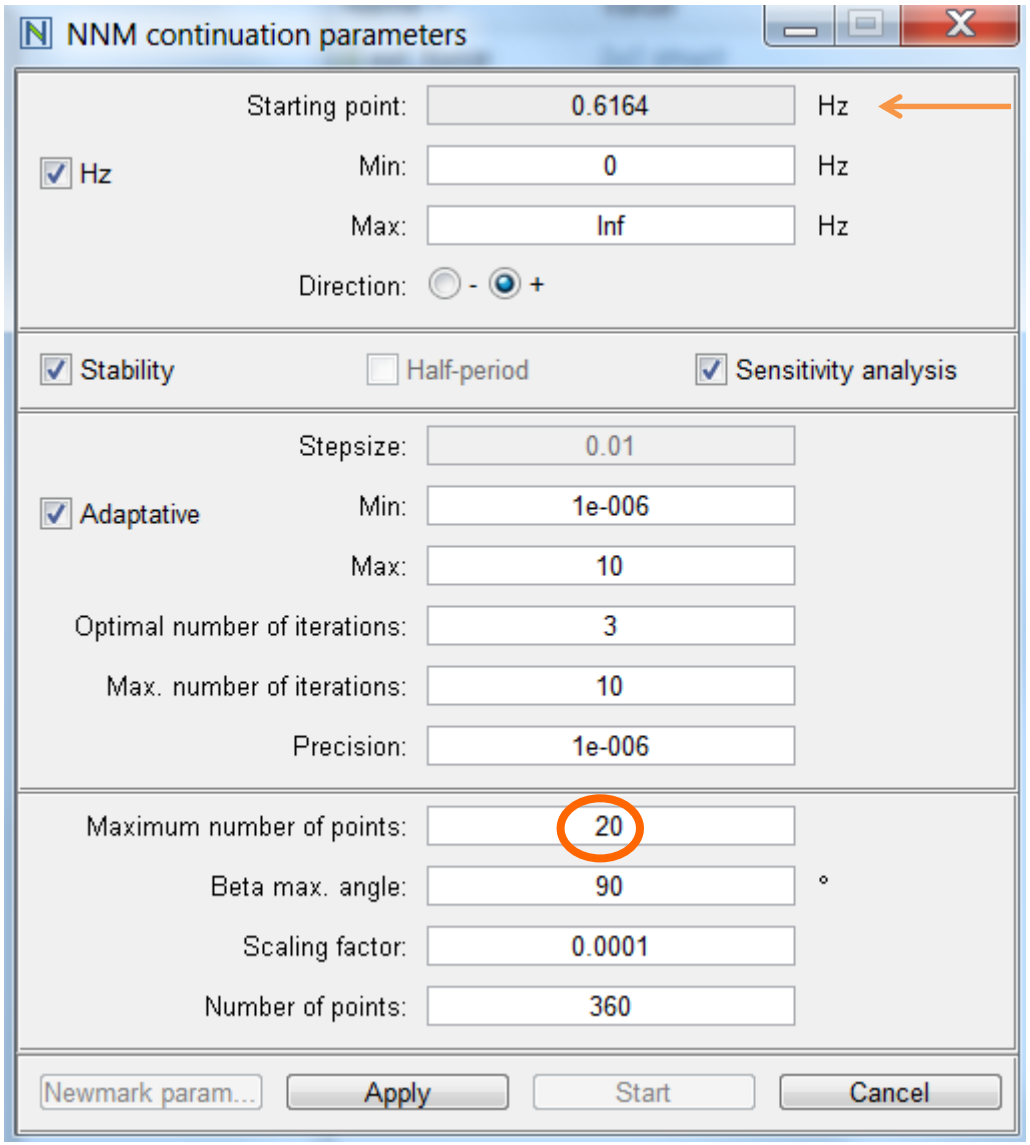


Double click + A



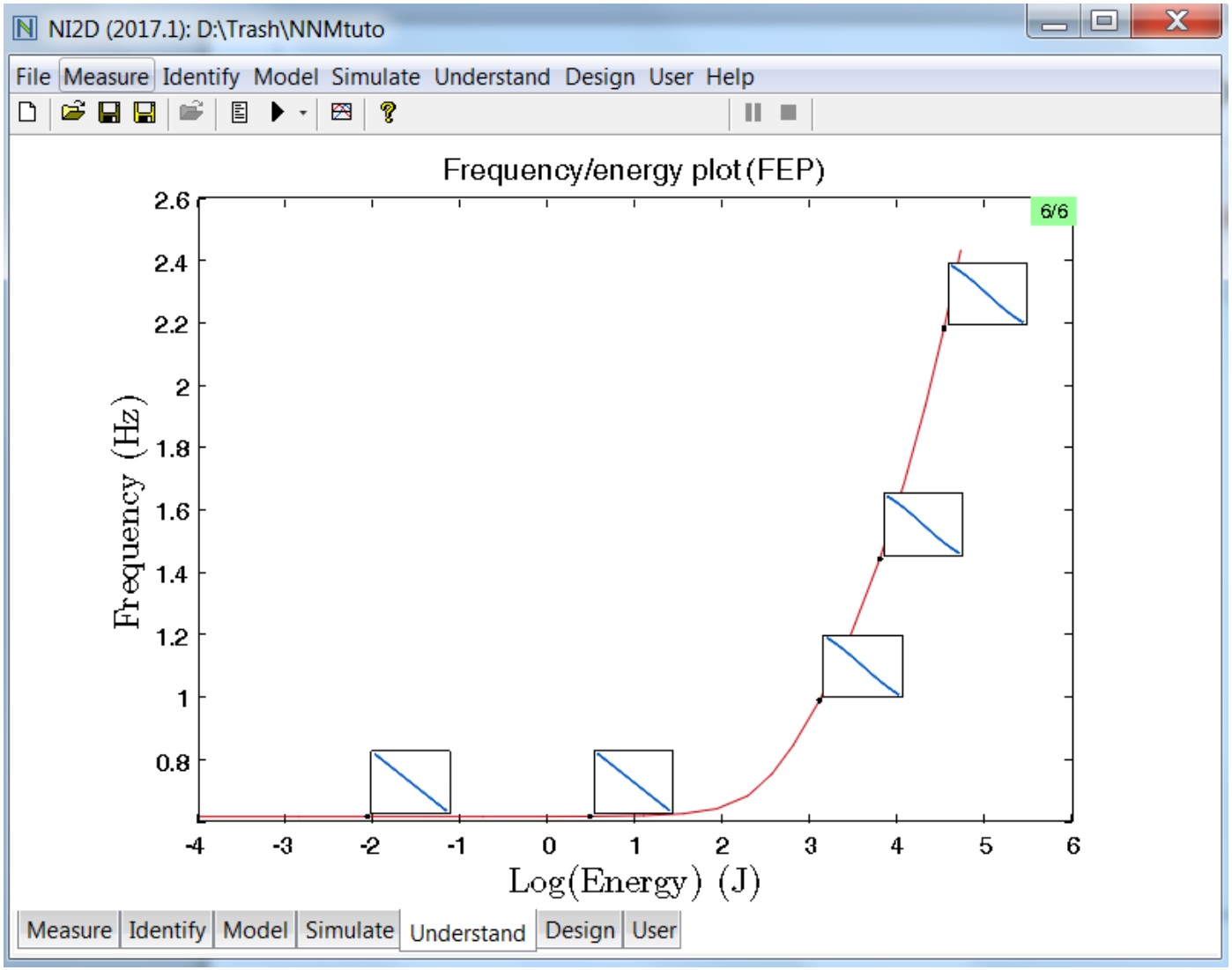
THE MOTION IS NON SYNCHRONOUS ?!?

Out-of-Phase Mode: Set the Parameters

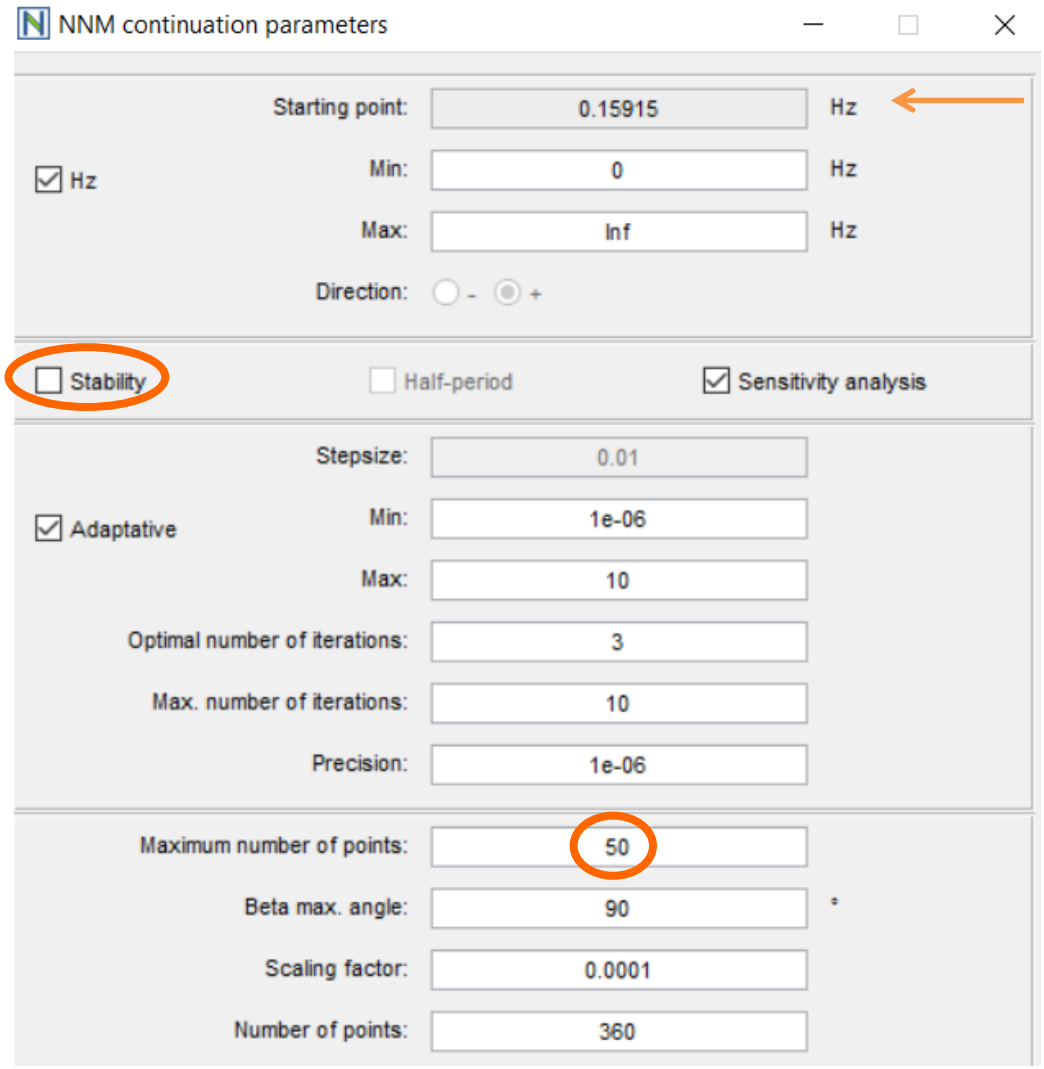


Right click

Out-of-Phase Mode: Frequencies and Modal Shapes

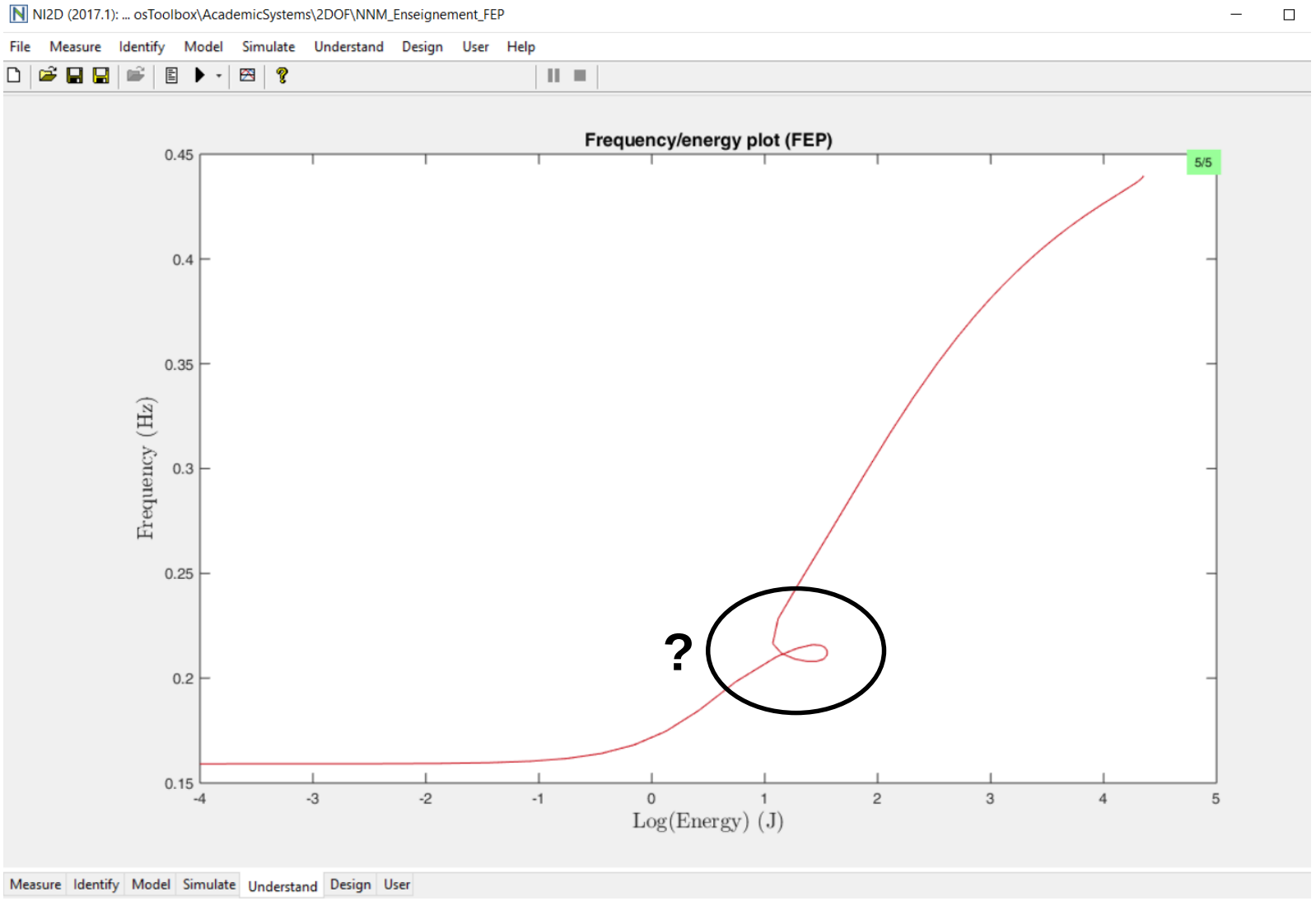


Let's Go Back to the In-Phase Mode

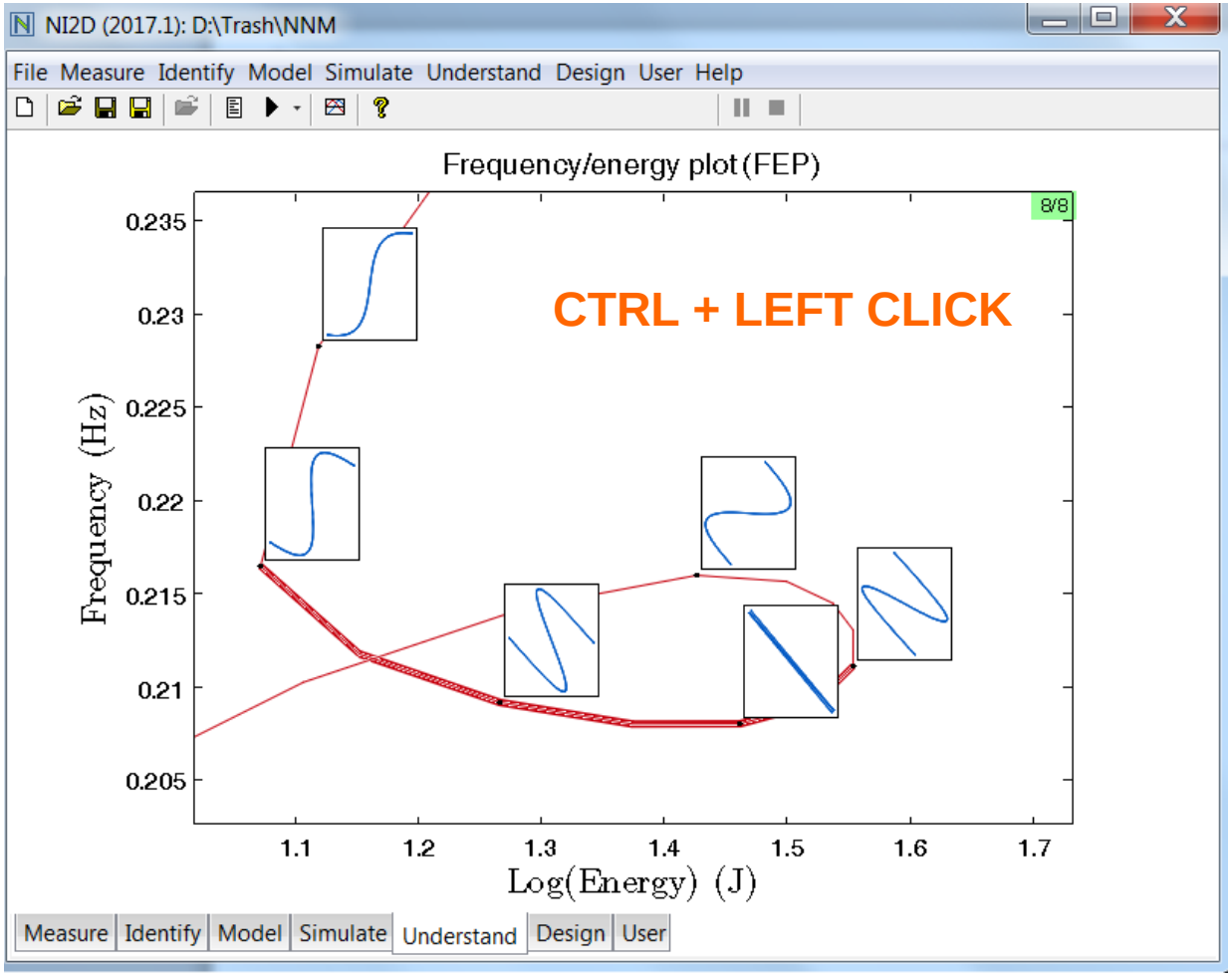


Right click for mode 2

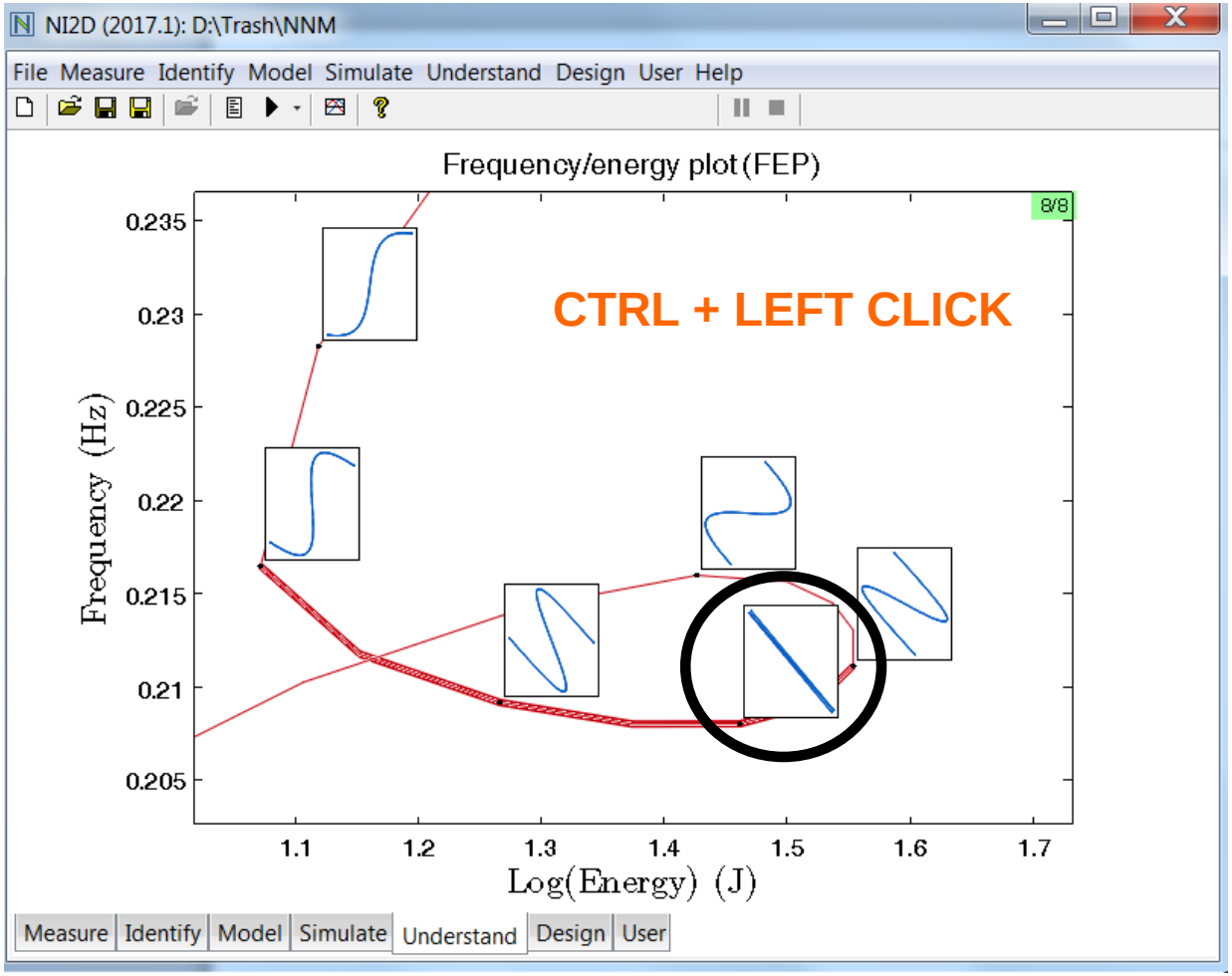
One New Feature !



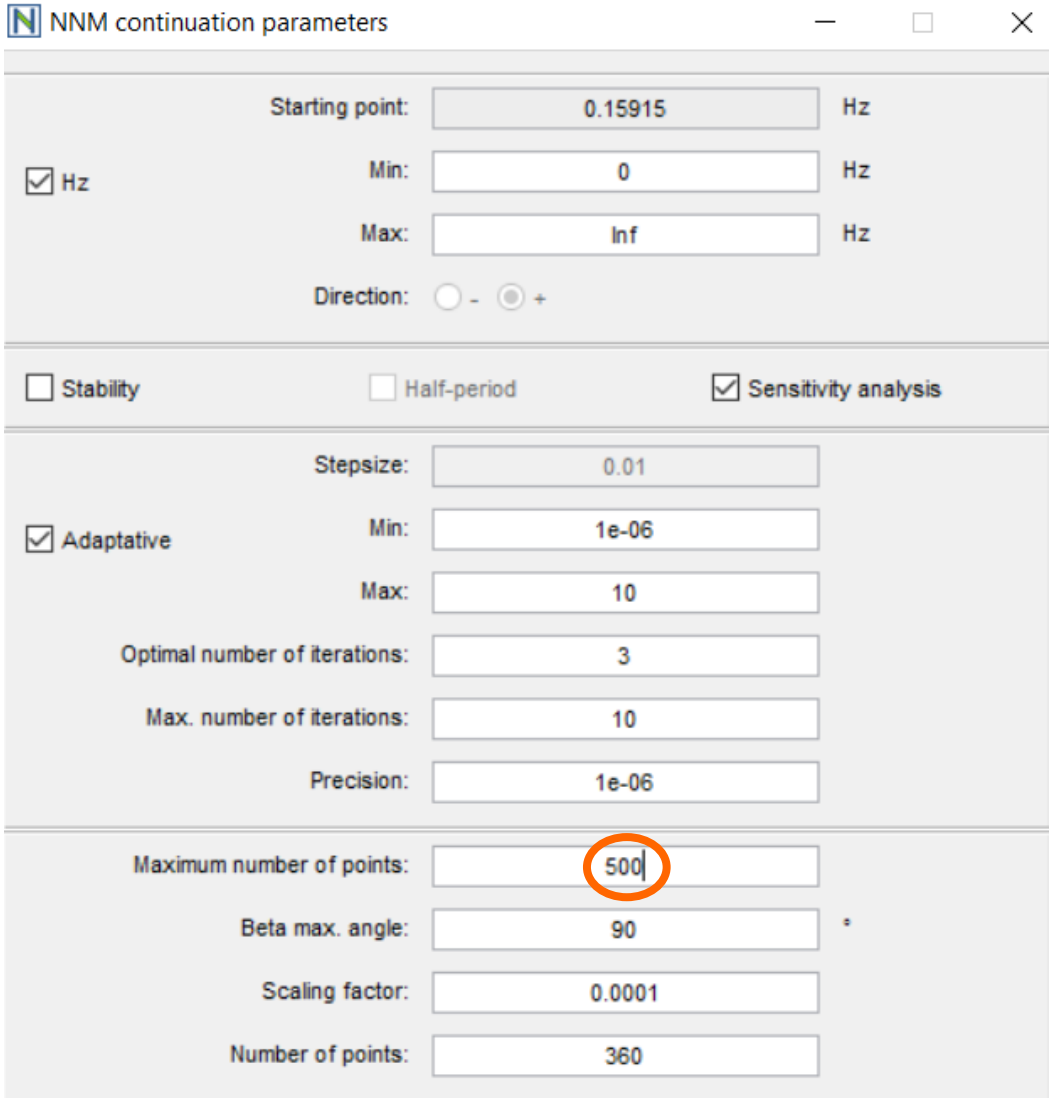
Zoom Around the Loop



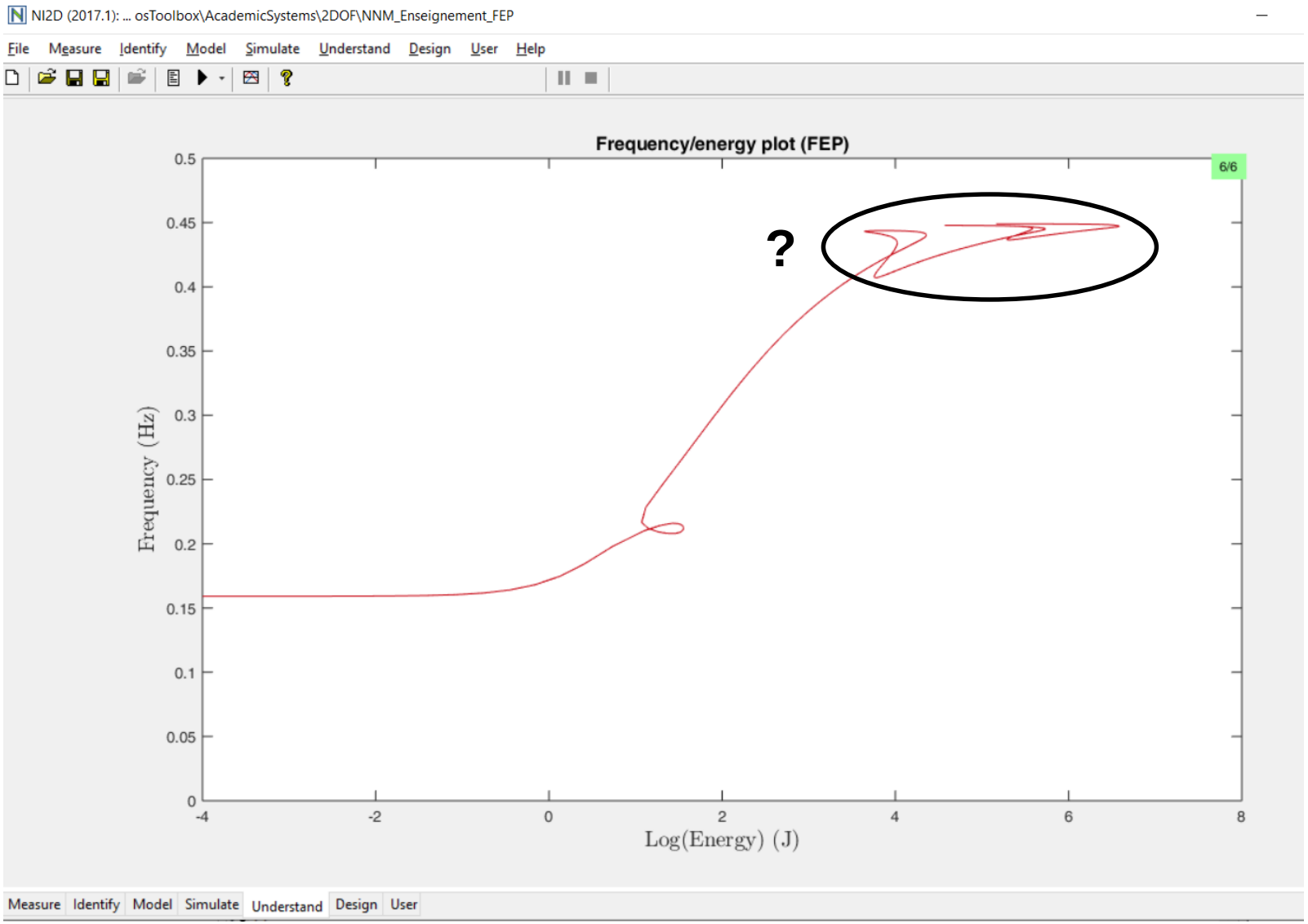
In-Phase and Out-of-Phase NNMs “Connected” !



Let’s Go Even Further



Additional Loops



Zoom Around the Loops