

the SmartSim
community

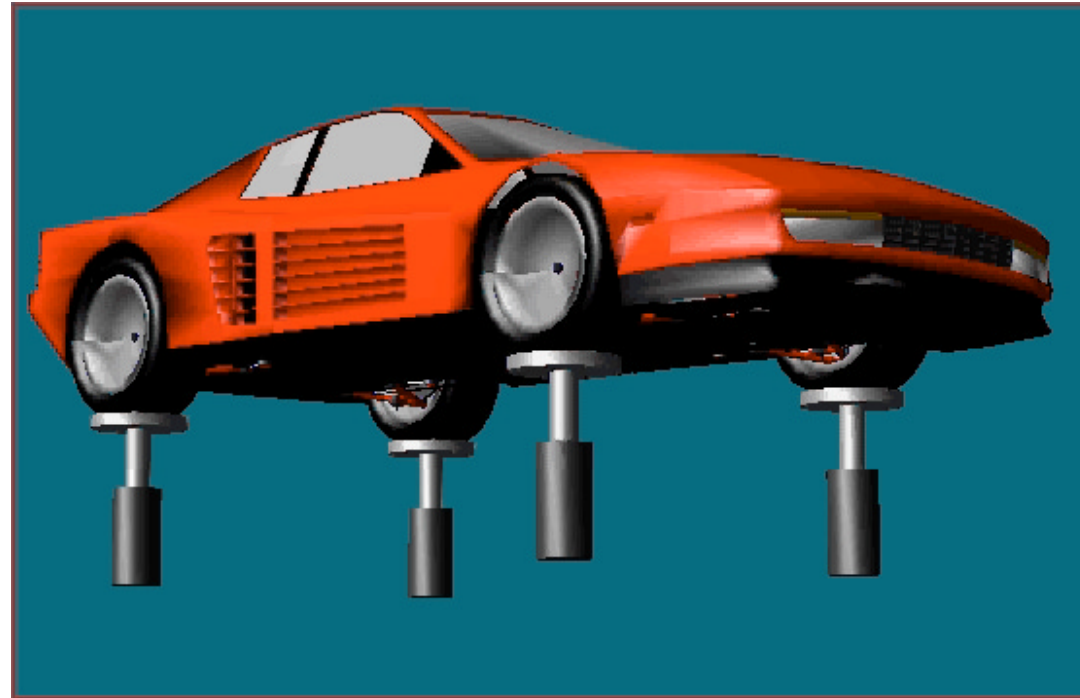
MTS



Mechanical
Dynamics

A Virtual NVH Test

With ADAMS/Car and I-DEAS Test



Christophe Sinsou, European Market Manager, MTS

Gene Smiley, NVD Market Manager, MTS

Gabriele Ferrarotti, Sr. Industry Manager, MDI

16th MDI European Users Conference

Berchtesgaden, D - November 14-15, 2001

Integrated
analytical
physical
virtual
Simulation



3 Key Themes:

- **MTS and MDI, partners in the SmartSim community, are cooperating to provide a unified solution for virtual prototyping for the NVH industry.**
- **ADAMS can be used to produce time-domain and frequency-domain responses for virtual NVH investigations.**
- **I-DEAS Test can be used as a post-processing tool for virtual NVH results from ADAMS.**



The logo for 'the SmartSim community' features the text 'the SmartSim' in a stylized font with a green swoosh under 'SmartSim', and 'community' in a smaller font below it.The MTS logo consists of the letters 'MTS' in a bold, white, sans-serif font, centered within a red rectangular box.The Mechanical Dynamics logo features a stylized grey and white geometric shape resembling a mountain or a peak, with the text 'Mechanical Dynamics' below it.

Agenda

- Present *The Virtual NVH Process* involving ADAMS and I-DEAS Test.
- Use an actual case study, involving both in-phase and out-of-phase inputs to a full-vehicle model, to illustrate the virtual NVH tests available in the non-linear, time-domain in ADAMS.
- Describe the process for getting ADAMS results into I-DEAS Test.
- Touch on the ability to perform virtual NVH tests in the linear, frequency-domain using ADAMS.
- Touch on incorporation of flexible bodies in the non-linear, time-domain solutions.

The Integrated Simulation logo features the word 'Integrated' at the top, followed by 'analytical', 'physical', and 'virtual' stacked vertically in a yellow, italicized font, and 'Simulation' at the bottom in a white, bold font. The background is a dark red with a glowing circular effect.



The Virtual NVH Process

Inputs to
Mechanical
Model

ADAMS solution

Post-processing

Time Domain
Inputs

Time Domain;
Physical Space;
Fully nonlinear

Slower; higher fidelity

Plots, animations,
& tables and
some frequency data
within
ADAMS

Frequency Domain
Inputs

Frequency Domain;
Modal Space;
Linear

Faster; approximate

NVH data processing
within
I-DEAS Test

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Actual Case Study

Engine-Mount Manufacturer's Sensitivity Test

Requirements:

- **Input** (to front wheels): Sine sweep, 0.8 – 40.0 Hz, 5mm displacement peak-to-peak.
 - Test #1: in-phase.
 - Test #2: out-of-phase.
- **Measure:** acceleration at 3DOF on both sides of all engine mounts. Also at selected points on body.
- **Graph:** response vs frequency, with phase.

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Virtual Test Overview

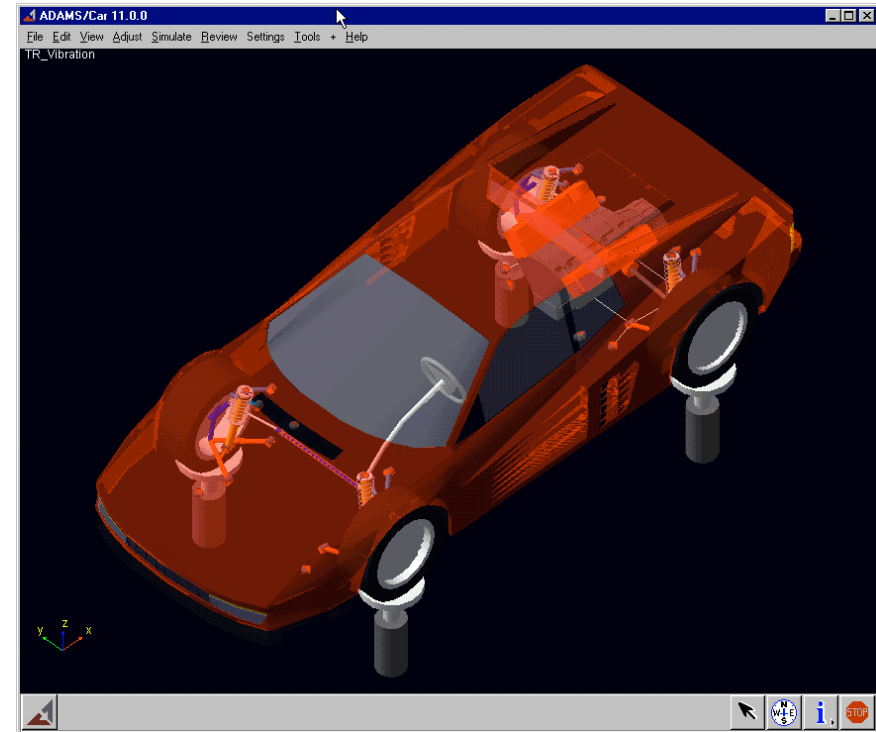
Input:

- Displacement time-histories at the actuators

Output:

- Engine mount acceleration time-history
- Steering column and seat track acceleration time-history

NVH post-processing



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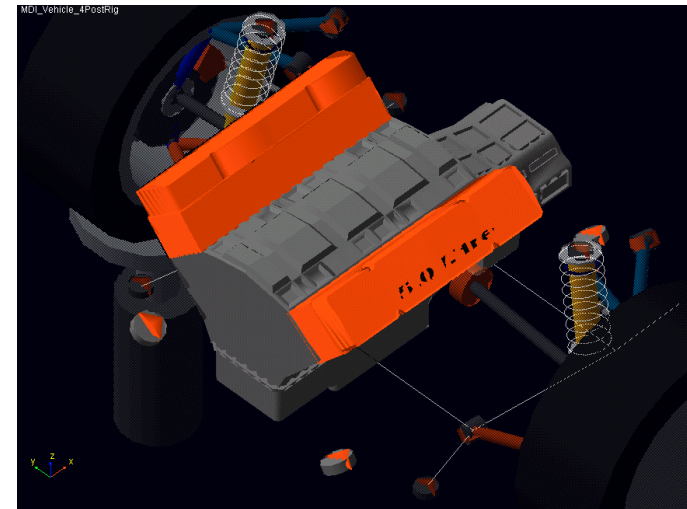
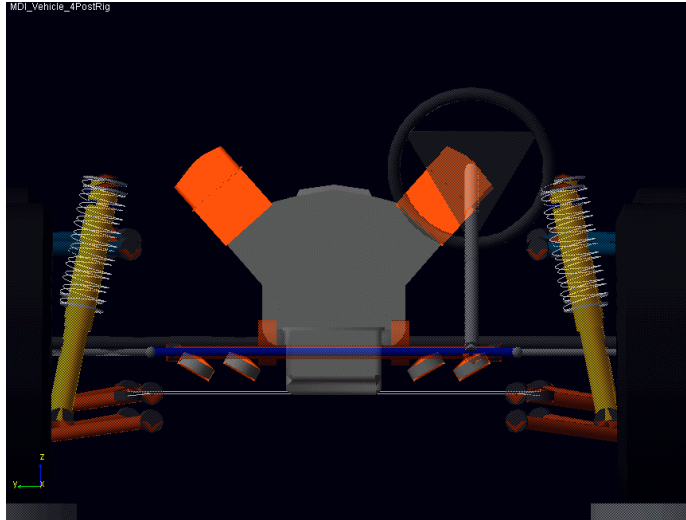
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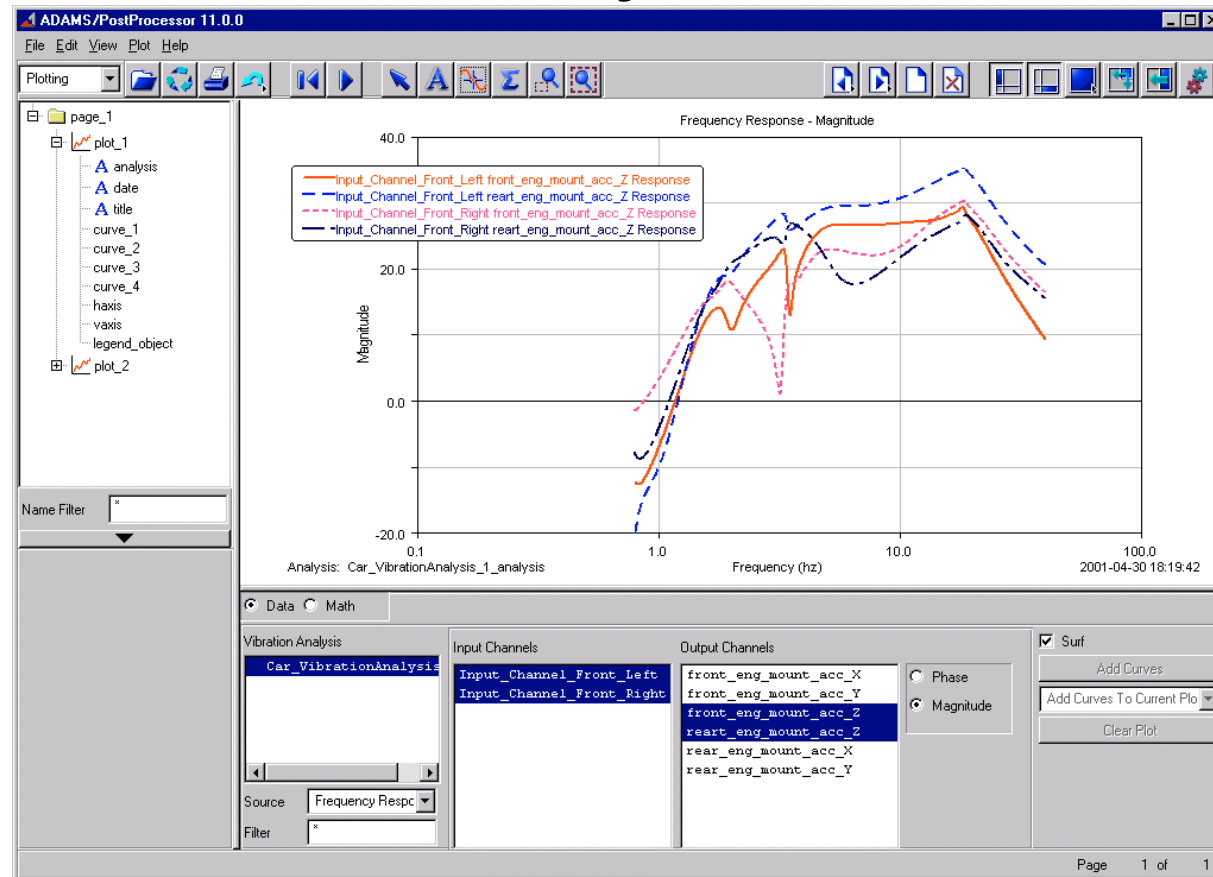
Model Details



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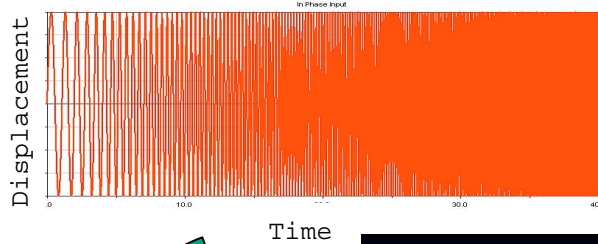
Frequency Domain Approach

- Can be obtained with ADAMS/Vibration.
- Offers fast calculation of FRFs to quickly understand vehicle dynamics.



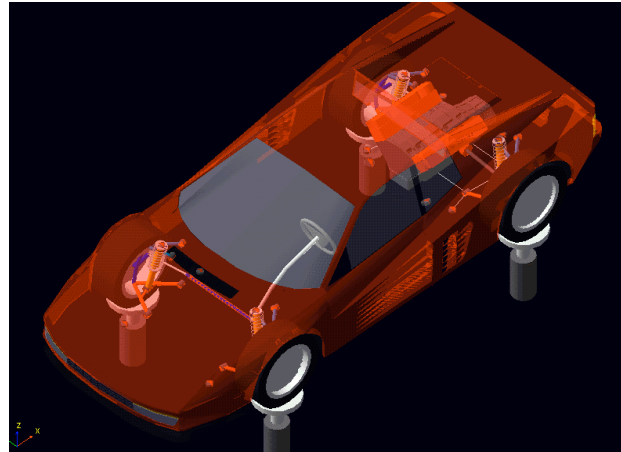
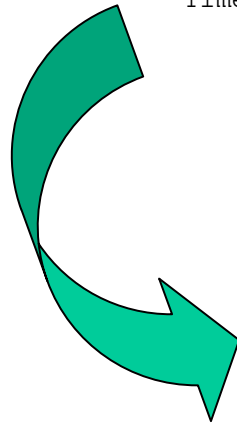


Time Domain Approach (Test #1)



Input in
Time Domain

(ADAMS/View
or
ADAMS/Car)

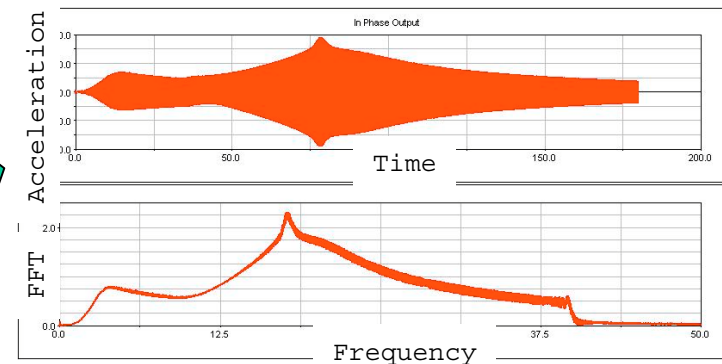


Solution in
Time Domain,
using $\Delta t = 0.002$,
 $t_f = 180$ sec.

(ADAMS/Solver)

Output in
Time Domain

(ADAMS/PostProcessor)



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ADAMS simulation results...

```
TextPad - [E:\Temp\output_OOP_mount_RL.dat]
File Edit Search View Tools Macros Configure Window Help
NH_output_OOP_mount_...
output_OOP_mount_RL.dat
A. .front_sweep_fourpost_out_phase.front_sweep_fourpost_out_phase.accel_rear_engine_mount_left.TIME (
B. .front_sweep_fourpost_out_phase.front_sweep_fourpost_out_phase.accel_rear_engine_mount_left.x_rear
C. .front_sweep_fourpost_out_phase.front_sweep_fourpost_out_phase.accel_rear_engine_mount_left.y_rear
D. .front_sweep_fourpost_out_phase.front_sweep_fourpost_out_phase.accel_rear_engine_mount_left.z_rear

      A          B          C          D
0 0.000000E+000 -5.303260E-003 -4.876320E-002 8.182350E-002
2 0.000000E-003 -6.830520E-001 7.115870E-001 -1.196870E+000
4 0.000000E-003 -7.545580E-001 7.528060E-001 -1.046530E+000
6 0.000000E-003 -3.722800E-001 6.801680E-001 -1.882120E-001
8 0.000000E-003 1.452570E-001 1.005800E+000 5.449110E-001
1 0.000000E-002 5.108490E-001 1.829310E+000 7.461090E-001
1 2.000000E-002 6.902120E-001 3.097390E+000 4.635660E-001
1 4.000000E-002 7.712000E-001 4.686970E+000 -3.893480E-002
1 6.000000E-002 7.796550E-001 6.473530E+000 -6.675580E-001
1 8.000000E-002 7.512260E-001 8.360740E+000 -1.378170E+000
2 0.000000E-002 7.102490E-001 1.023790E+001 -2.120540E+000
2 2.000000E-002 6.619780E-001 1.205070E+001 -2.887490E+000
2 4.000000E-002 6.144920E-001 1.375130E+001 -3.672130E+000
2 6.000000E-002 5.770190E-001 1.528520E+001 -4.447550E+000
2 8.000000E-002 5.547580E-001 1.661300E+001 -5.185210E+000
3 0.000000E-002 5.491810E-001 1.771850E+001 -5.866980E+000
3 2.000000E-002 5.611940E-001 1.859600E+001 -6.478960E+000
3 4.000000E-002 5.918090E-001 1.924200E+001 -7.003990E+000
3 6.000000E-002 6.402710E-001 1.965860E+001 -7.425930E+000
3 8.000000E-002 7.034250E-001 1.985870E+001 -7.737160E+000
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4 2.000000E-002 8.595940E-001 1.968630E+001 -8.029950E+000
4 4.000000E-002 9.477520E-001 1.935080E+001 -8.016060E+000
4 6.000000E-002 1.039770E+000 1.887570E+001 -7.902660E+000
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6 2.000000E-002 1.715310E+000 1.252580E+001 -5.122930E+000
6 4.000000E-002 1.775610E+000 1.165490E+001 -4.764130E+000
ANSI Characters
33 !
34 "
35 #
36 $
37 %
38 &
39 '
40 (
41 )
42 *
43 +
44 ,
45 -
46 .
47 /
48 0
49 1
File: output_OOP_mount_RL.dat, 6300601 bytes, 90010 lines, ANSI
```

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virtual
Simulation



Mechanical
Dynamics

Provided to the NVH analyst...

Inbox - Microsoft Outlook

File Edit View Favorites Tools Actions Help

New Reply Reply to All Forward Send/Receive Find Organize

Inbox

Folder List	From	Subject	Size	Received
Mailbox - Smiley, Ger	Englerth, Mike	RE: See draft/layout	11 KB	Wed 4/25/2001 7:19 PM
Outlook Today - [Per	Bell, Dianne	New Events in NVD?	4 KB	Wed 4/25/2001 4:28 PM
Calendar	Grant Smiley	size thing	169 KB	Wed 4/25/2001 8:14 AM
Contacts	Nessler, Jerry	Spindle Acceleration	3 KB	Thu 4/19/2001 7:30 AM
Deleted Items	Steven Arshonsky	Re: Windows User-Interface Presentation	6 MB	Tue 4/17/2001 4:30 PM
Drafts	Warwick Marx	Compumod	4 KB	Sun 2/25/2001 8:25 PM
Inbox (1)	Gabriele Ferrarotti	Virtual NVH - the news	341 KB	Wed 5/9/2001 1:36 PM
Journal	Steven Blaski	Your site has been listed on TenLinks.com	11 KB	Wed 5/9/2001 12:52 PM
Notes	Byers, Errol	[rwdlist] RE: Environmental noise regs	5 KB	Tue 4/24/2001 1:26 PM
Outbox	Bigot, Bill	PPT	146 KB	Tue 4/24/2001 10:00 AM
Sent Items	Seeger, Jan	Plastics Letter	139 KB	Tue 4/17/2001 4:31 PM
Tasks	Giclais, Stephane	RE: Spreadsheet channel setup	151 KB	Mon 2/26/2001 10:39 AM
Public Folders	Direct@hunting...	Re: internetspecialist@huntington.com	6 KB	Wed 9/6/2000 10:27 AM
	gunther willems	RE: Ford report (important!!!)	47 KB	Tue 8/8/2000 9:29 AM
	Little, Eric	NVD at KRC = Time savings and Success!	9 KB	Tue 4/4/2000 6:06 PM
	Hering, Dave	from Ron Kirsch	40 KB	Thu 3/16/2000 5:24 PM

From: Gabriele Ferrarotti **To:** Smiley, Gene
Subject: Virtual NVH - the news **Cc:**

Hello Gene,

I wanted to touch base with you and follow up on some of the pending issues:

- 1) I am still working on the model with flexible steering column, which actually requires some extra effort to obtain something meaningful. I need to find the time for that. In the meantime a colleague of mine working with MTS for VTL gave me some measured data for a 4post testing machine, and we used this as input for the model you know. This produced (we performed a heave test on the 4 actuators) the results I am sending in attachment (for only 1 engine mount -- since it is a heave test, the 4 mounts behave in the same way) I think they look interesting -- I propose to introduce this in the presentation -- case study as well.
- 2) Did you have any time to work on the PPT? We'll have still approx 1 week to put it together and provide it for the conference CD. I'll work on the

243 Items, 1 Unread

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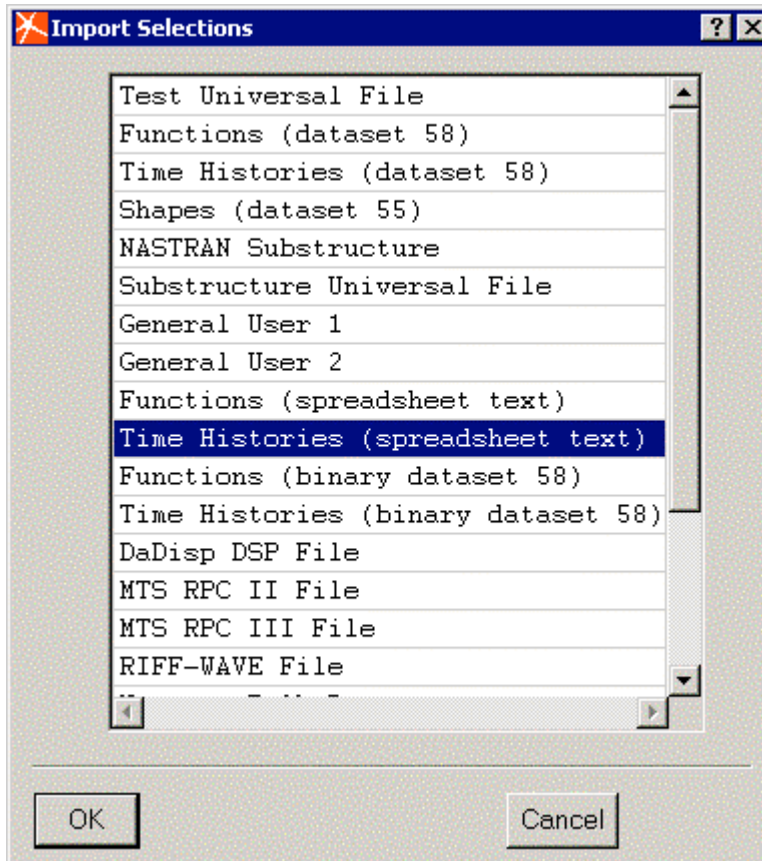
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Imported into I-DEAS Test...

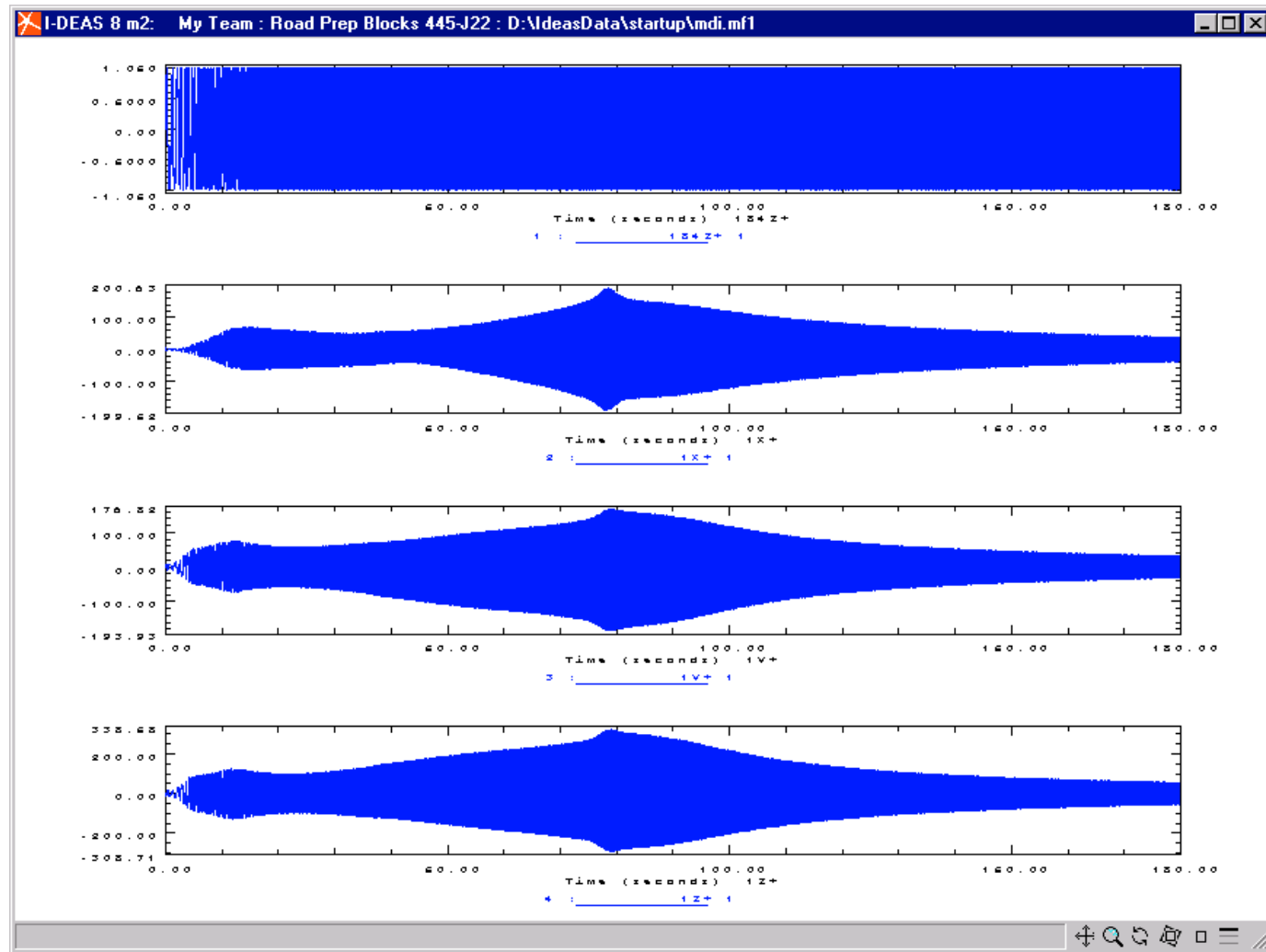


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Data now in I-DEAS Test

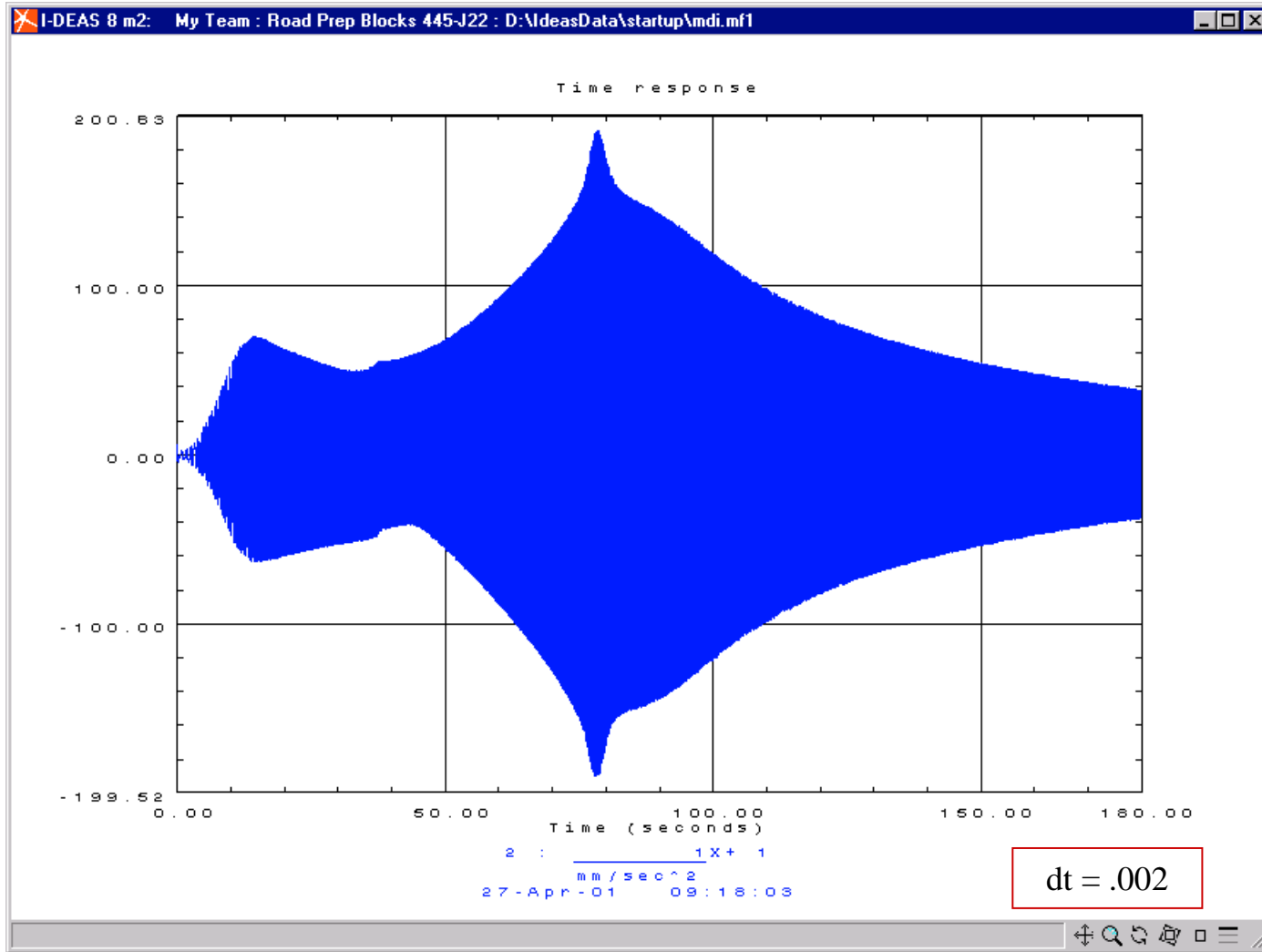


Using $\Delta t = 0.002$, $t_f = 180$ sec

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Fore-Aft response



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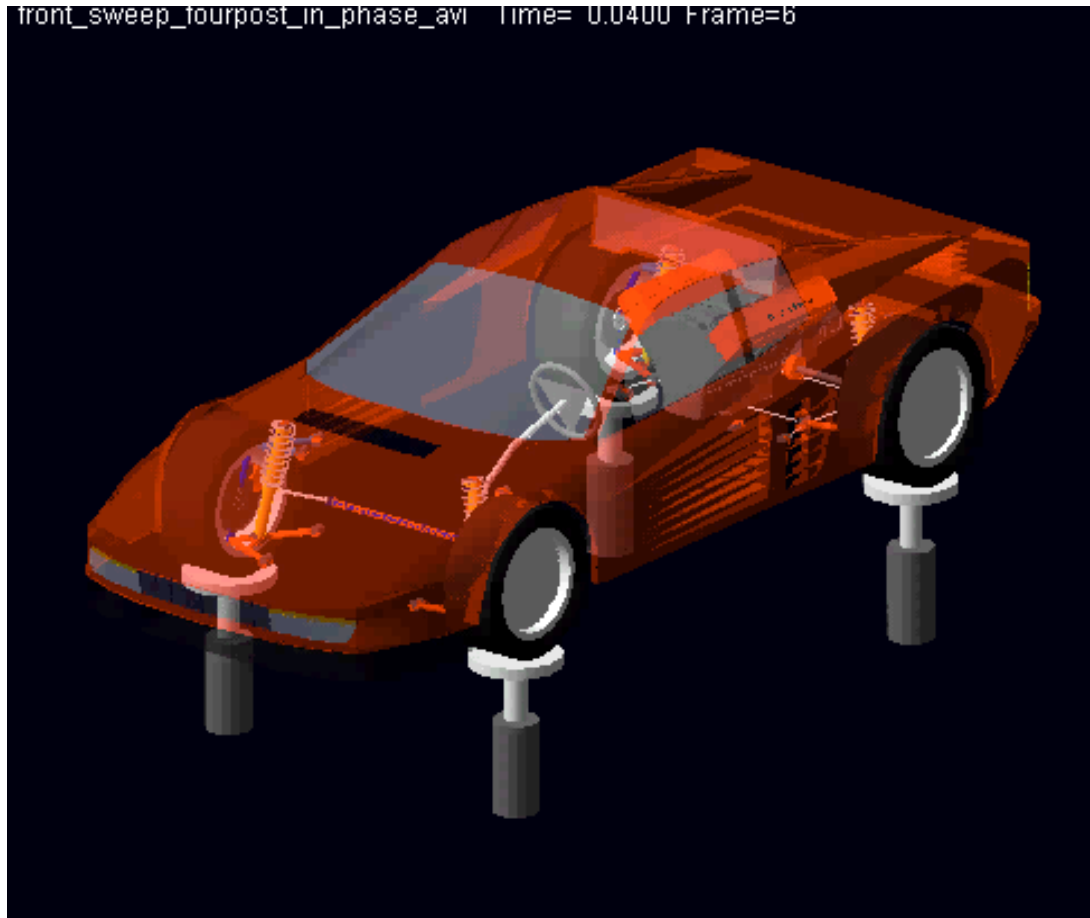
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In-Phase Test Results



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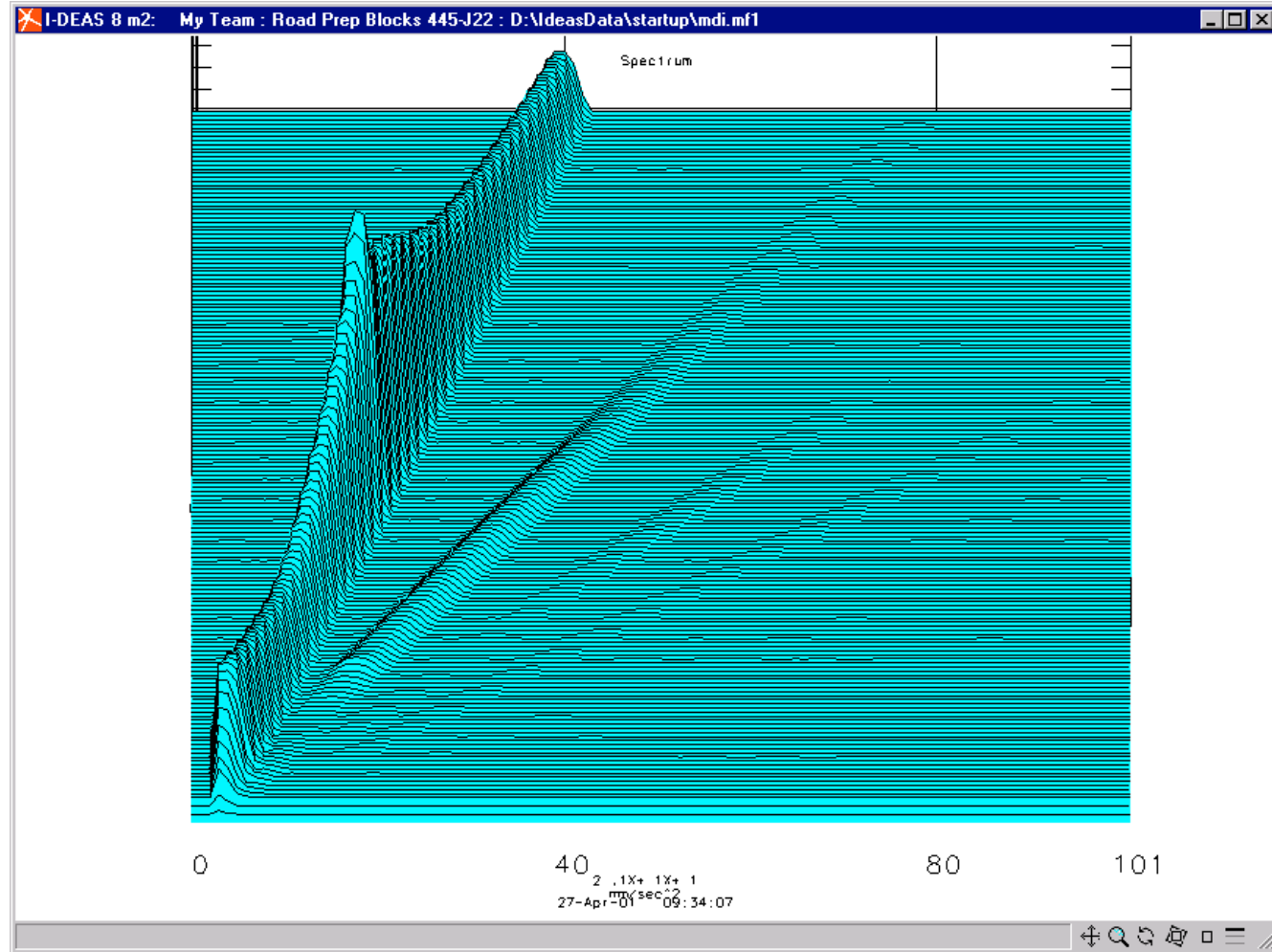
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Mechanical Dynamics

In-Phase: Linear amplitude



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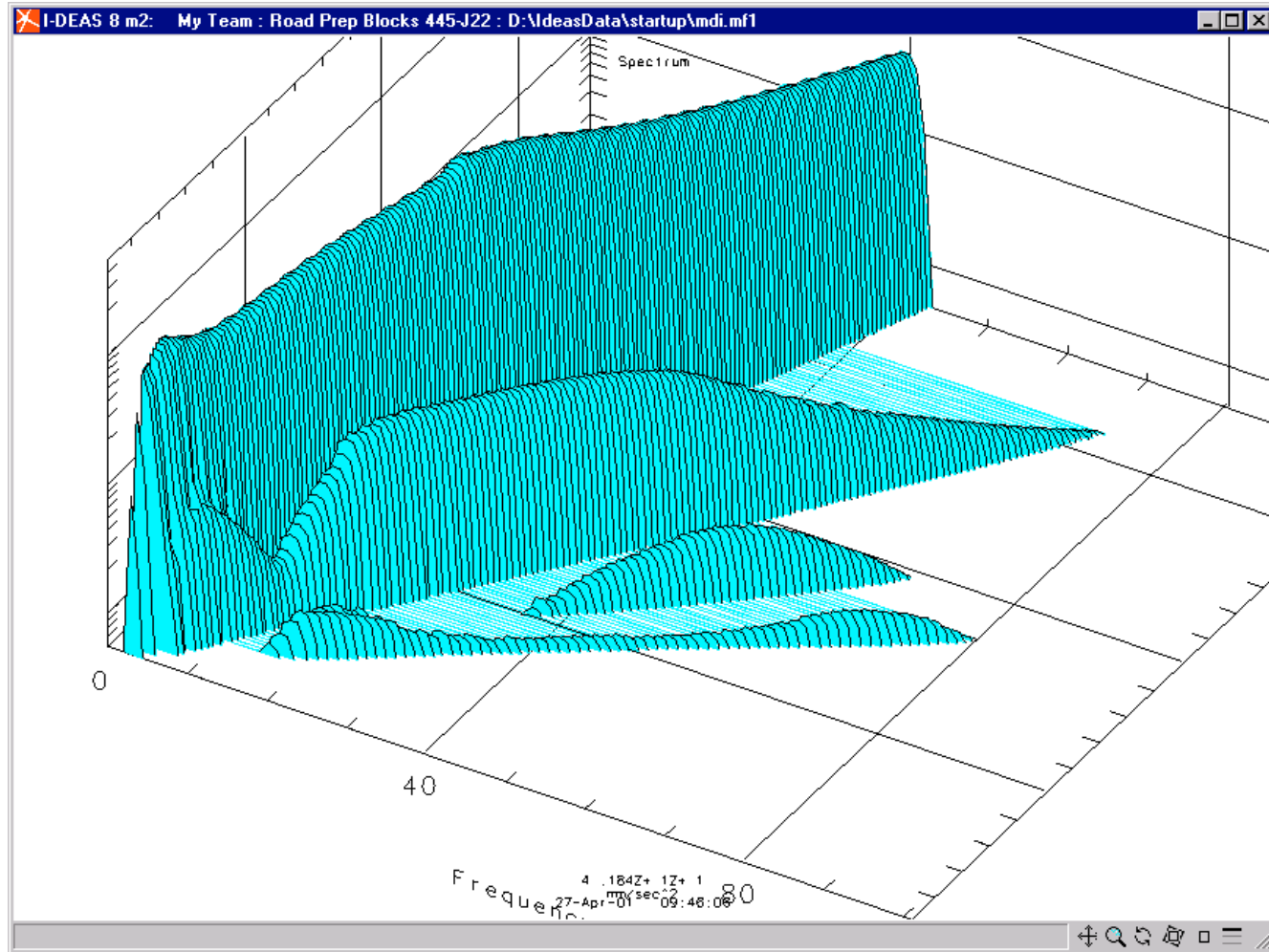
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Mechanical Dynamics

In-Phase: Log amplitude



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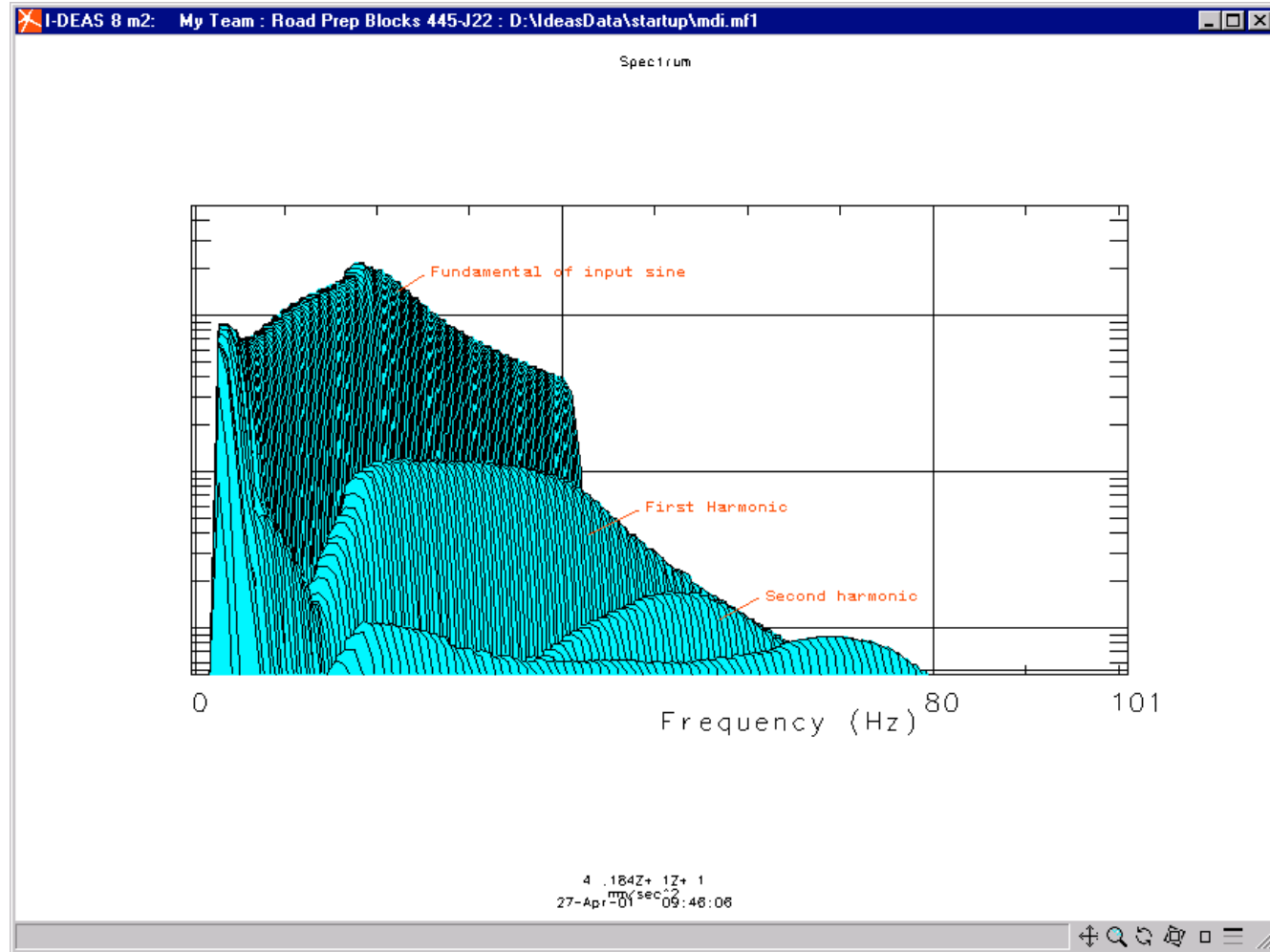
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In-Phase: Log amplitude



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The logo for 'the SmartSim community' features the text 'the SmartSim' in a blue and green font with a stylized 'S' and 'M' that overlap, and 'community' in a smaller blue font below it.The MTS logo consists of the letters 'MTS' in a bold, white, sans-serif font, centered within a red rectangular box.The Mechanical Dynamics logo features a stylized grey and red geometric shape resembling a mountain or a peak, with the text 'Mechanical Dynamics' in a black, sans-serif font below it.

Observations

- Harmonics are due to non-linear components in the model (bushings, mounts, suspension dampers).
- A purely “modal space analysis” is, by definition, a linear model.
- This non-linear analysis is higher fidelity.

The Integrated Simulation logo features the word 'Integrated' in white, bold, sans-serif font at the top. Below it, the words 'analytical', 'physical', and 'virtual' are stacked in a yellow, italicized, sans-serif font. At the bottom, the word 'Simulation' is written in white, bold, sans-serif font. The background is a dark red with a glowing, circular, ripple-like effect.

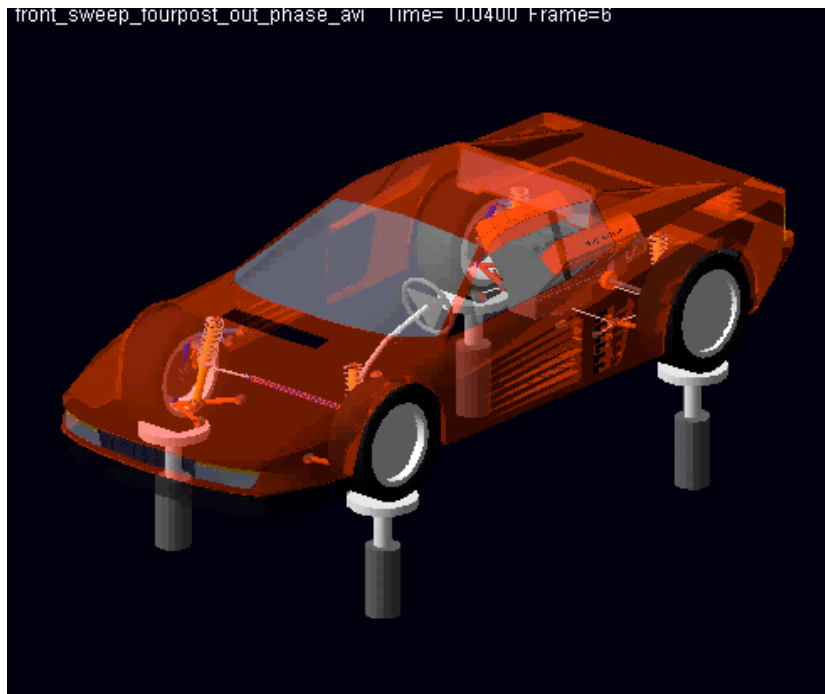
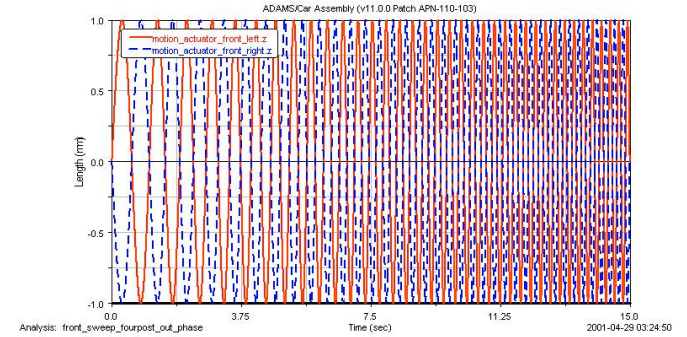
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Repeat with out-of-phase input

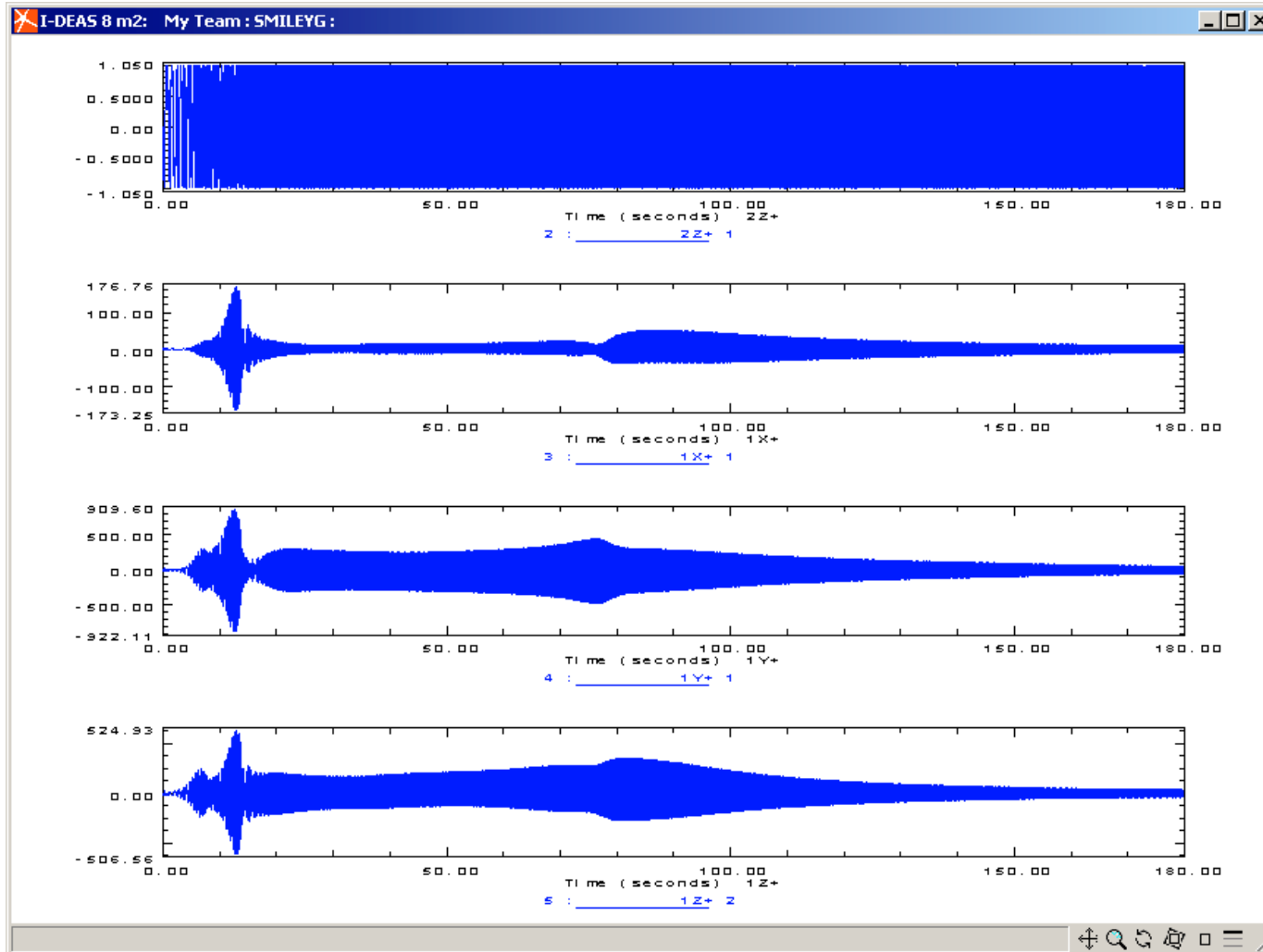


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Out-of-phase (OOP) Results

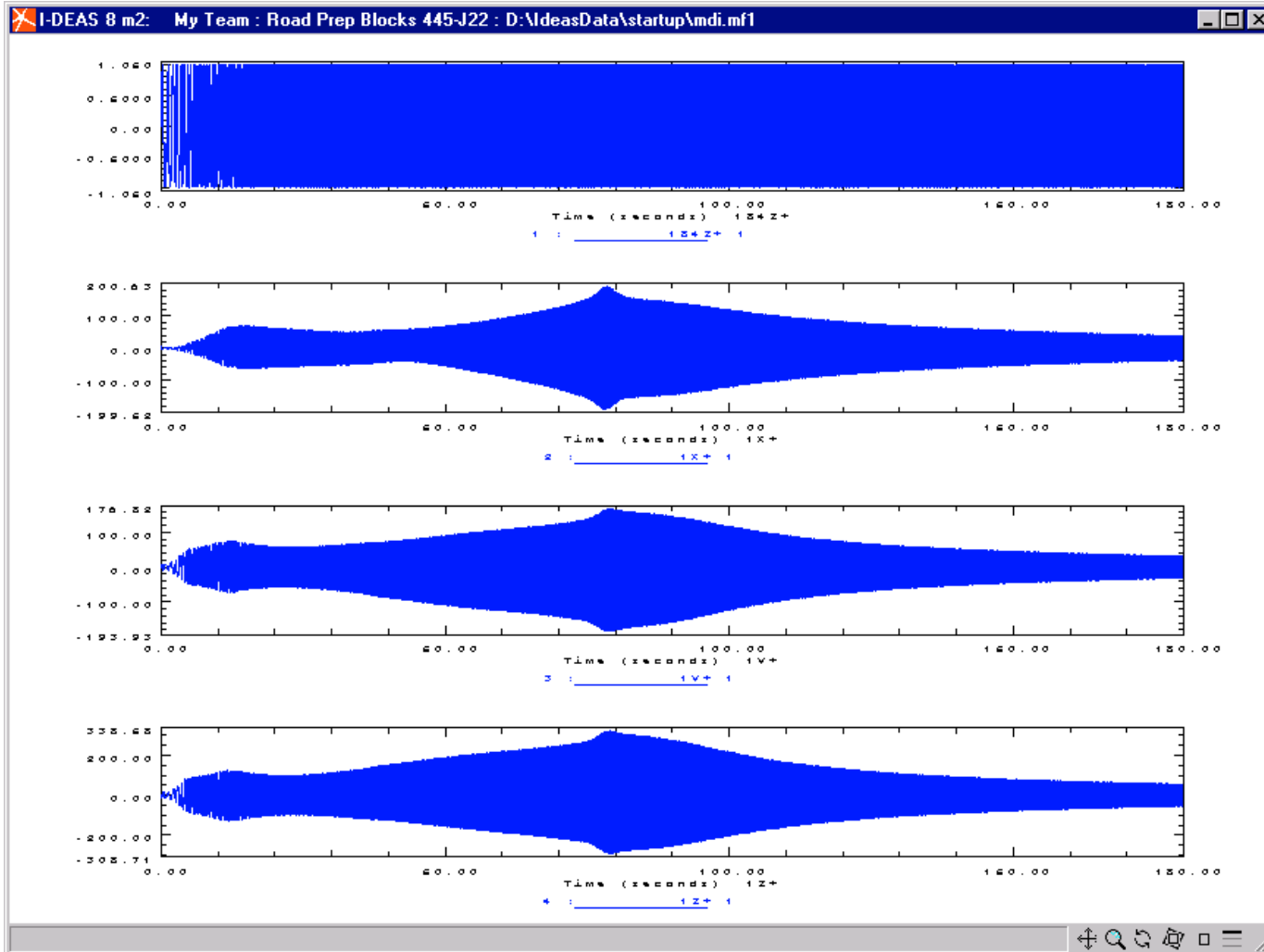


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In-phase Results (repeated for comparison)



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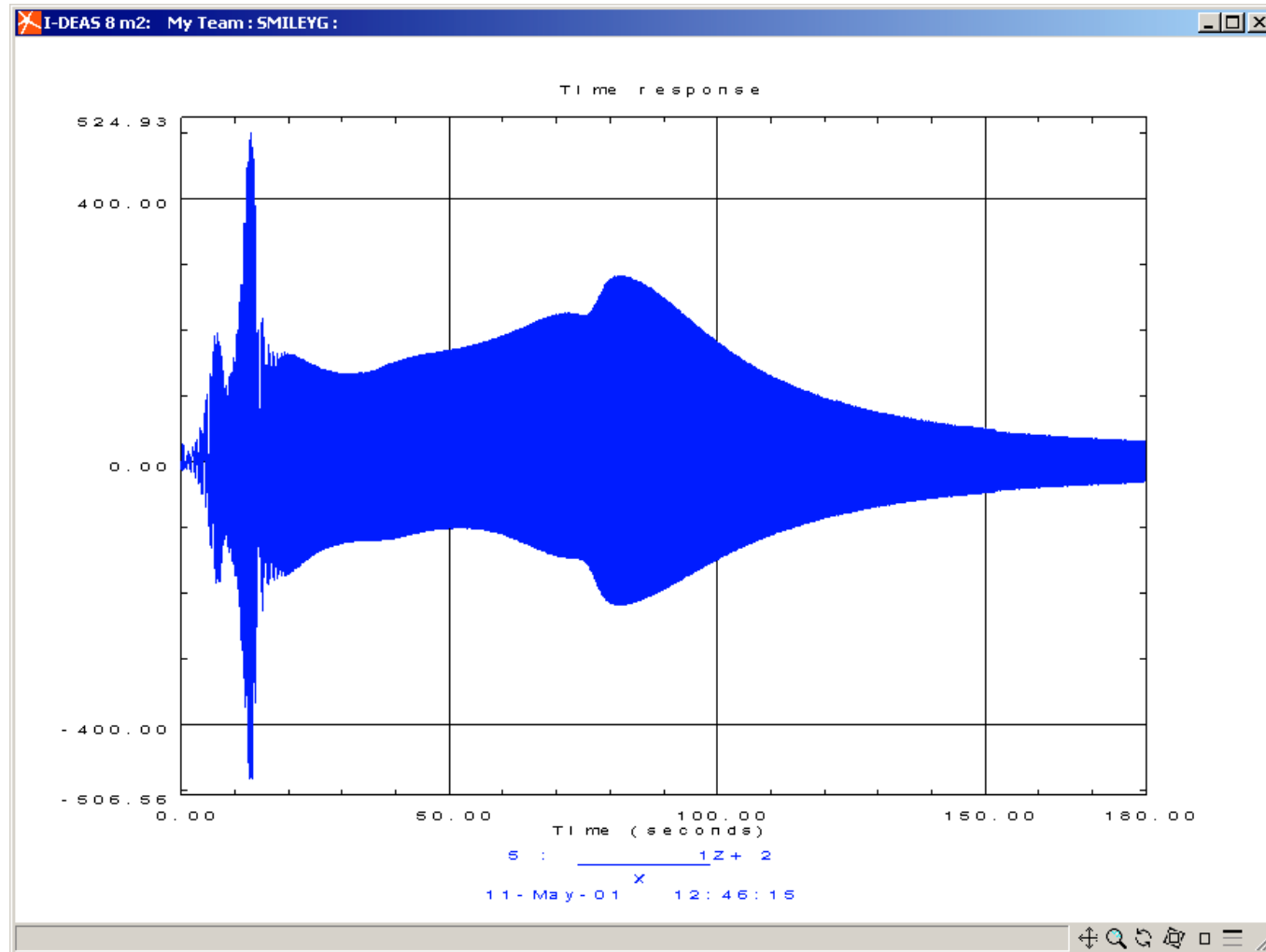
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Rear mount vertical response



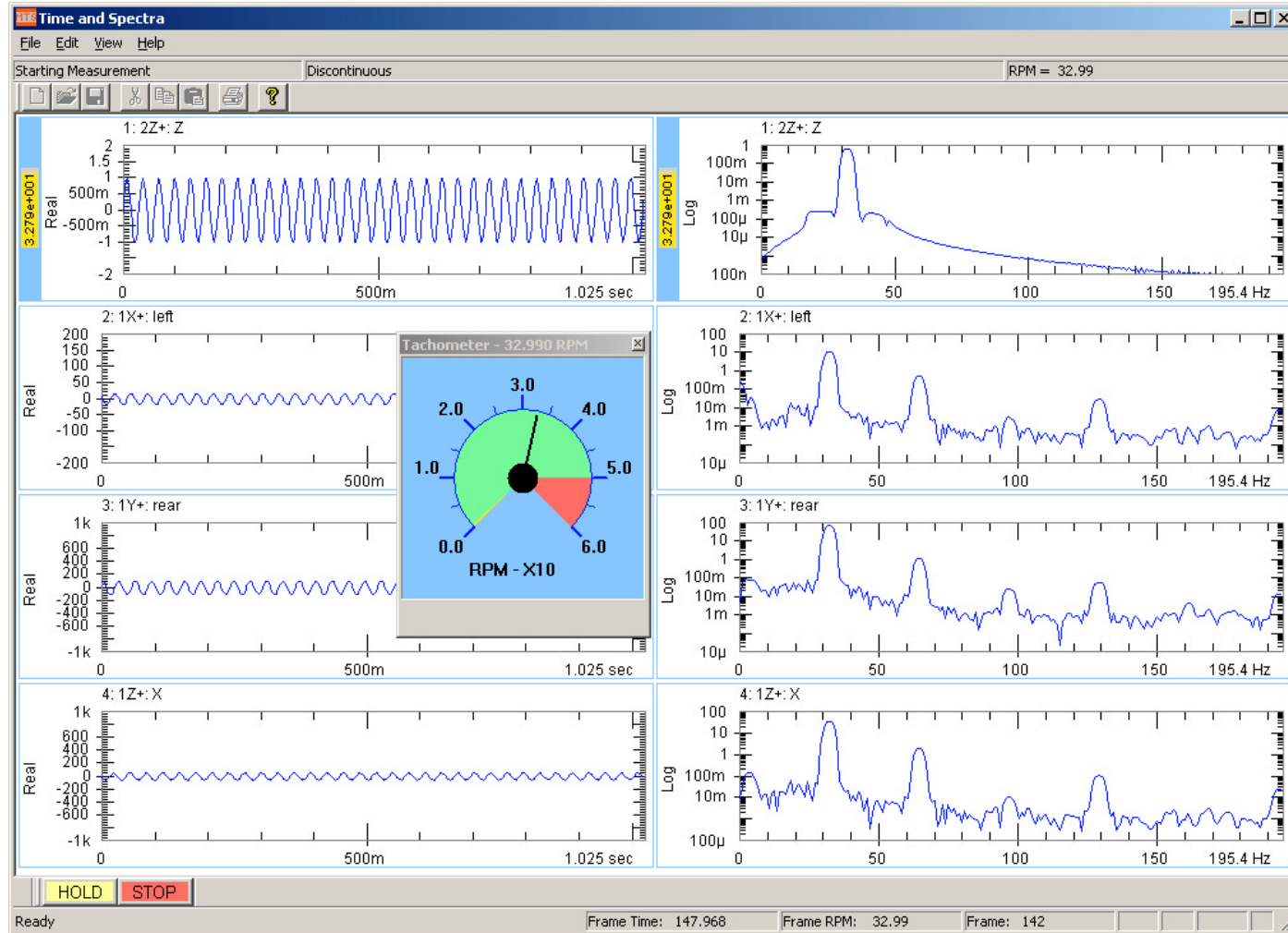
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Snapshot at ~33 Hz



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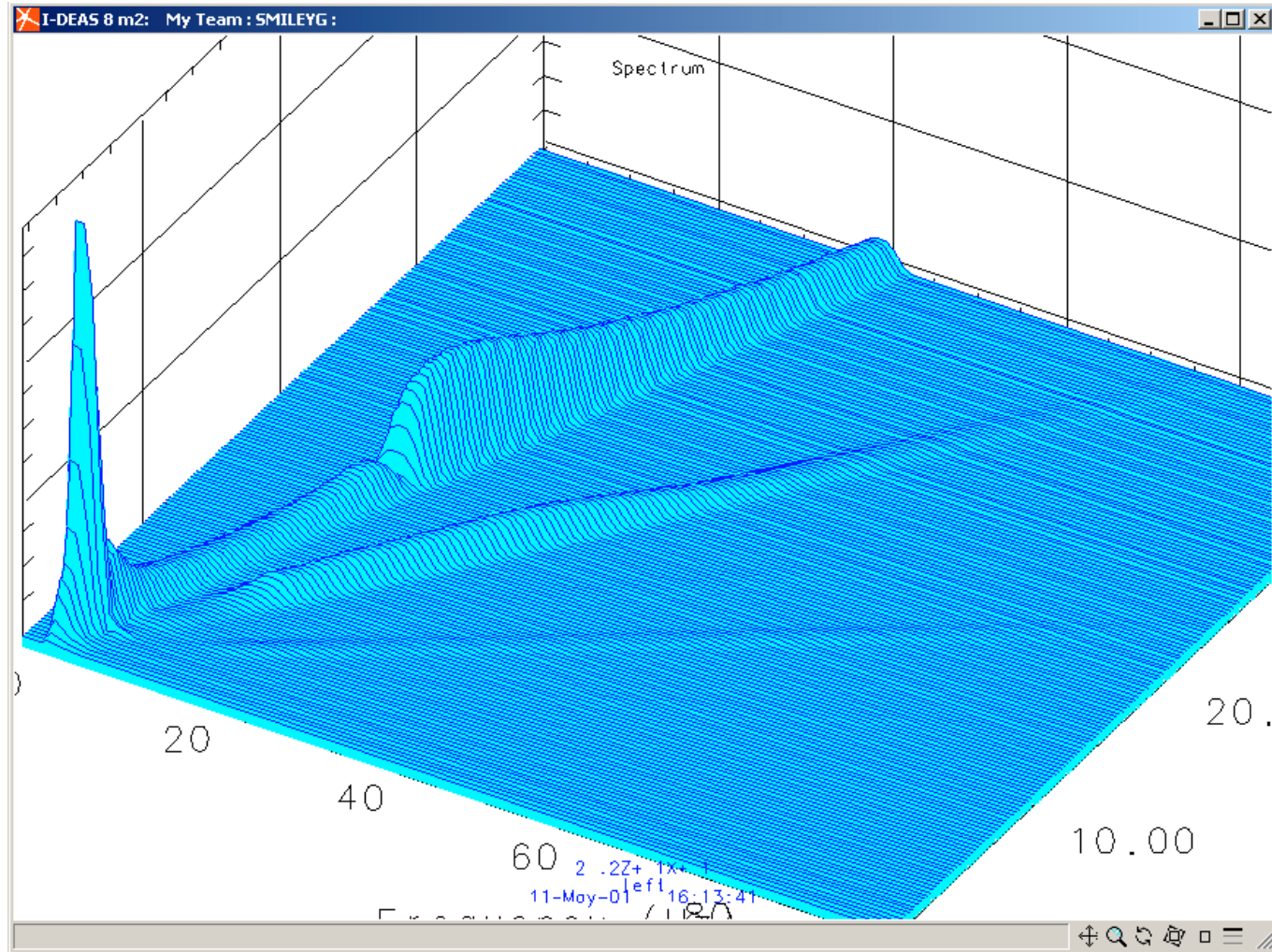
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OOP Results: Linear amplitude



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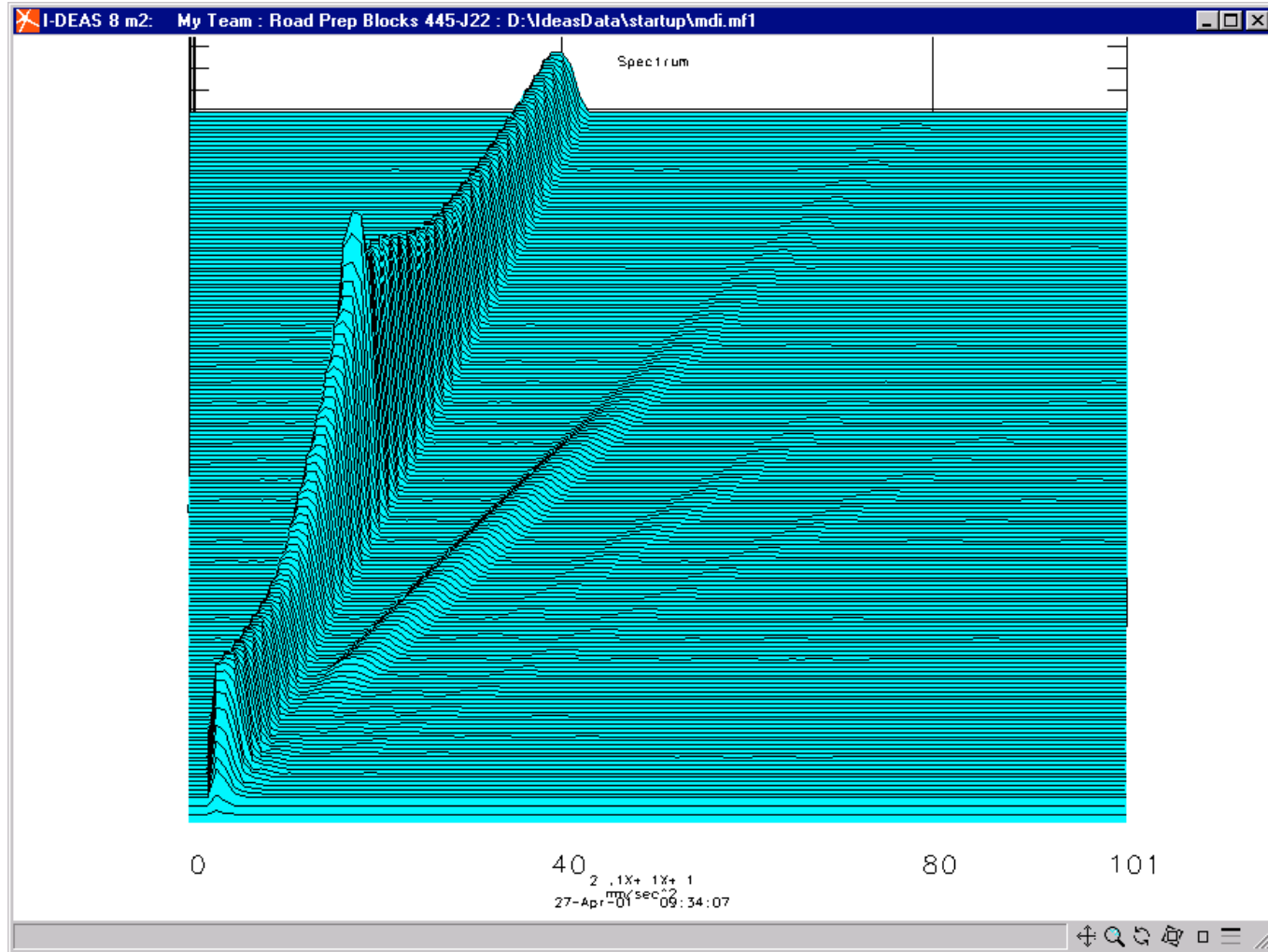
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In-Phase Results (repeated for comparison)



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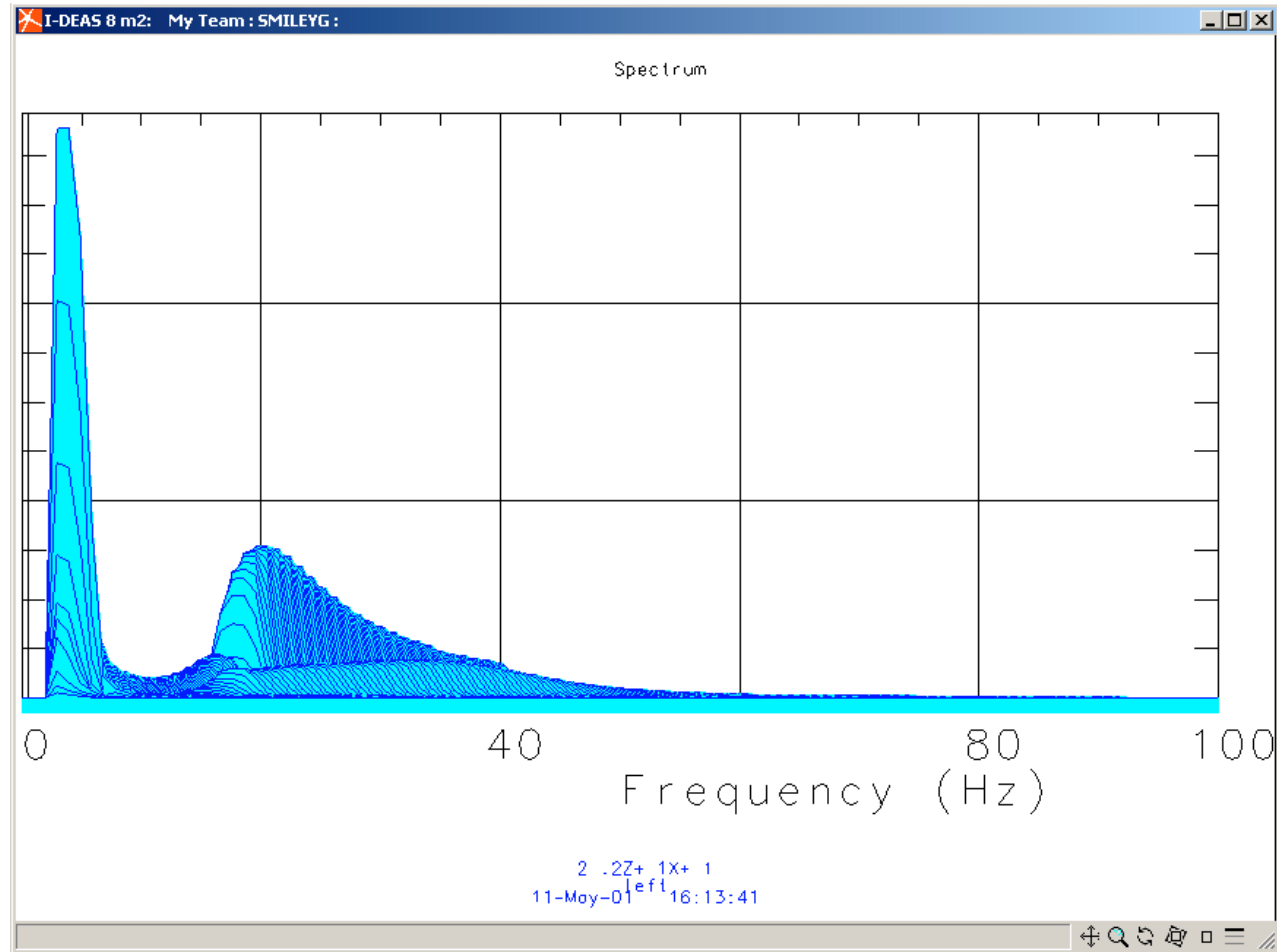
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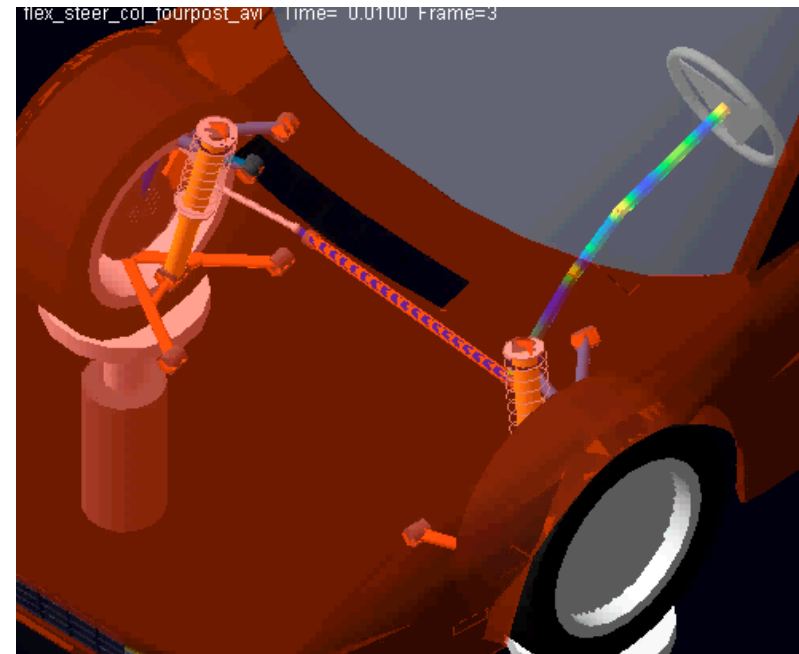
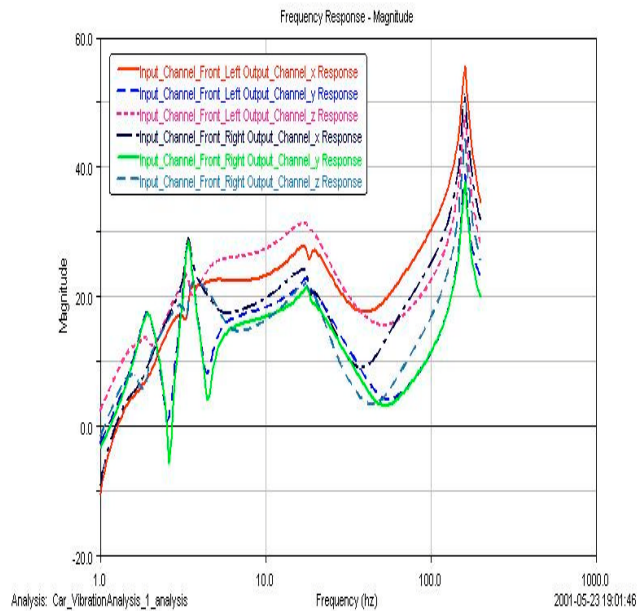
OOP Results: Log amplitude



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Add Flexible Steering Column

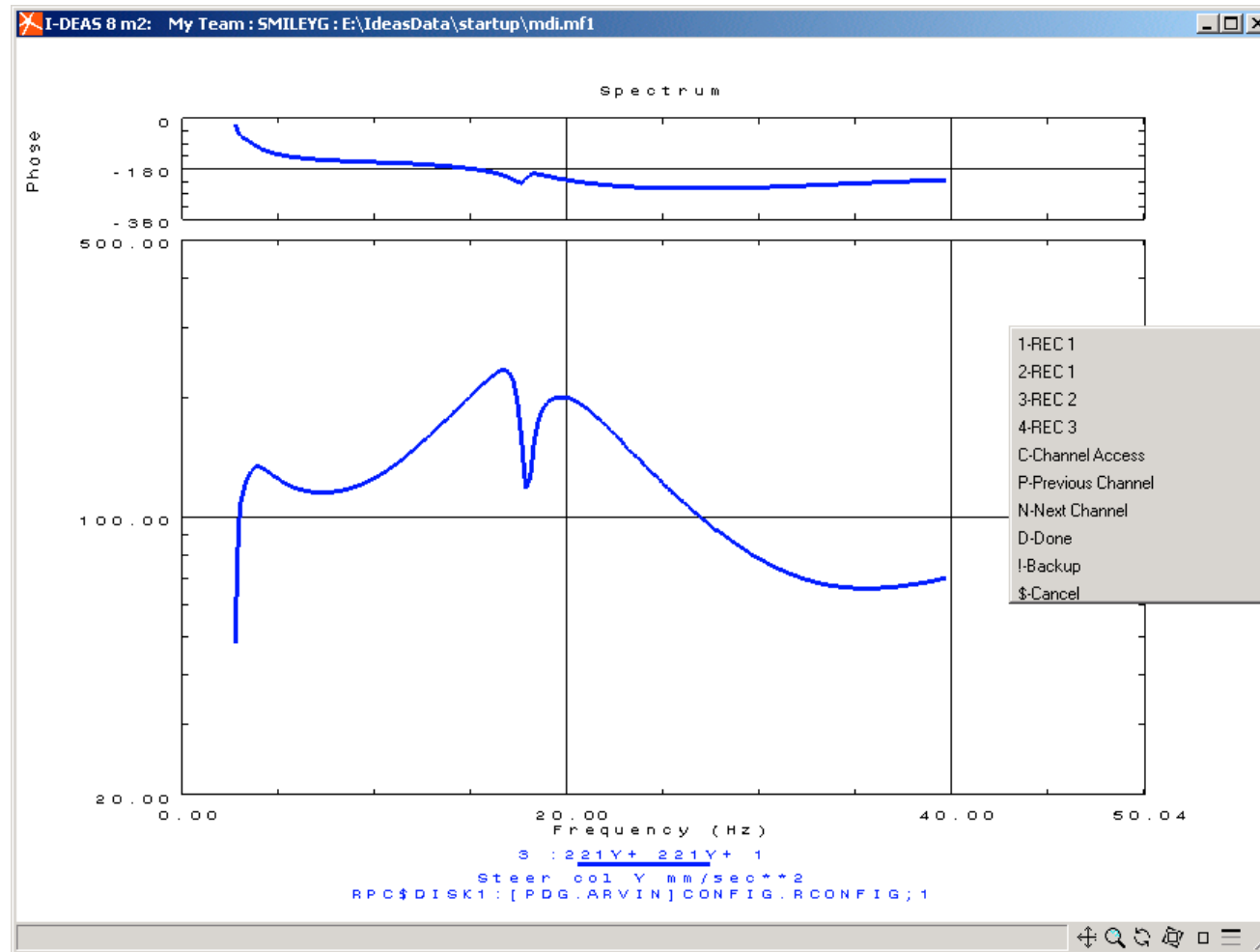
- In-phase sweep excitation applied to front wheels.
- Parametric flexible steering column modeled in ADAMS.





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Lateral Steering Column Response



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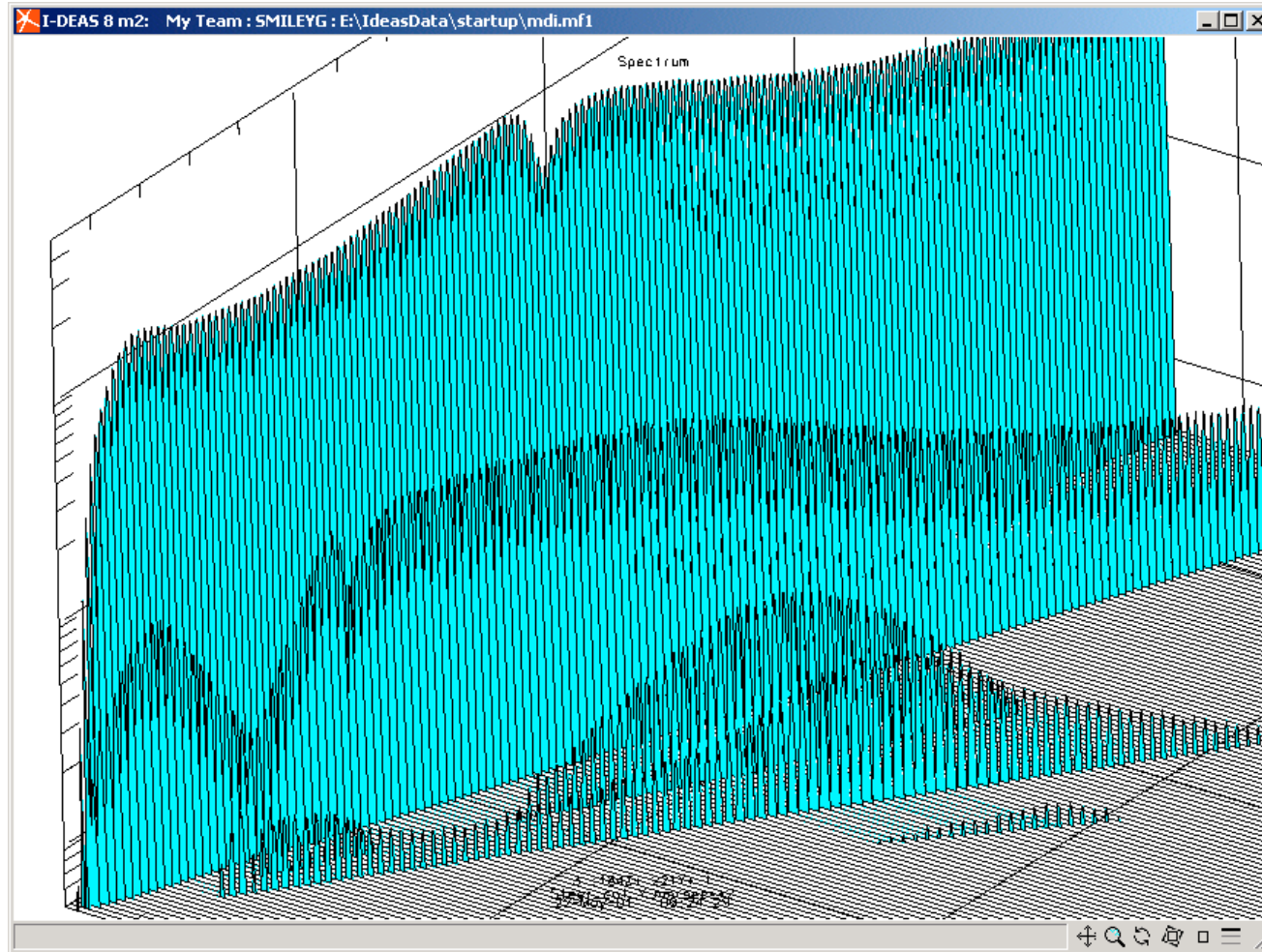
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Lateral Steering Column Response

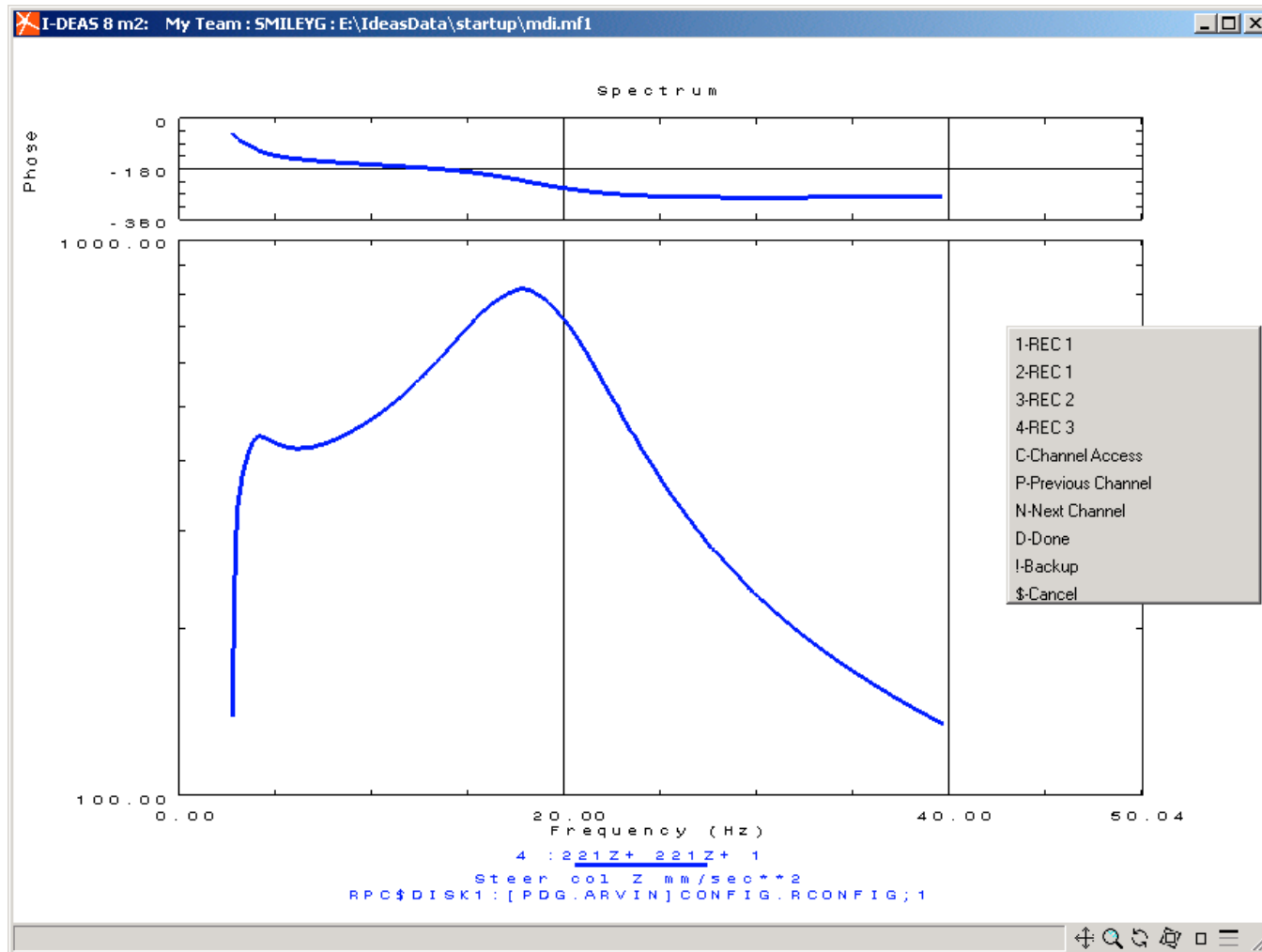


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Vertical Steering Column Response

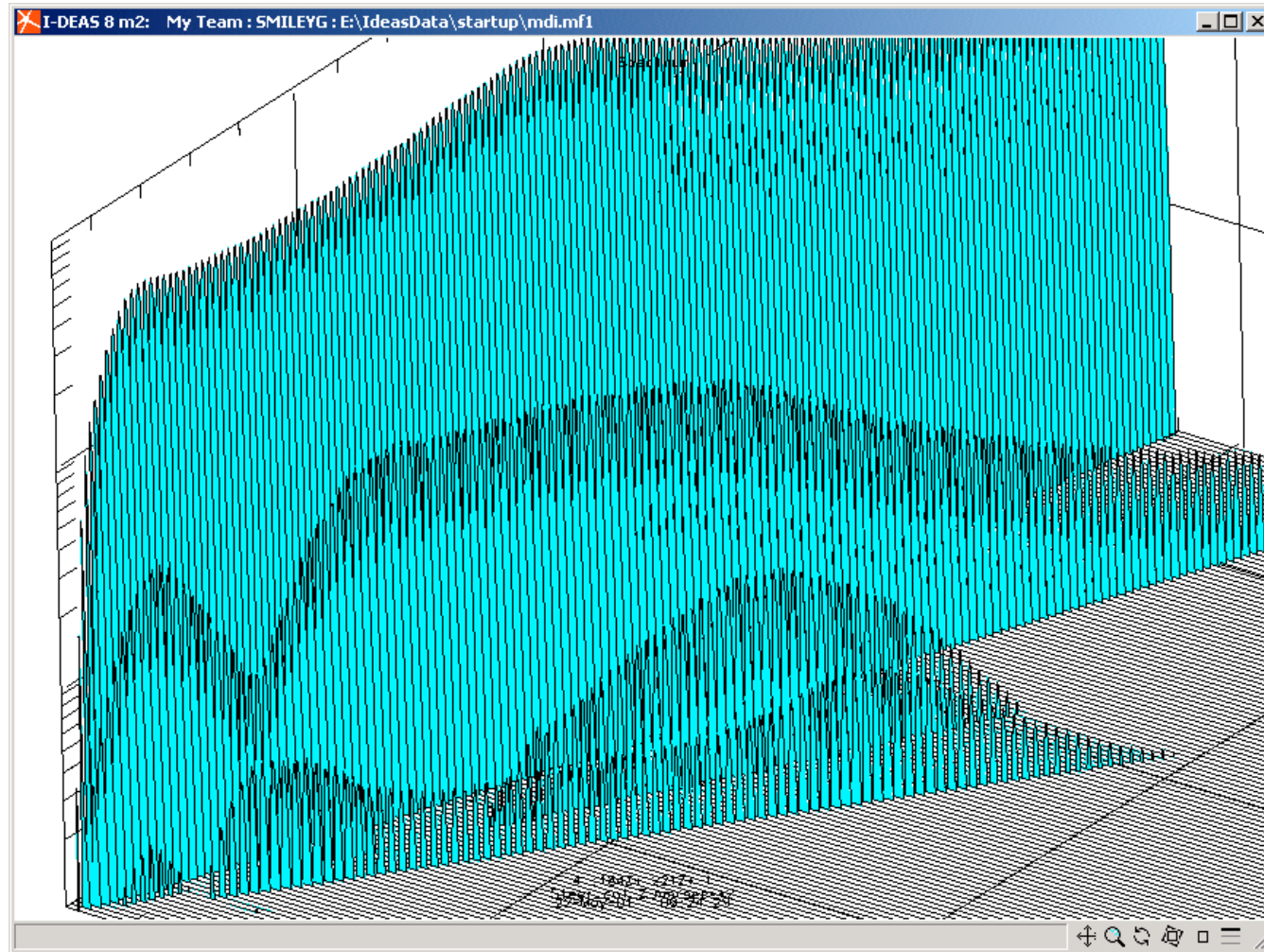


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Vertical Steering Column Response



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Conclusions

- **MDI & MTS, partners in the SmartSim community, can provide a unified solution for virtual prototyping for the NVH industry.**
- **ADAMS can be used as a virtual response-generator for NVH investigations:**
 - **Frequency-domain simulations are instantaneous, but are based on linearization.**
 - **Time-domain simulations require longer CPU time, but take into account non-linearities.**
- **I-DEAS Test can import results from ADAMS and be used as a virtual NVH post-processing tool.**





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Alternative way to post-process

Virtual Sine Post-Processing

- Automatically tracks the reference (input sine) signal in one channel.
- Produces the “tracked” response only at the reference frequency, as would occur in an actual experiment.
- Ignores distortions (harmonic amplitudes), as would actual test equipment.

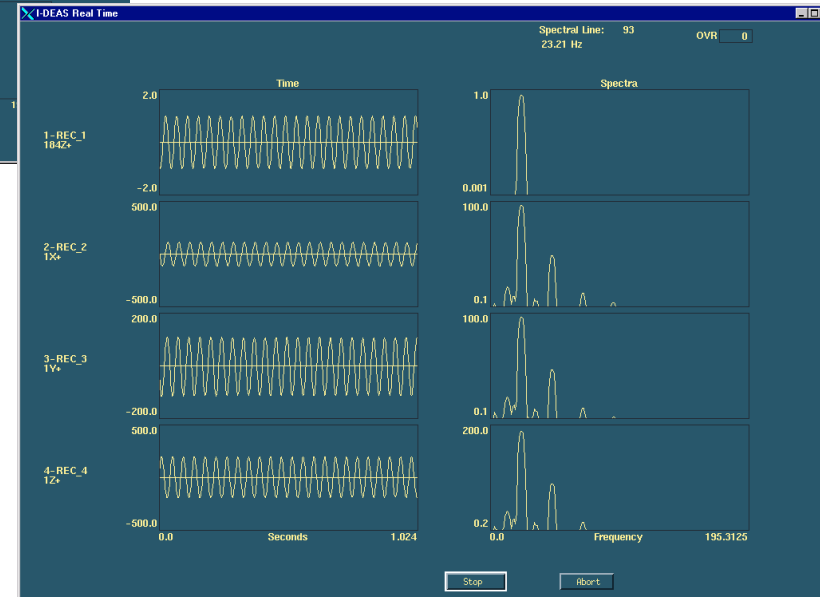
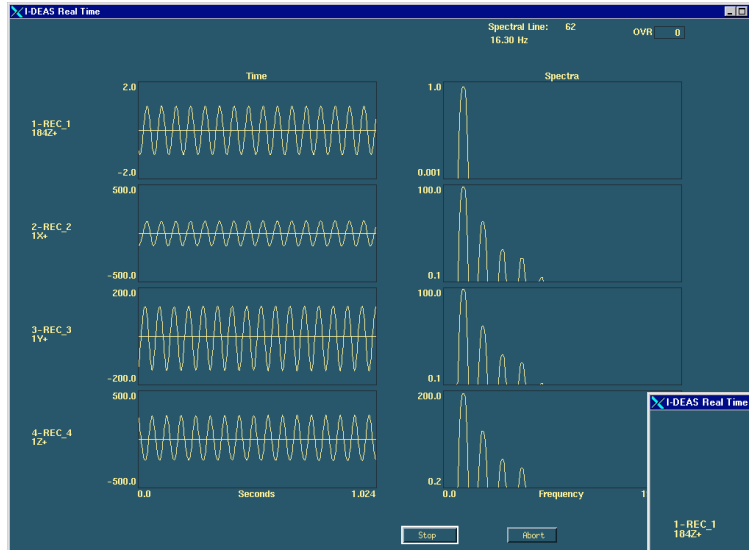


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Virtual Sine Post-Process

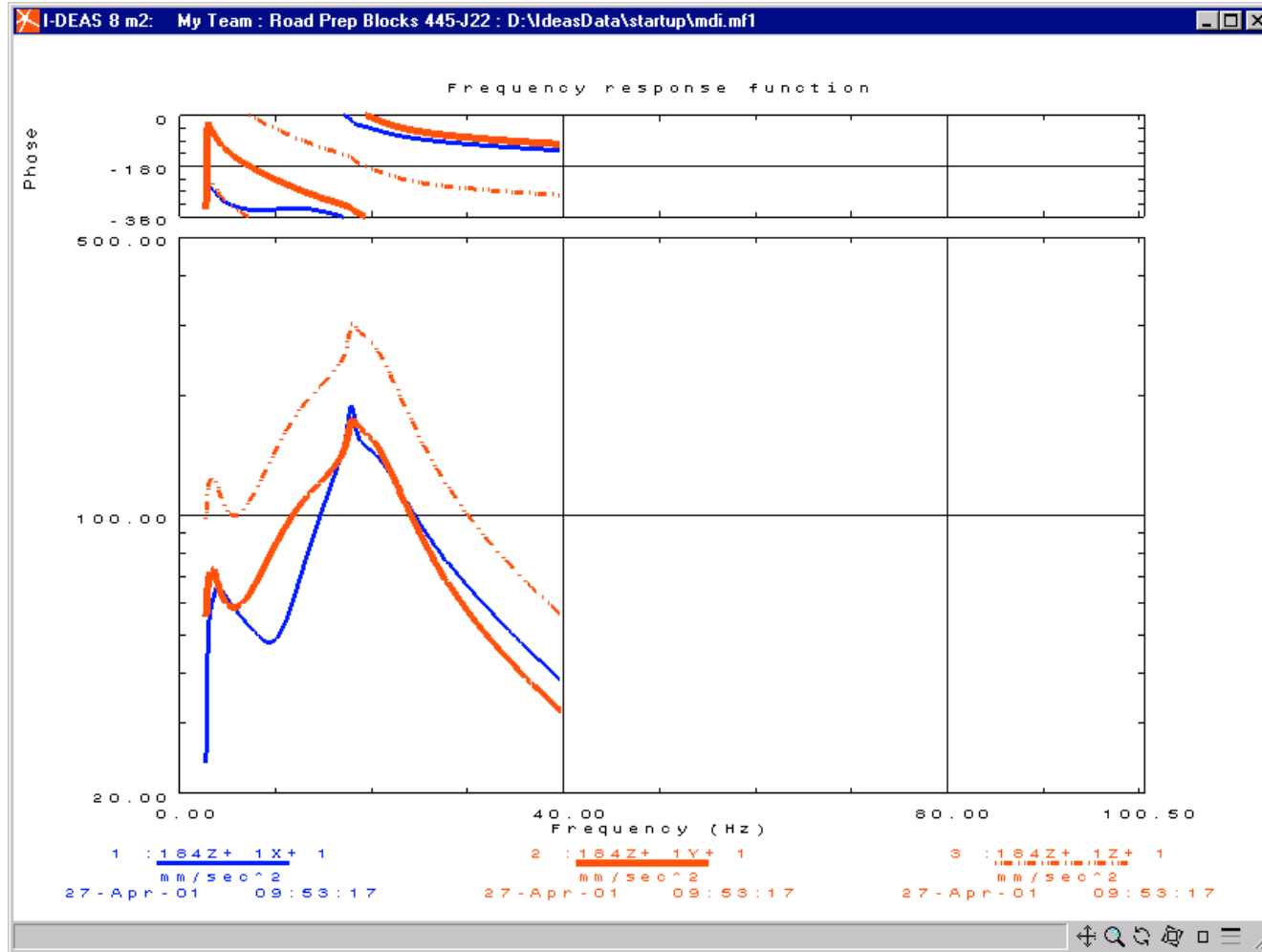


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Sine Post-Process Results



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