MEscope Application Note 27

Impact Testing Using the Acquisition Window

The steps in this Application Note can be carried out using any MEscope package that includes the **VES-3600 Advanced Signal Processing** and **VES-700 Multi-Channel Acquisition** options. Without these options, you can still carry out the steps in this App Note using the **AppNote27** project file. These steps might also require MEscope software with ***a more recent release date***.

APP NOTE 27 PROJECT FILE

- To retrieve the Project file for this App Note, **click here** to download **AppNote27.zip**

This Project contains ***numbered Hotkeys & Scripts*** of commands for carrying out the steps of this App Note.

- ***Hold down*** **the Ctrl key** and ***click on a*** **Hotkey** to open its Script window

INTRODUCTION

The VES-700 Multi-Channel Acquisition option adds an Acquisition window within MEscope that can directly control a variety of multi-channel front-end acquisition hardware systems, analyzers, and recorders. The User Interface in the Acquisition window is the same, regardless of the front-end acquisition hardware chosen.

The User Interface is designed specifically for structural testing. It consists of an Acquisition window connected to a Structure window, where the next test location is depicted on a 3D model of the test article, and also connected to a Data Block window in which measurements are accumulated. Animation of shapes can take place even while measurements are being acquired.

The front-end acquisition hardware is attached to the computer running MEscope using the interface supported by equipment (USB, Firewire, Ethernet, ISA, etc). A single Acquisition window can be connected to different types of acquisition hardware, but only to one at a time.

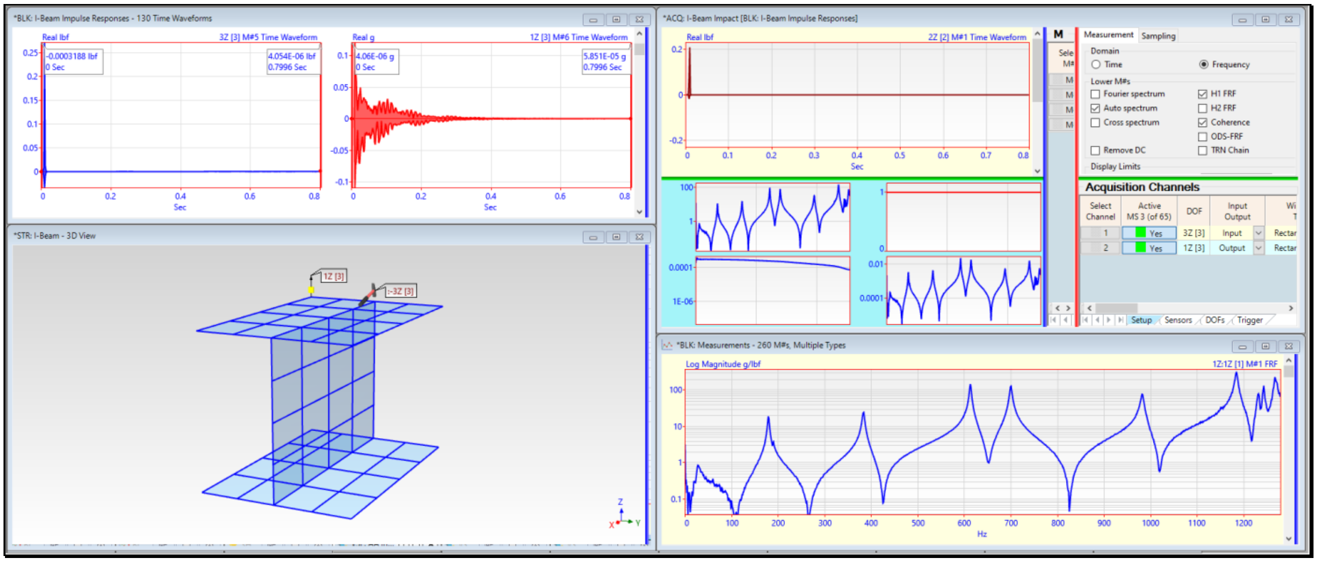
POST-PROCESSING FROM A DATA BLOCK

The Acquisition window only post-processes time domain waveforms from the front-end. All post-processing is done within MEscope.

A unique advantage of an Acquisition window in MEscope is that it can also be used to post-process multi-channel data that has been pre-recorded and saving in a Data Block.

In this note, a Date Block containing pre-recorded impact waveforms will be used in place of actual front-end hardware. This feature of the Acquisition window allows you to acquire multi-channel data ***using any acquisition hardware***, save the time records into a disk file, import them into MEscope, and post-process the data.

Used in this way, an Acquisition window can be used to ***post-process data multiple times*** using different processing parameters such as **Block Size, Number of Averages, Overlap Processing, windowing, triggering**, etc.. This App Note will also illustrate the advantages of a graphical user interface that provides tight integration between data acquisition and post-processing.



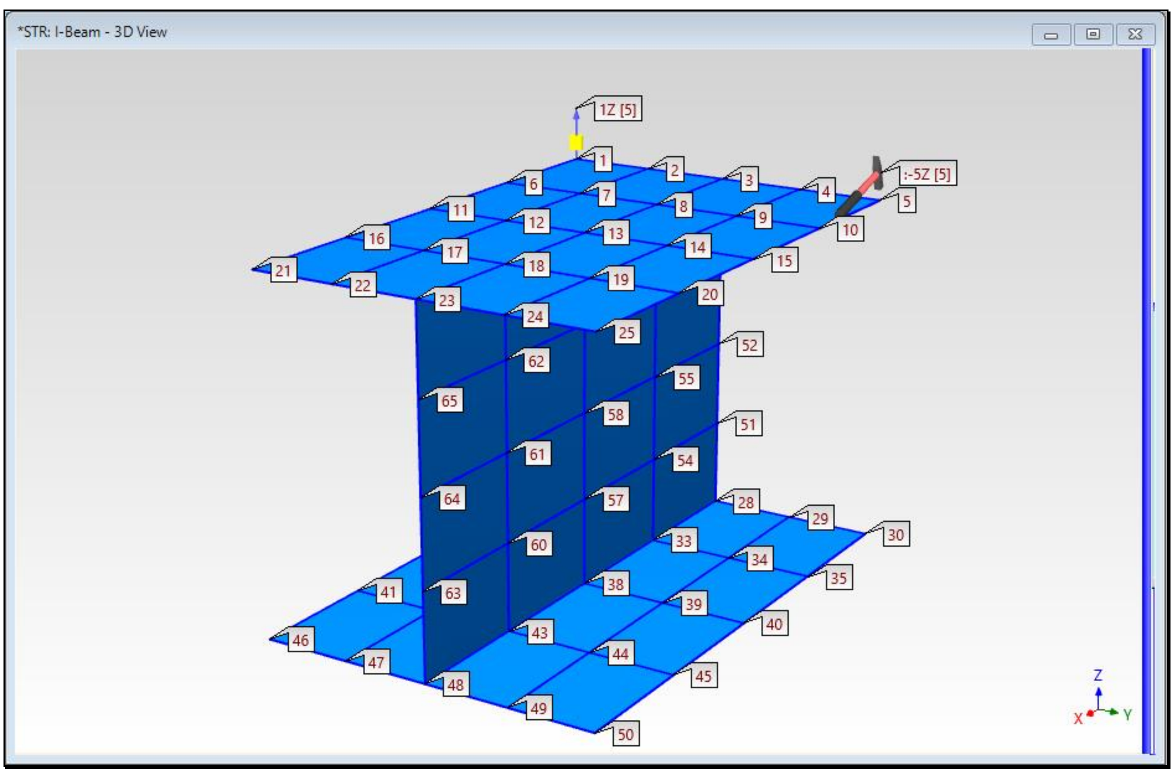
Acquisition Window Connected to Structure Window & Two Data Block Windows.

ROVING IMPACT TEST OF THE I-BEAM

A Roving Impact Test was performed on the I-Beam shown below, using an instrumented impact hammer and a uni-axial accelerometer. The accelerometer was attached at Point 1 and sensed motion in the vertical direction (**DOF 1Z**) throughout the impact test. The I-Beam was impacted at 65 Points which are numbered below.

The I-Beam was impacted in the vertical direction (**Z-direction**) at each of the numbered Points on the horizontal top & bottom flanges, and in the **Y-direction** at each of the numbered Points on the vertical web.

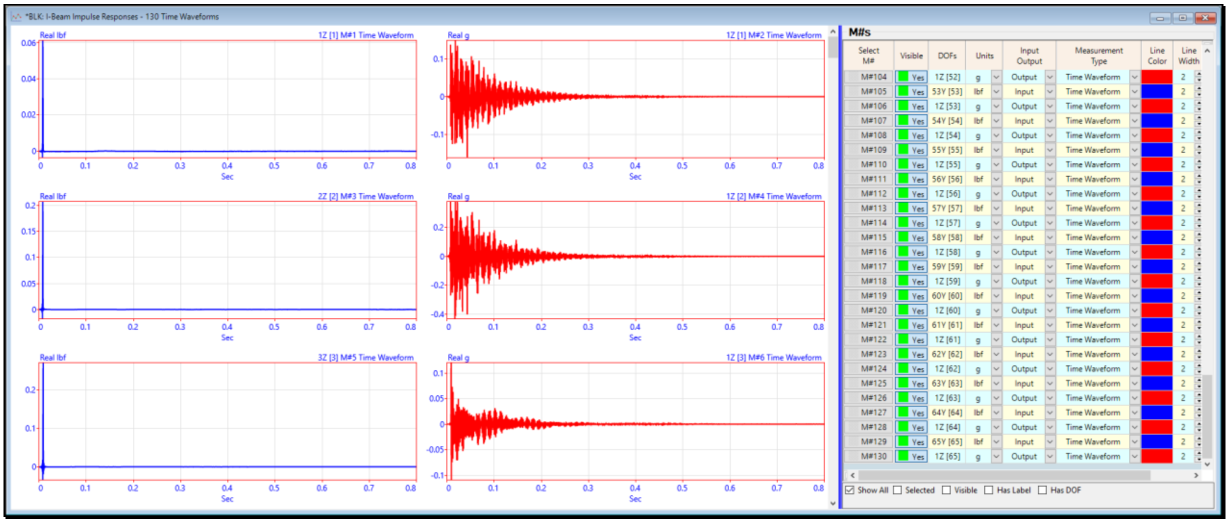
Each time the I-Beam was impacted, both the impact signal and the accelerometer response at **DOF 1Z** were ***simultaneously acquired*** with 2-channel acquisition hardware.



I-Beam Showing 65 Impact Points.

DATA BLOCK OF RECORDED IMPACTS & RESPONSES

During the impact test, only one pair of impact & accelerometer time waveforms was acquired at a time. Therefore, each pair of acquired time waveforms was giving a [Measurement Set number]. Sixty-five Measurement Sets of data were acquired during the test and were saved in the Data Block **BLK: I-Beam Impulse Responses**, shown below.



Three Measurement Sets of I-Beam Impulse Responses.

Each pair of M#s contains the same **Output DOF (1Z)** and a different **Input DOF (1Z, 2Z, 3Z, etc.)**. This is evidence that a **Roving Impact test** was performed on the I-Beam.

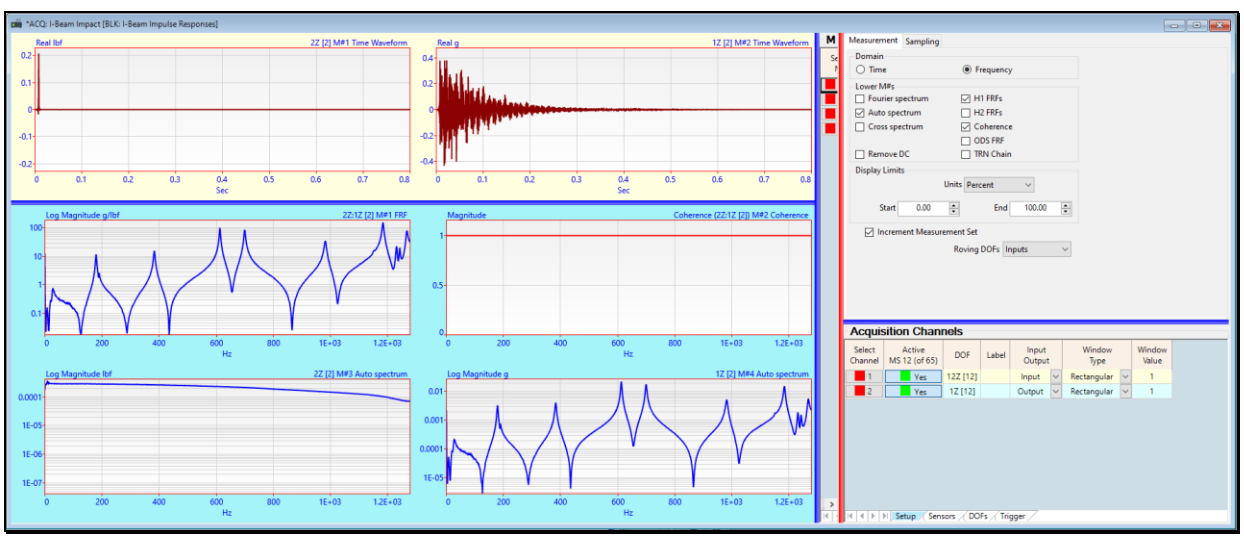
Each **Input Output** pair of DOFs has a **[Measurement Set]** appended to it, and there are ***65 different*** **[Measurement Sets]** listed in the **DOFs column** in **BLK: I-Beam Impulse Responses**.

ACQUISITION WINDOW

An Acquisition window in MEscope was used to acquire data during the Roving Impact Test. As each Measurement Set of time waveforms was acquired, it was added to the Data Block **BLK: I-Beam Impulse Responses.**

In this App Note, the Acquisition window is used again to post-process the 65 [Measurement Sets] of time waveform pairs and calculate an **FRF**, Coherence, and Impact & Response Auto Spectra for each Measurement Set.

The Acquisition is already setup in the project file for this App Note, as shown below.



Acquisition Window Set Up to Acquire 65 Measurement Sets of Data from ***BLK: I-Beam Impulse Responses***

Data for each Measurement Set is ***"acquired"*** from **BLK: I-Beam Impulse Responses**, and the **FRF** (Transfer Function) and Coherence are calculated together with the Auto spectra of the Impact and Response time waveforms.

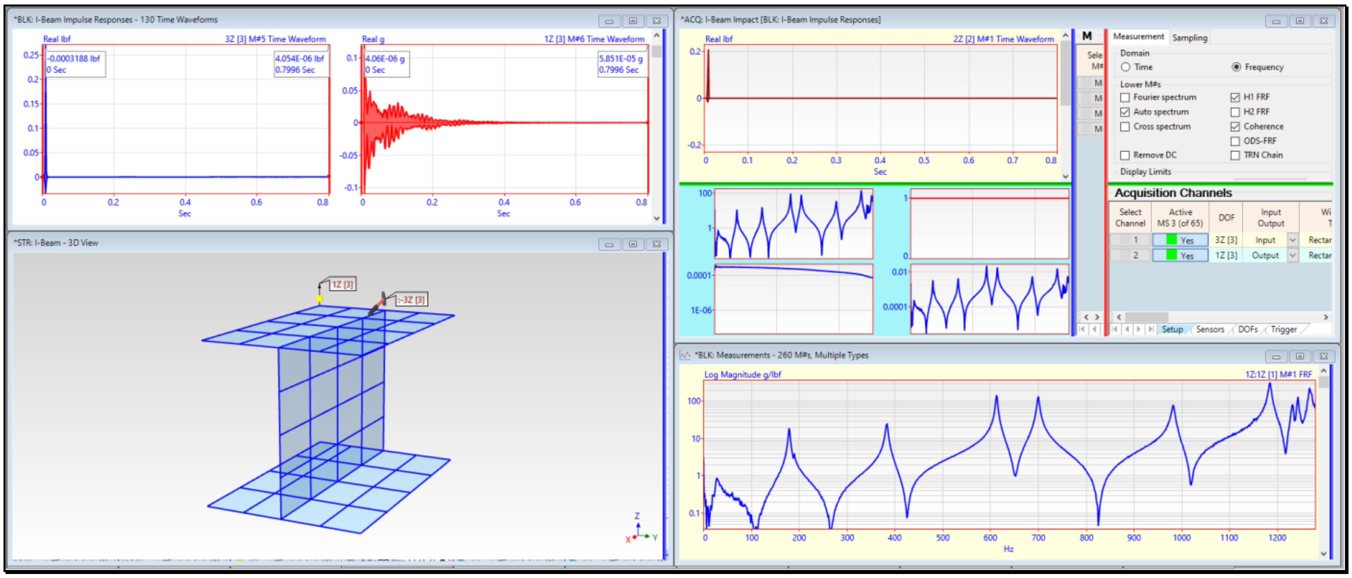
The two ***"acquired"*** time waveforms are displayed in the ***upper left*** graphics area of the Acquisition window.

The **FRF**, **Coherence** and **two Auto spectra** are displayed in the ***lower left*** area.

STEP 1 - ACQUIRING DATA FROM A DATA BLOCK

- ***Press*** **Hotkey 1 FRFs, Coherences & Auto Spectra**

The Acquisition window, shown below ***on the upper-right***, is connected to the **BLK: I-Beam Impulse Responses** window ***on the upper-left***. Data is acquired from **BLK: I-Beam Impulse Responses,** one Measurement Set at a time. The **FRF**, Coherence, and Auto Spectra are displayed ***in the lower graphics area*** of the Acquisition window. The Acquisition window is connected to the **STR: I-Beam** window, shown ***in the lower-left corner*** below.



The Acquisition Window Connected to Three Other Windows during Acquisition.

COHERENCE

Since ***only one average*** of data was acquired, the **Coherence ➔ 1** for all frequencies.

At least two averages of data are necessary to calculate Coherence ➔ ***less than or equal to* "1"**.

DISPLAY OF THE HAMMER (INPUT) & ACCELEROMETER (OUTPUT)

The Hammer (**Input**) and Accelerometer (**Output**) have been defined for each Measurement Set in the **Acquisition Channels** spreadsheet. As each Measurement Set of data is acquired, the ***locations & directions*** of each **Input-Output** pair are displayed on the model.

During a **Roving Impact Test**, showing the **Input-Output** pair for each Measurement Set ensures that the correct Point in impacted.

ACCUMULATING MEASUREMENTS INTO A DATA BLOCK

The Data Block **BLK: Measurements**, shown **in the lower-right corner** above, is also connected to the Acquisition window. After each Measurement Set of time waveforms has been processed, the **FRF, Coherence, Input Auto spectrum & Output Auto spectrum** for each Measurement Set are added to the **BLK: Measurements** Data Block.

When all acquisitions and calculations have been completed, four measurements for Measurement Set [1] are displayed as shown below.

*Accumulator Data Block Showing **FRF**, Coherence, **Input** Auto Spectrum, **Output** Auto Spectrum.*

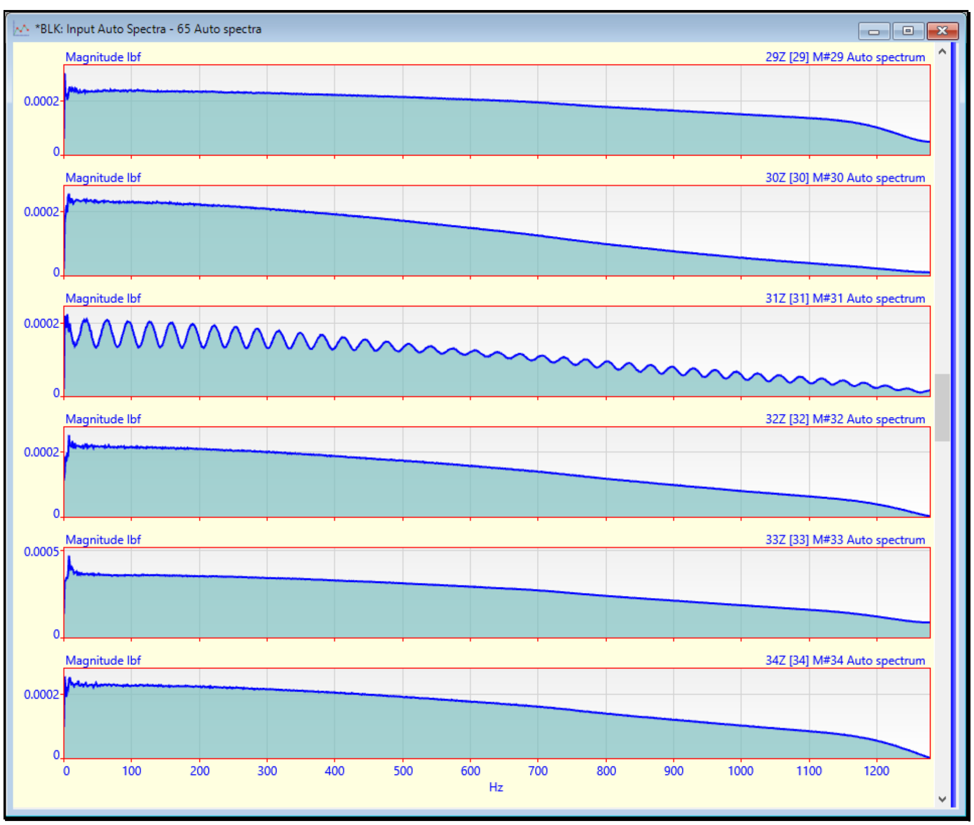
STEP 2 - FORCE (INPUT) AUTO SPECTRUM

- ***Press*** **Hotkey 2 Force (Input) Auto Spectra**

The **Input** Auto spectra shown below reveal that an invalid impact signal was acquired at **DOF 31Z [31]**.

The invalid impact at Point 31 will also result in an ***invalid* Output Spectrum** and an ***invalid* FRF** for **Measurement Set [31].**

- ***Scroll*** through the **M#s** to examine the remaining **Input** Auto spectra



***Input** Auto Spectra on the Right Showing Invalid Impact at* **DOF 31Z [31]**

STEP 3 - ACCELEROMETER (OUTPUT) AUTO SPECTRUM

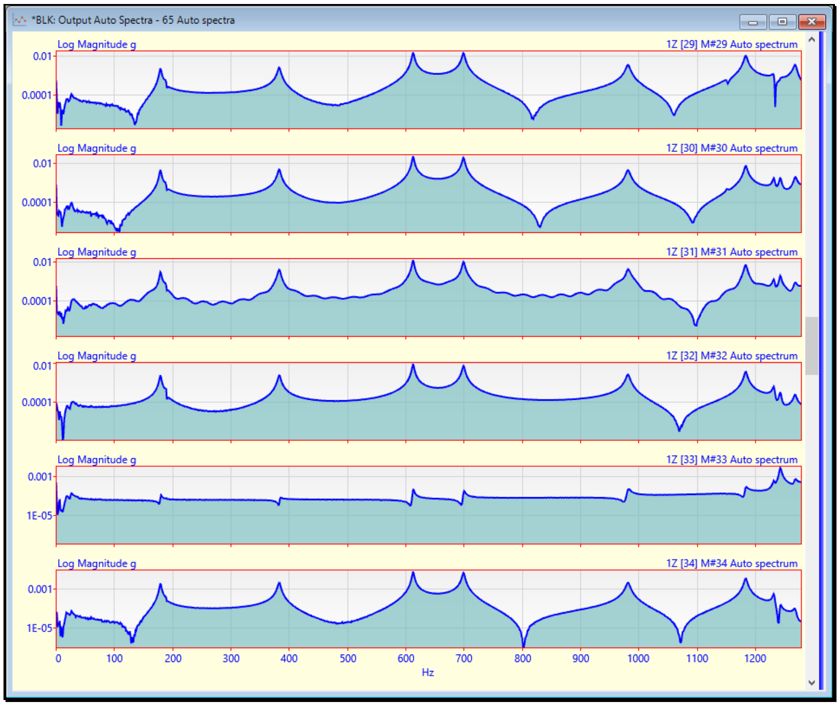
- ***Press* Hotkey 3 Accelerometer (Output) Auto Spectra**

To verify that the impact hammer excited all modes over the analysis range (1280 Hz), it is also useful to display the **Output** Auto spectra for all 65 Measurement Sets.

Although an **FRF** is calculated differently, it is defined as the ***Output Auto Spectrum divided by the Input Auto Spectrum*** of each Measurement Set.

Because the I-Beam was not excited properly at **DOF 31Z**, an ***invalid* Output spectrum** was also calculated for **DOF 1Z [31]**.

- ***Scroll*** through the **M#s** to examine the remaining **Output** Auto spectra



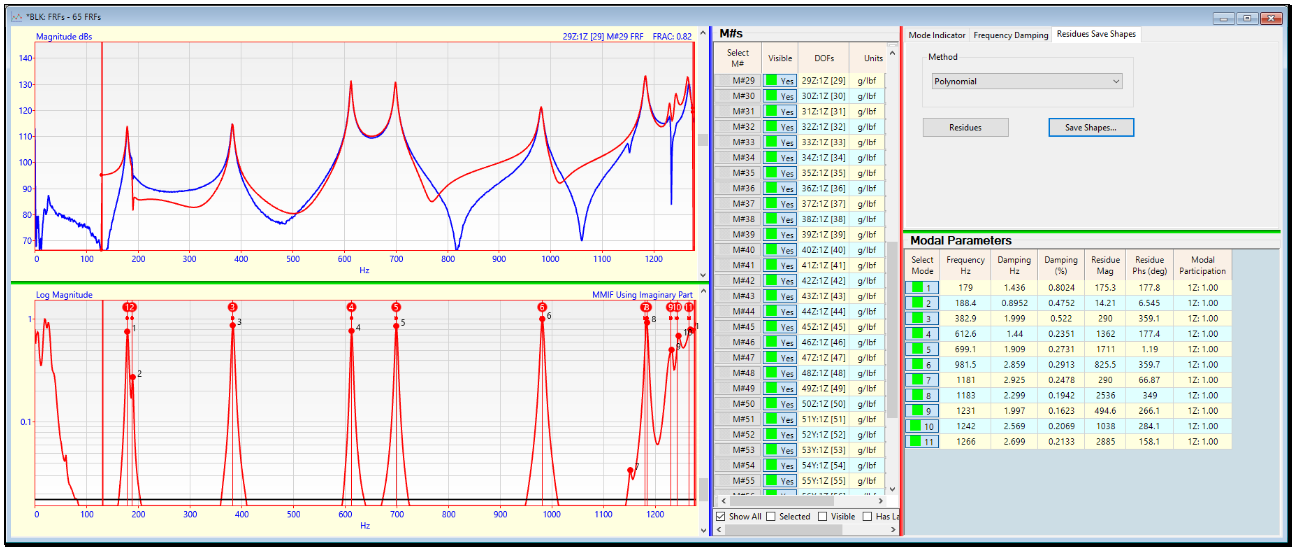
Output *Auto Spectra Showing Invalid Spectrum from Impact at* **DOF 31Z [31]**

STEP 4 - ESTIMATING MODAL PARAMETERS BY QUICK FITTING THE FRFs

- ***Press* Hotkey 4 Quick Fit the FRFs**

When **Hotkey 4 is *pressed*** a Quick Fit of the FRFs is performed. When the Quick Fit of the FRFs is completed, a dialog box will open allowing you to examine the curve fitting results.

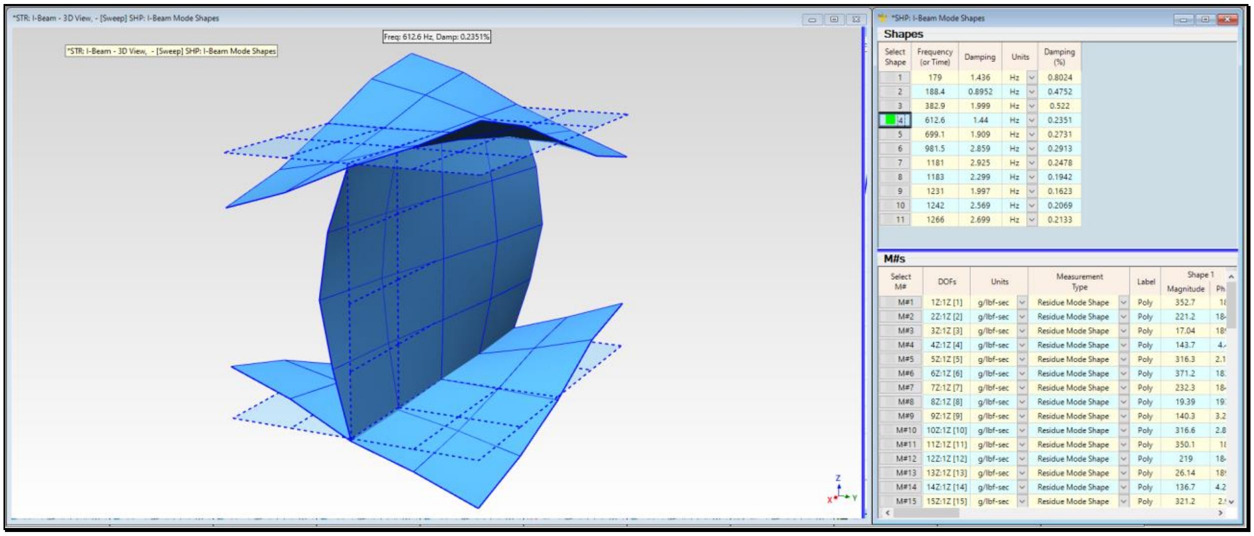
- ***If you press* No, *scroll*** through the **M#s** to examine the curve fit of each **FRF**
- ***Press* Yes** to continue and display the mode shapes in animation on the I-beam model



Quick Fit Curve Fitting Results.

When you ***press*** **Yes** to continue, Residue mode shapes are saved into a Shape Table **SHP: I-Beam Mode Shapes**, and sweep animation is begun through the mode shapes, as shown below.

- ***Click*** on a **Select Shape** button in **SHP: I-Beam Mode Shapes** to display that shape



Sweep Animation of I-Beam Mode Shapes

Mode shapes **1 through 7** are recognizable at ***valid mode shapes*** of the I-Beam.

Even though curve fitting identified mode shapes at **1230, 1240 & 1270 Hz**, the display of these mode shapes shows that they were not excited sufficiently by the impact force.

Examination of the **Input Auto** spectra in **Step 2** verifies that the ***force level was extremely low*** at those frequencies.

STEP 5 - COMPARING MODE SHAPES WITH ODS's

- ***Press* Hotkey 5 Mode Shapes vs. ODS's**

In this step, each mode shape is compared in animation with its ***closest matching* ODS**.

The ***closest matching* ODS** to a mode shape is the one that has a **Maximum MAC** value with the mode shape.

MODAL ASSURANCE CRITERION (MAC)

MAC is a measure of the ***co-linearity*** of two shape vectors. If two shapes ***lie on the same straight line***, they are ***co-linear*** and their **MAC *equals* 1.0**. If two shapes ***do not lie on the same straight line***, they are ***linearly independent*** and their **MAC *value is less than* 1.0**.

The following ***rules of thumb*** are used with **MAC**,

MAC values ➔ ***between 0 & 1***

MAC = 1.0 ➔ two shapes ***are co-linear***

MAC >= 0.9 ➔ two shapes ***are similar***

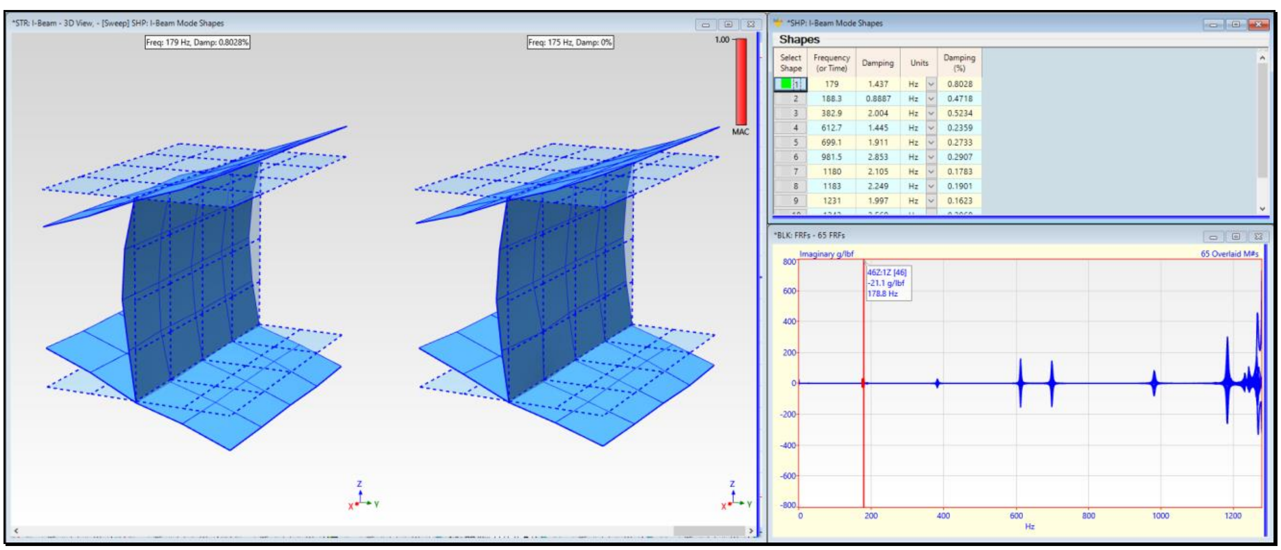
MAC < 0.9 ➔ two shapes ***are linearly independent***

During animation, the ***closest matching* ODS** at the **Line cursor** position in **BLK: FRFs** is displayed side-by-side with the currently selected mode shape in **SHP: I-Beam Mode Shapes**. Several things are done for the comparison.

- The ***imaginary parts*** of the FRFs ***are overlaid*** to show the resonance peaks more clearly
- **Animate | Normalize Shapes** ***was checked*** to ***remove the complexity*** from the mode shapes and provide a ***higher* MAC** between each mode shape and its closely matching ODS

The mode shape at **189 Hz *is closely-coupled*** with the mode shape at **179 Hz**, so it ***does not correlate well*** with its ODS.

The mode shapes at **1230, 1240 & 1270 Hz *do not correlate well*** with the ODS because they were not excited well by the impact forces at those high frequencies



Side-by-Side Animation of an I-Beam Mode Shape vs. Its Closest Matching ODS.

STEP 6 – REVIEW STEPS

To review the steps of this App Note,

- ***Press* Hotkey 6 Review Steps**