MEscope Application Note 43

Multi-Channel Data Acquisition

The steps in this Application Note can be carried out using any MEscope package that includes the **VES-700 Multi-Channel Data Acquisition** option. Without this option, you can still carry out the steps in this App Note using the **AppNote43** project file. These steps might also require a ***more recent release date*** of MEscope.

APP NOTE 43 PROJECT FILE

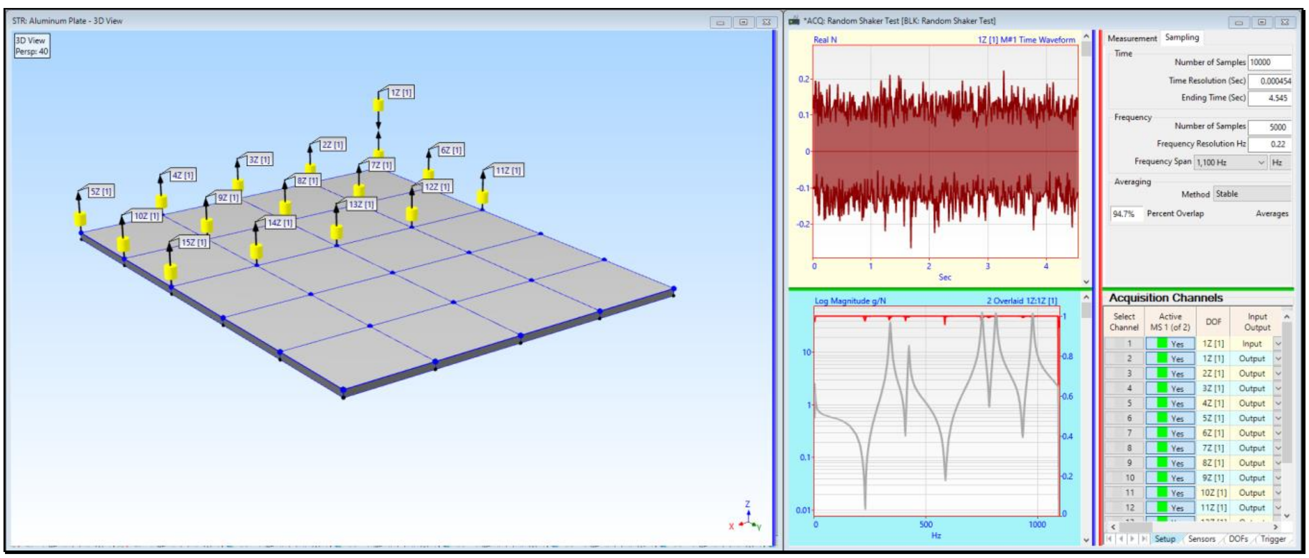
- To retrieve the Project for this App Note, **click here** to download **AppNote43.zip**

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

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

USING THE ACQUISITION WINDOW

The **VES-700 Multi-Channel Acquisition** option allows you to setup and acquire multi-channel data directly from supported third-party acquisition hardware. The **Acquisition window** connects directly to the front-end hardware using software provided by the third-party hardware supplier.



Acquisition of FRFs & Coherence from Measurement Set [1].

MULTIPLE MEASUREMENT SETS

When a multi-channel front end does not have enough channels to ***simultaneously acquire all the necessary data***, a test can be setup in the Acquisition window to acquire data **in several Measurement Sets**.

A Measurement Set consists of all the channels of data that ***are simultaneously acquired*** and post-processed together.

Any **cross-channel measurement** such as a Frequency Response Function (**FRF**) requires that the excitation force and the responses caused by that force ***be simultaneously acquired***.

Measurement Sets are defined in the Acquisition window prior to performing a test. Each Measurement Set contains the entire front-end channel settings **required to simultaneously acquire** a set of data from a machine or structure.

The Acquisition window can perform the following post-processing tasks,

Acquire **multi-channel time waveforms** and calculate **time or frequency domain functions** for each Measurement Set

Add each Measurement Set of measurements into **an accumulator Data Block**

Display **Icons** on the structure model in a ***connected* STR window** to indicate where response sensors (**Outputs**) and excitation forces (**Inputs**) are to be located for each Measurement Set

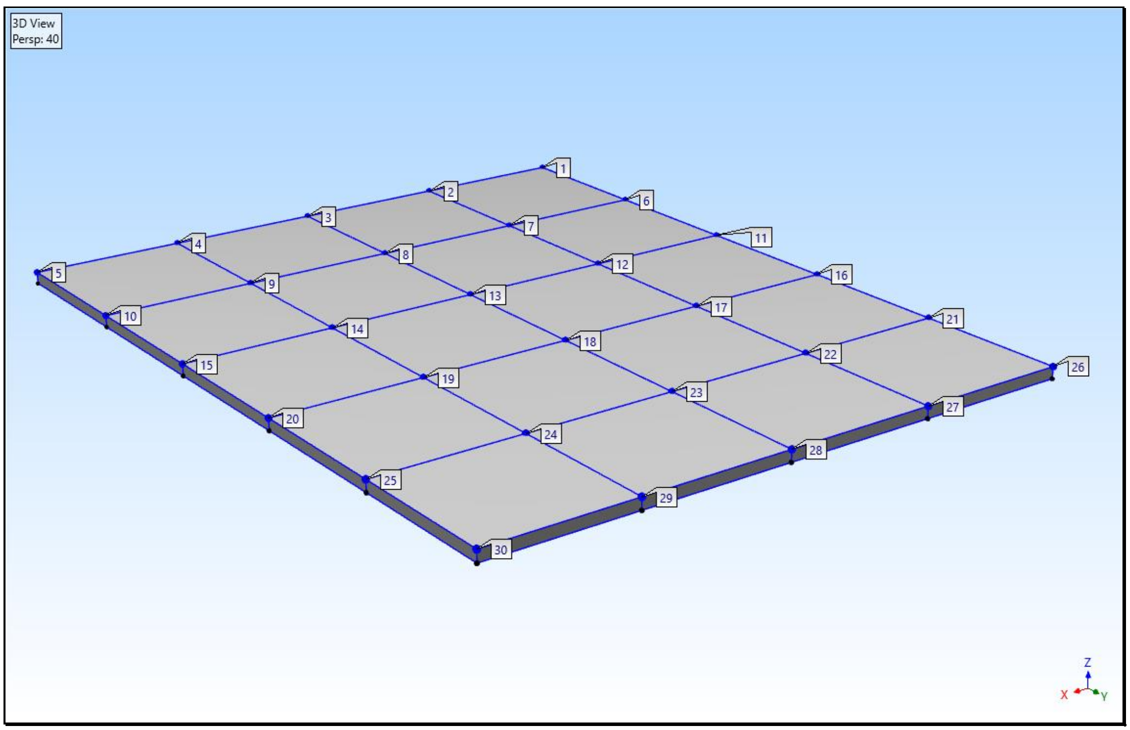
Display **Operating Deflection Shapes (ODS's)** in animation on a structure model in a ***connected* STR window** directly from the **cursor position on waveforms** in the Acquisition window

ALUMINUM PLATE

The data in **BLK: Random Shaker Test** was acquired by attaching a shaker to **one corner of a rectangular aluminum plate** and attaching uni-axial accelerometers at **Points in a 5 by 6 grid of Points** on the plate.

Measurement Set [1] was acquired with a shaker attached at **DOF 1Z** and uni-axial accelerometers that sensed motion in the Z direction attached at Points **1** through **15**

Measurement Set [2] was acquired with a shaker attached at **DOF 1Z** and uni-axial accelerometers that sensed motion in the Z direction attached at Points **16** through **30**



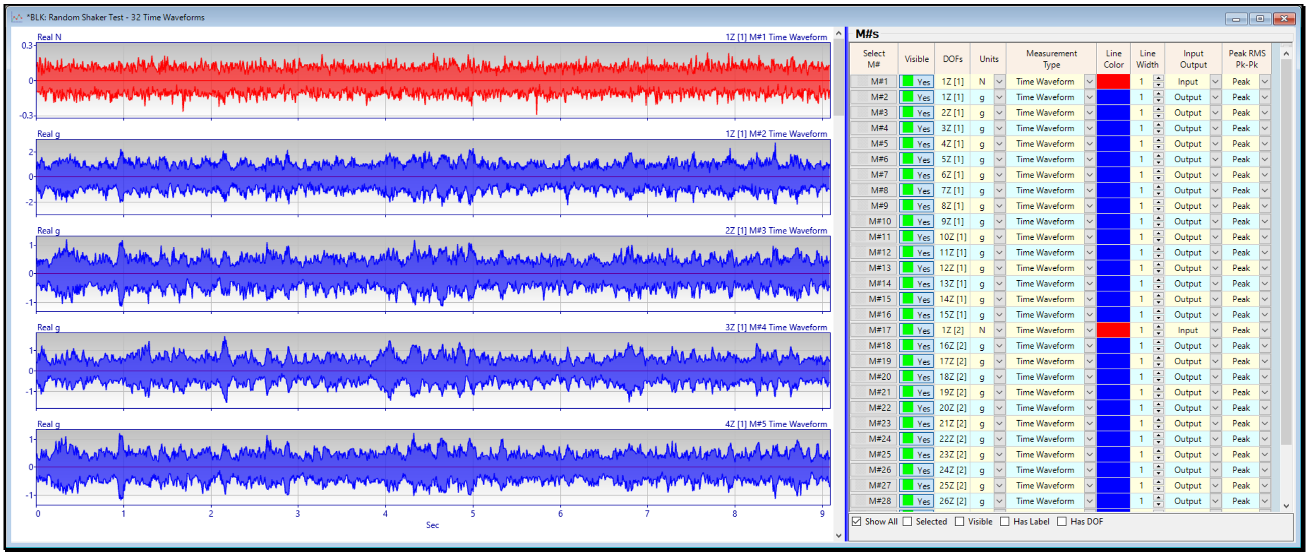
Point Numbering on the Aluminum Plate Model.

STEP 1 - TIME WAVEFORMS FROM A RANDOM SHAKER TEST

- ***Press* Hotkey 1 Shaker Test Time Waveforms**

When **Hotkey 1 is *pressed***, a Data Block file of **pre-recorded force (Input)** and **response** (**Output**) data is displayed.

This data is typical of data that would be acquired during a random shaker test using a 16-channel data acquisition system or spectrum analyzer.



Data Block Window Showing Time Waveforms in BLK: Random Shaker Test.

The **BLK: Random Shaker Test** Data Block contains the following,

32 random time domain waveforms with a Block Size of **20,000** samples

Two Measurement Sets of data, denoted by the numbers in square brackets **[1]** & **[2]** added to the **DOFs** of the **M#s**

Each Measurement Set has **15** accelerometer responses (**Outputs**) and one force (**Input**)

Measurement Set **[1]** contains an **Input** at **DOF 1Z [1]** and **Outputs** with **DOFs** from **1Z [1]** through **15Z [1]**

Measurement Set **[2]** contains an Input at **DOF 1Z [2]** and **Outputs** with **DOFs 16Z [2]** through **30Z [2]**

- Scroll through the **M#s** in **BLK: Random Shaker Test** to verify these properties

STEP 2 - OPENING THE ACQUISITION WINDOW

- ***Press* Hotkey 2 Open the Acquisition Window**

When **Hotkey 2 is *pressed***, an empty Acquisition window is opened, as shown below

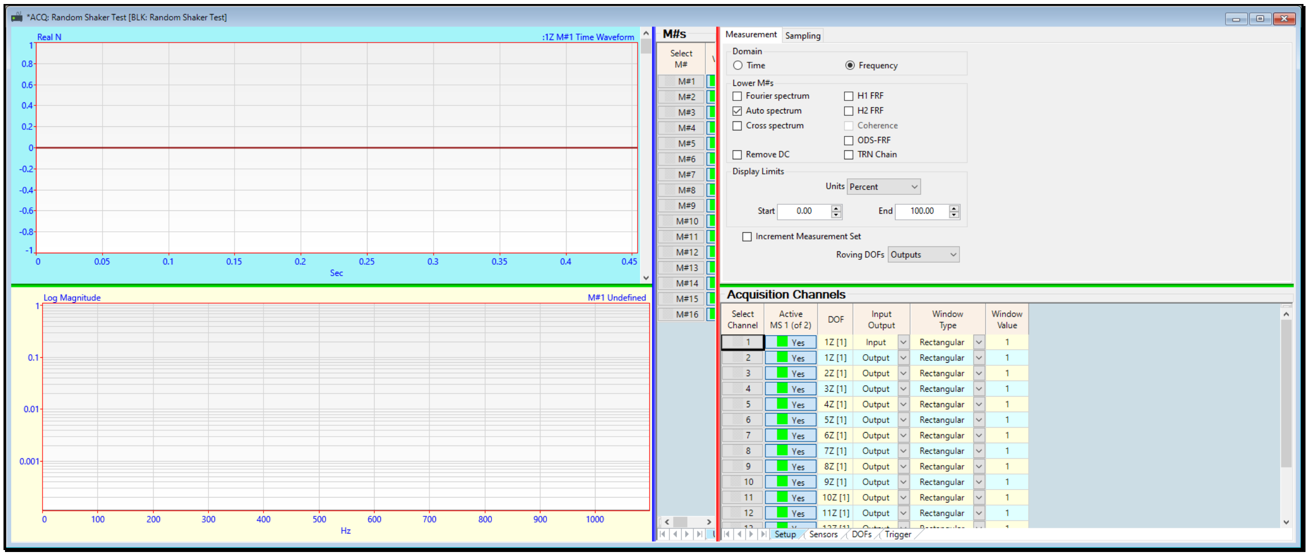
The acquired time waveforms are **always displayed in the *upper* graphics area**

Time or frequency waveforms derived from the acquired time waveforms are **always displayed in the *lower* graphics area**

The ***upper or lower* graphics areas** are empty because **no data has not yet been acquired** from the **BLK: Random Shaker Test** Data Block.

The Acquisition window is already setup to acquire data for **Measurement Set [1]**. In the **Channels** spreadsheet, **16 channels are *active*** and have the proper **Input Output** and **Units** properties.

- Click on the **Setup**, **Units**, and **DOFs** tabs below the **Channels** spreadsheet in succession to examine the channel parameters
- Channel **1** is the force channel with **Input Output ➔ Input** and **DOF ➔ 1Z [1]** and **Units ➔ N**
- Channels **2** through **16** are accelerometer channels with **Input Output ➔ Output** and **DOFs ➔ 1Z [1]** through **15Z [1]** and **Units ➔ g**



*Acquisition Window Connected to **BLK: Random Shaker Test.***

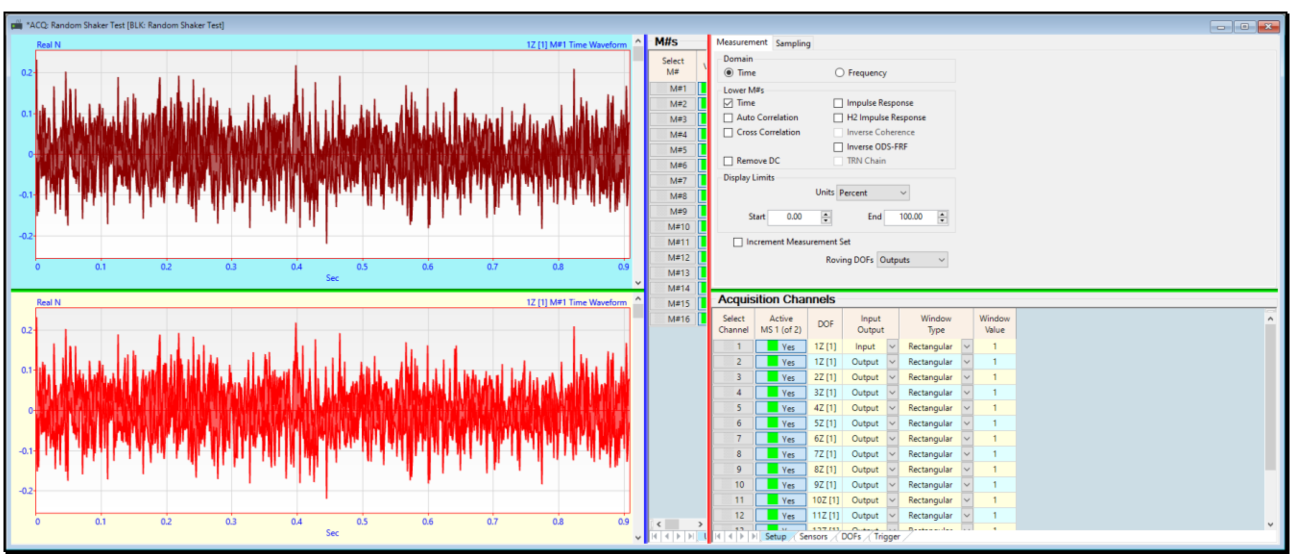
POST-PROCESSING ACQUIRED TIME WAVEFORMS

Multi-channel time waveforms can be ***pre-recorded*** from front-end hardware and ***post-processed later*** in two ways,

1. Use an Acquisition window to connect directly to supported front-end hardware, acquire time waveforms, save them into a Data Block, and post-process them later with an Acquisition window
2. Use the software provided with the front-end acquisition hardware, acquire time waveforms, save them into one or more disk files, **import the files into a Data Block** and post-process the data with the Acquisition window

For this App Note, multi-channel time waveforms have already been acquired and saved in the Data Block **BLK: Random Shaker Test**.

- In the **Domain** section on the **Measurement** tab, choose **Time**, and **check Time** in the **Lower M#s** section
- In the **Time** section on the **Sampling** tab, enter **Number of Samples → 2000**
- Execute **Acquire | Front End Scope**



Acquisition of Time Waveforms Using Front End Scope.

Using the **Front-End Scope** for acquisition, data is ***continuously acquired*** from the ***16 active front end channels*** for **Measurement Set [1**], in **blocks of 2000 samples each**. Since **Time** was ***checked*** in the **Calculate** section, the same time waveforms are displayed in both the ***upper (acquired)*** & ***lower (calculated)*** **graphics areas**.

- Execute **Acquire | Stop (F7)** to stop the acquisition

APPLYING A HANNING WINDOW

Since the acquired data is random in nature, each Block of 2000 samples of time waveform data is non-periodic in its sampling window.

Consequently, the **Digital Fourier Transform (DFT)** of this **non-periodic random data** will have **leakage in it**.

To **reduce the effect of leakage** in the spectrum of a **non-periodic signal**, a **Hanning** window **must be applied** to each channel of data **before the FFT** is applied to it.

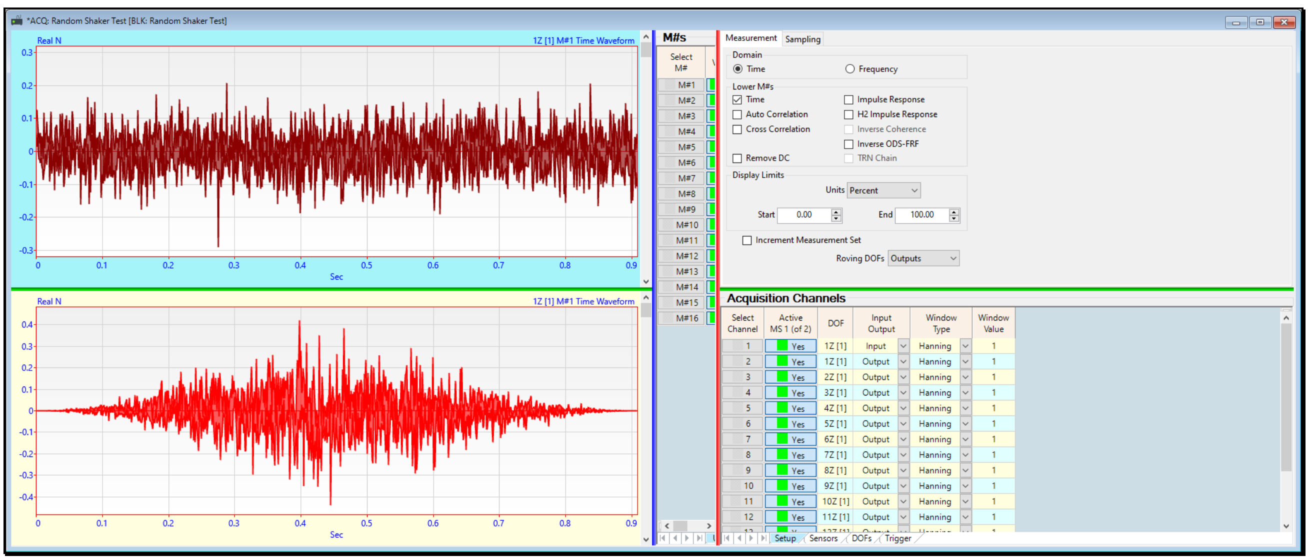
On the **Setup** tab in the **Channels** spreadsheet***, double click*** on the **Window Type** column heading

Choose **Hanning** from the list in the dialog box that opens, and ***click*** on **OK**

Choose **Yes** in the next dialog box to apply the **Hanning** window to all Measurement Sets

Execute **Acquire | Front End Scope *again***

The time waveforms in the ***lower*** **graphs area** are **smoothly tapered to zero** at the ends of the sampling window. This shows that **each time waveform in the *upper* graphics area** is **multiplied by a Hanning window**.



Lower Graphics Areas Showing the Hanning Window Applied to the Time Waveforms.

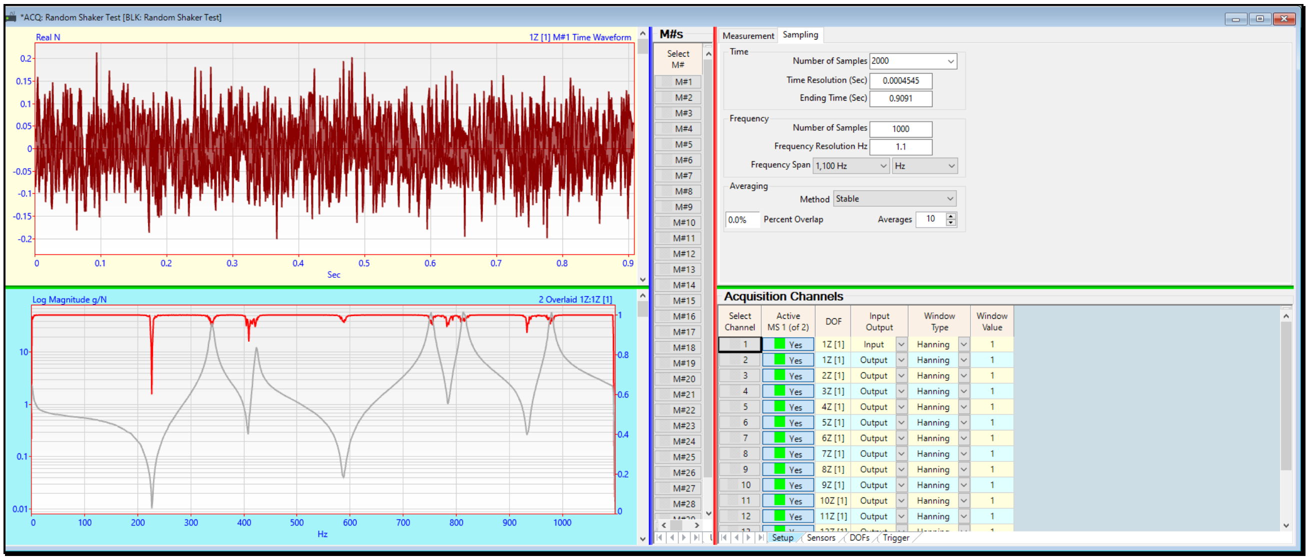
STEP 3 - CALCULATING FRFS & COHERENCE

- ***Press*** **Hotkey 3 Calculate FRFs & Coherences**

When **Hotkey 3 is *pressed***, the windowed time waveforms in the ***upper*** **graphics area** are processed to calculate **FRFs & Coherences** between the **force (Input)** and **each acceleration response (Output)**.

- On the **Measurement** tab, choose **Frequency** in the **Domain** section, and ***check only*** **H1 FRF** & **Coherence** in the **Lower M#s** section
- On the **Sampling** tab, ***choose*** the **Stable** method, and ***choose*** **Averages → 10** in the **Averaging** section
- Execute **Acquire | Start**

The Acquisition window will acquire **10 blocks of data of 2000 samples each** from **BLK: Random Shaker Test** and calculate **FRFs & Coherences** using **Stable spectrum averaging**. The result is shown below.



FRF & Coherence Overlaid (Hanning Window &10 Spectrum Averages).

The log magnitude of each **FRF** is overlaid with its **Coherence in red**.

- Scroll through the **15 pairs of FRF & Coherence**

The Coherences have values **"close to 1"** at all frequencies except at resonance peaks, called **"poles"**, and where the **FRF** has low values called **"zeroes" or "anti-resonances".**

The drop in Coherence near a resonance peak **is caused to leakage**.

The Hanning window **only reduces leakage,** but **does not eliminate leakage**.

OVERLAP PROCESSING

Each **M#** in **BLK: Random Shaker Test** has **20000** samples of time waveform data in it. There is **exactly enough data** in each **M#** for calculating **10 estimates** of an Auto & Cross spectrum using **2000 successive samples of data for each estimate**. With spectrum averaging, the 10 spectrum estimates are **"averaged together" to yield a single estimate** for each Auto & Cross spectrum. If the number of averages **is greater than 10**, **overlap processing** of the data **will be automatically used** by the Acquisition window.

When overlap processing is used, each successive sampling window **will contain some samples from the previous sampling window**.

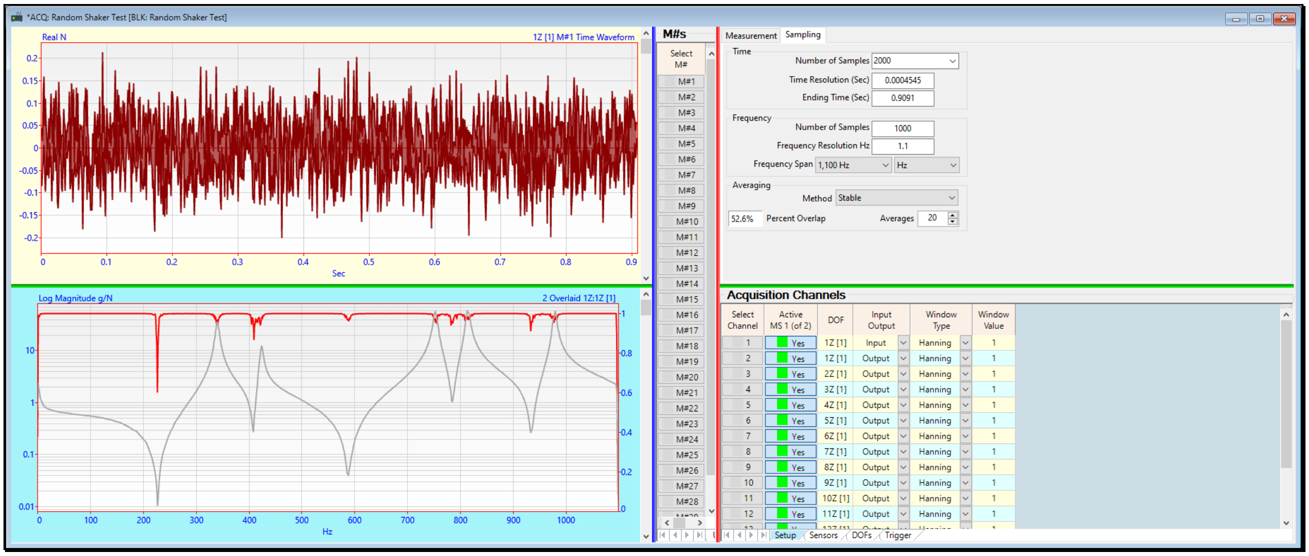
The **Percent Overlap will increase** as the number of averages is increased.

Overlap processing allows **more spectral estimates to be calculated and averaged together**.

Spectrum averaging **reduces the effects of extraneous random noise** and **non-linearities** in the average spectral estimate.

- On the **Sampling** tab, ***change*** **Averages** to **20** in the **Averaging** section
- **Execute Acquire | Start**

Acquisition will continue until **20** sampling windows of data have been acquired from **BLK: Random Shaker Test** and post-processed. As data is acquired, **FRFs & Coherences** are calculated using the **Auto** spectra of the **force Input** and **each response Output**, and the **Cross** spectrum between the **force Input** and **each response Output**



FRF & Coherence Overlaid (Hanning Window &20 Averages).

The drop in Coherence at each anti-resonance **is expected** since the structural response is **close to zero** at an anti-resonance. The drop in Coherence at a resonance peak is due to the **remaining effects of leakage**.

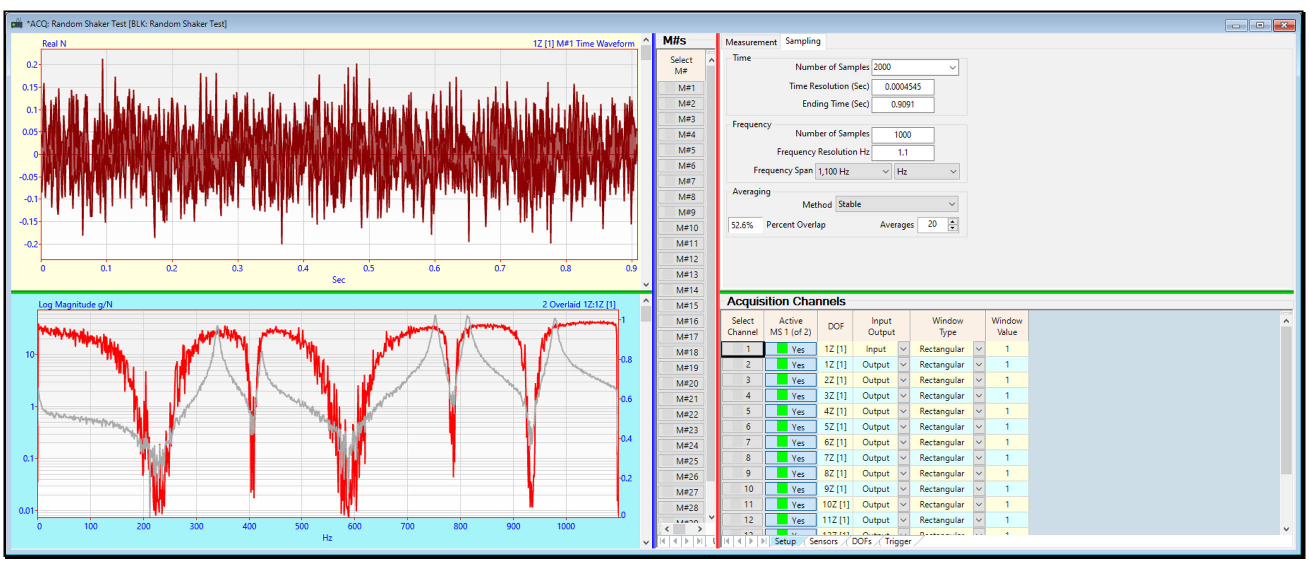
20 averages did raise the Coherence values at the poles & zeros slightly compared to 10 averages.

LEAKAGE WITHOUT A HANNING WINDOW

It is instructive to observe the **drastic effects of leakage** on post-processed random data if a **Hanning window is not applied** to the random time waveforms before the **FFT** is applied to them. To observe this, the **Hanning** window will be replaced with a **Rectangular** window.

- On the **Setup** tab in the **Channels** spreadsheet, ***double click*** on the **Window Type** column heading
- ***Choose*** **Rectangular** from the list in the dialog box that opens, and ***click*** on **OK**
- Execute **Acquire | Start**

The result is shown below. The drop in Coherence ***is dramatic***, and the **FRFs** are much noisier.

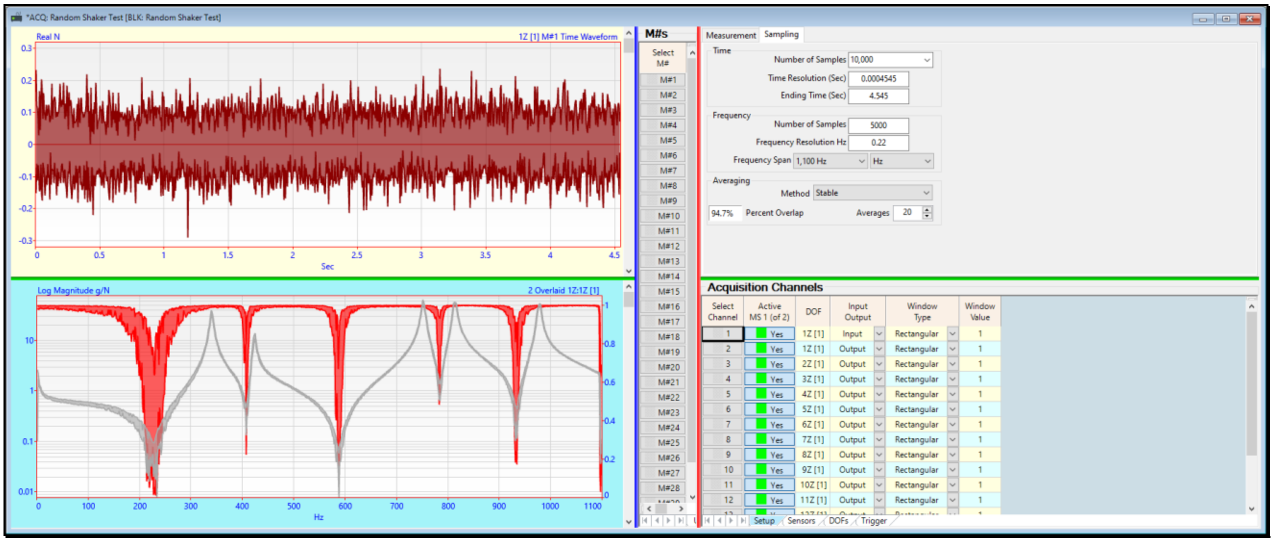


FRF & Coherence Overlaid (Rectangular Window & 20 Averages).

LARGER BLOCK SIZE REDUCES LEAKAGE

Acquiring random data **using a larger Block Size** will also reduce the effects of leakage, but not as effectively as applying a Hanning Window.

- On the **Sampling** tab in the **Time** section, enter **Number of Samples ➔ 10000**
- Execute **Acquire | Start**



***FRF** & Coherence Overlaid (Rectangular Window, Averages ➔ 20, Block Size ➔ 10000).*

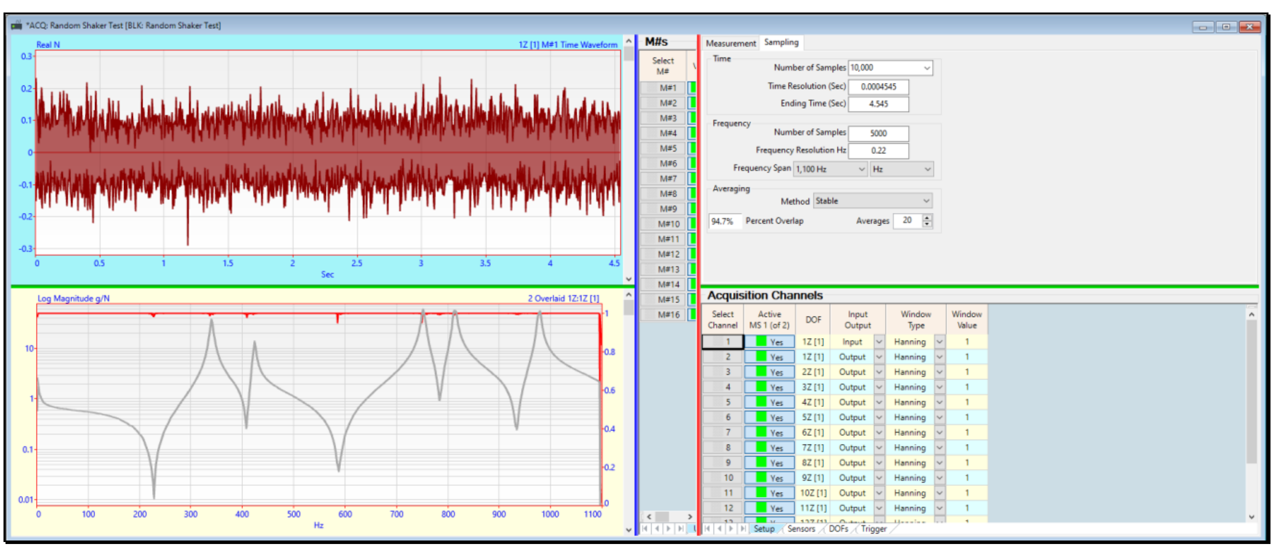
The Coherence **drops below "1"** only at the frequencies where the ***zeros (anti-resonances)*** occur in the **FRF** data. Near each resonance peak, the Coherence is **close to "1".**

- Data surrounding each resonance peak is used by **FRF-based curve fitting** to extract modal parameters

LARGER BLOCK SIZE & HANNING WINDOW

Using a Hanning window together with a larger Block Size will further reduce the effects of leakage.

- On the **Setup** tab in the **Channels** spreadsheet**,** ***double click*** on the **Window Type** column heading
- ***Choose*** **Hanning** from the list in the dialog box that opens, and ***click*** on **OK**
- Execute **Acquire | Start**



***FRF** & Coherence Overlaid (Hanning Window, Averages ➔ 20, Block Size ➔ 10000).*

Using a larger Block Size and a Hanning window, the **Coherence** values are **close to "1" over the entire frequency span**. These high coherence values indicate that the **FRFs** are **linear, noise-free** & **leakage-free**.

STEP 4 - POST-PROCESSING TWO MEASUREMENT SETS

- ***Press* Hotkey 4 Process Two Measurement Sets**

ACQUIRING MEASUREMENT SET [1]

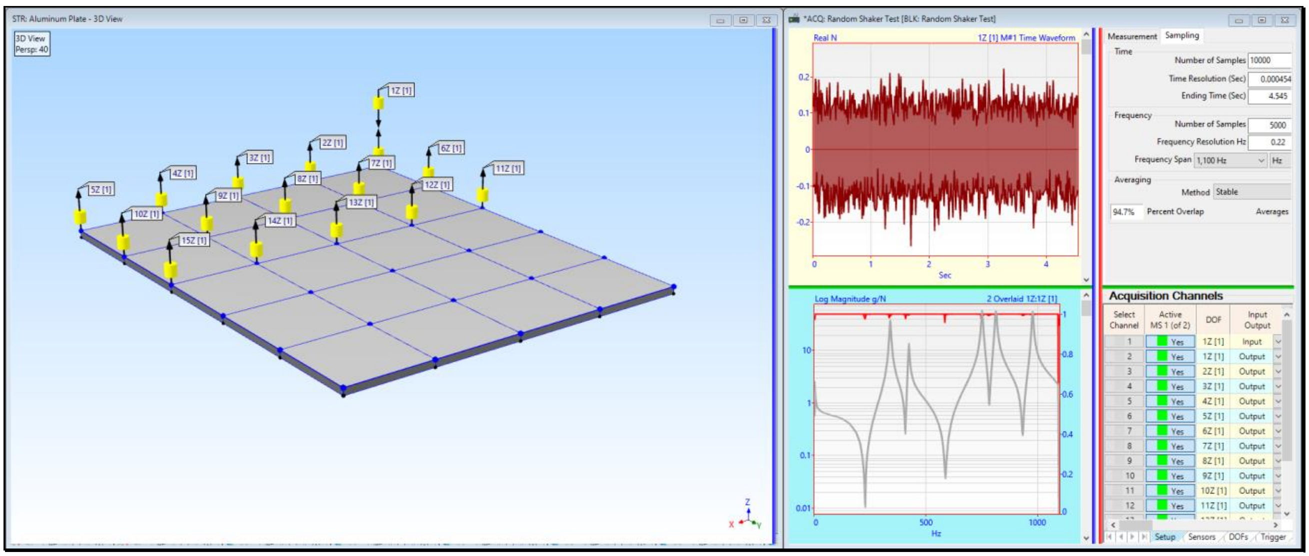
First, the **FRFs & Coherences** are calculated from the time waveforms in **Measurement Set [1]**. Then they are saved in an ***accumulator*** **Data Block BLK: FRFs & Coherence**.

The **force** (**Input**) and **accelerometer** (**Outputs**) for **Measurement Set [1]** are displayed on the Plate Model ***on the left***.

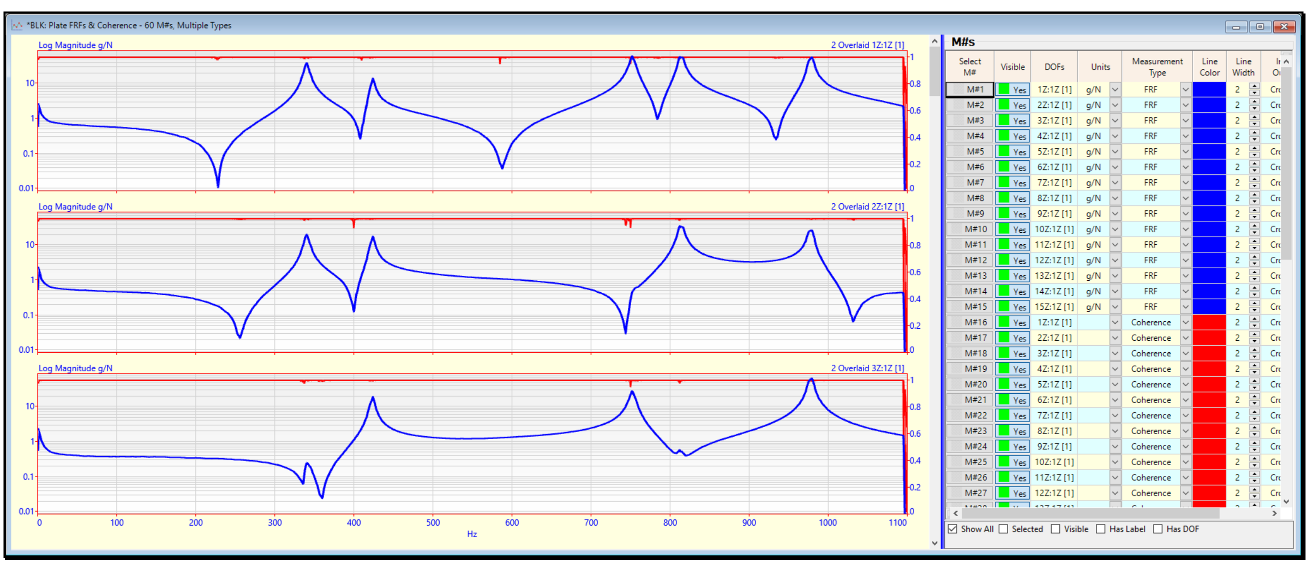
ACQUIRING MEASUREMENT SET [2]

Next, the **FRFs & Coherences** are calculated from the time waveforms in **Measurement Set [2]**. Then they are then added to the **M#s** in **Data Block BLK: FRFs & Coherence**.

The **force** (**Input**) and **accelerometer** (**Outputs**) for **Measurement Set [2]** are displayed on the Plate Model ***on the left***.



Acquisition of FRFs & Coherence from Measurement Set [1].



FRFs & Coherence Overlaid from Both Measurement Sets.

When both Measurement Sets of time waveform data have been post-processed, the accumulator Data Block **BLK: FRFs & Coherence** is displayed in the center of the screen and each **FRF** is overlaid with its **Coherence** function.

- Scroll through the 30 pairs of **FRFs & Coherence**

STEP 5 - DISPLAYING THE ODS's IN ANIMATION

- ***Press*** **Hotkey 5 ODS Display**

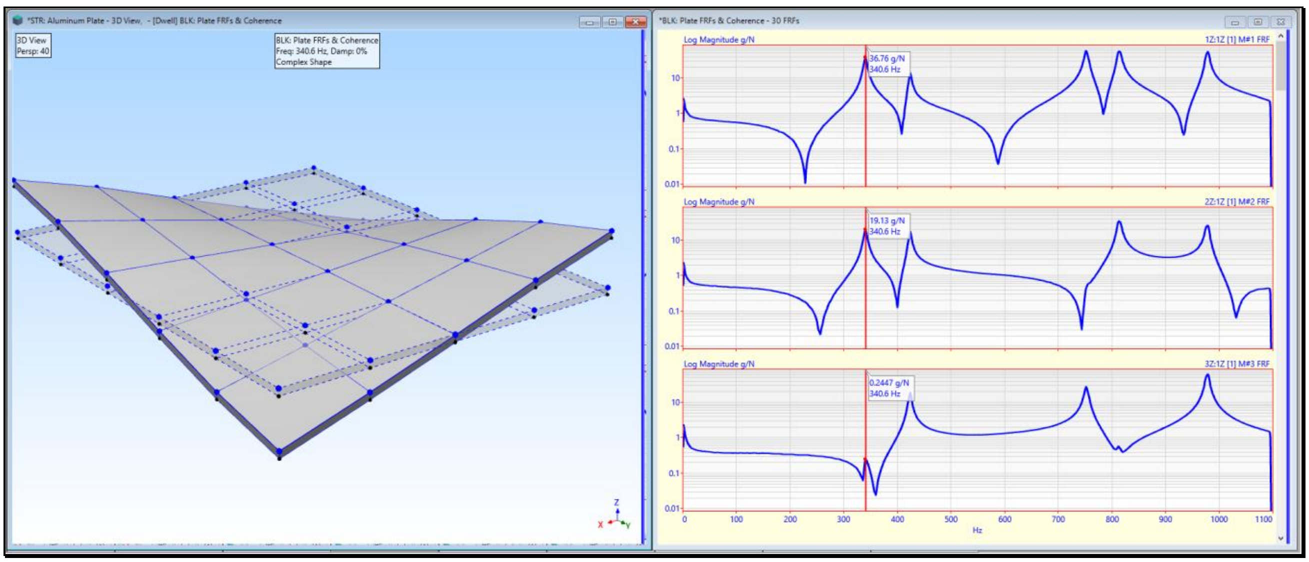
When **Hotkey 5** ***is pressed*** the following is done by its Script.

The Coherences are ***selected & deleted*** from the Data Block **BLK: FRFs & Coherence**

Measured Links are created linking **each FRF to the Point on the model** from which the acceleration data was acquired

Interpolated Links are created so that each bottom Point on the model is **deflected with the data from the Point above it**

Animation of the **frequency-based ODS at 340.5 Hz** is begun



ODS at a Resonance Peak Dominated by the Mode Shape of the Resonance.

The ODS at each resonance peak **is dominated by a resonance**. Hence the **ODS approximates the mode shape** for that resonance.

- ***Drag*** the **Line** cursor to another resonance peak to display its ODS

STEP 6 - REVIEW STEPS

To review the steps of this App Note,

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