VES-3600 Advanced Signal Processing

March 7, 2025

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Table of Contents

VES-3600 Advanced Signal Processing

NOTE: If the **VES-3600 Advanced Signal Processing** option is authorized by your MEscope license, the following commands are enabled in the Data Block (**BLK**) and Shape Table (**SHP**) windows. Execute **Help | License Manager** to verify the Options authorized by your MEscope license.

Additional Data Block (BLK) Commands

- Tools | Integrate
- Tools | Differentiate
- Tools | Remove DC
- Tools | Statistics
- Tools | Histogram
- Tools | Save Statistics
- Tools | Math menu
- Tools | **M#** Matrix menu
- Tools | Data Block Correlation
- Tools | **M#** Pairs Correlation
- Tools | Tachometer Peak Finder
- Tools | Log Decrement
- Tools | M# Envelope

- Transform | Block Size
- Transform | FFT
- Transform | Inverse FFT
- Transform | Window **M#s**
- Transform | Spectra
- Transform | Seed **TRN Chain**
- Transform | **ODS-FRFs**
- Transform | Scale **ODS-FRFs**
- Transform | H1 **FRFs**
- Transform | H2 **FRFs**
- Transform | Outputs
- Transform | Inputs
- Transform | Sinusoidal **ODS**

- Acoustics | A, B, C Weighting
- Acoustics | Narrow to Octave Band
- Acoustics | Calculate Menu
- Acoustics | Intensity to Power
- Acoustics | Acoustic Source Ranking Menu
- Acoustics | Tone Calibration Menu
- Acoustics | Save Ln

Additional Shape Table (SHP) Commands

- Display | Shapes | Acc, Vel, Disp
- Tools | Integrate
- Tools | Differentiate
- Tools | Shape Product
- Tools | Math menu

Additional Data Block (BLK) & Acquisition (ACQ) M#s spreadsheet Columns

- Linear Power
- Input Output
- Peak RMS Pk-Pk
- FFT
- Window, Window Value, Window Correction
- Z-Axis
- Acoustic Weight
- Acoustic Source

Additional Shape Table (SHP) M#s spreadsheet Columns

- Linear Power
- Input Output
- Peak RMS Pk-Pk
- Z-Axis
- Acoustic Weight
- Acoustic Source

Data Block (BLK) M#s Spreadsheet

Linear Power Column

Converts ***all*** (or ***selected***) **M#s** between **Linear** & **Power** engineering units (**EU** & **EU^2**).

- All **M#s** with **Linear** engineering units (**EU**) are converted to **Power** engineering units (**EU^2**), and the measurement values are re-scaled using the formula,

  $$\textbf{Power M\# = (Linear M\#)}^2$$

- All **M#s** with **Power** engineering units (**EU^2**) are converted to **Linear** engineering units (**EU**), and the measurement values are re-scaled using the formula,

  $$\textbf{Linear M\#} = \sqrt{\textbf{Power M\#}}$$

Input Output Column

Defines an **M#** as either an **Input, Output**, **Both** or **Cross**.

- A **Cross** channel measurement such as an **FRF** is calculated between two DOFs of a **STR**ucture and is designated as **Cross** in the **Input Output** column of the **M#s** spreadsheet

IMPORTANT: Input, Output, Cross, & Both designations are used by the **Transform** menu commands.

Peak RMS Pk-Pk Column

Scales ***all*** (or ***selected***) **M#s** using the following scale factors.

Amplitude Scaling Choice	M# Is Multiplied By
Peak	1.0
Pk-Pk	2.0
RMS	0.707

FFT Column

Defines the FFT (or DFT spectrum) of each **M#** as either One Sided or Two Sided.

- The FFT calculates a **Two-Sided** spectrum, where ***half*** of a signal is represented by the negative frequency half and ***half*** by the positive frequency half of the spectrum.
- The frequency spectrum of a ***real valued*** time signal is symmetric about zero frequency (DC), so only the ***positive frequency half*** of the spectrum is displayed.
- The ***amplitude*** & ***power*** values for a **One-Sided** FFT are the ***same*** values as its corresponding time domain signal.
- The ***amplitude*** & ***power*** values for a **Two-Sided** FFT are only ***half*** of the values of the original time domain signal.

Window Column

Describes the type of time domain window applied to ***all*** (or ***selected***) **M#s**.

- A Time domain window is applied by executing the **Transform | Window M#s** command.

Window Value Column

Contains the window value corresponding to the **Exponential** or **Force** window listed in the **Window** column.

- The **Exponential** window value is the amount of damping added by the window (in Hz).
- The **Force** window value is the **number of samples** following the beginning of signal where the Force window transitions to zero.

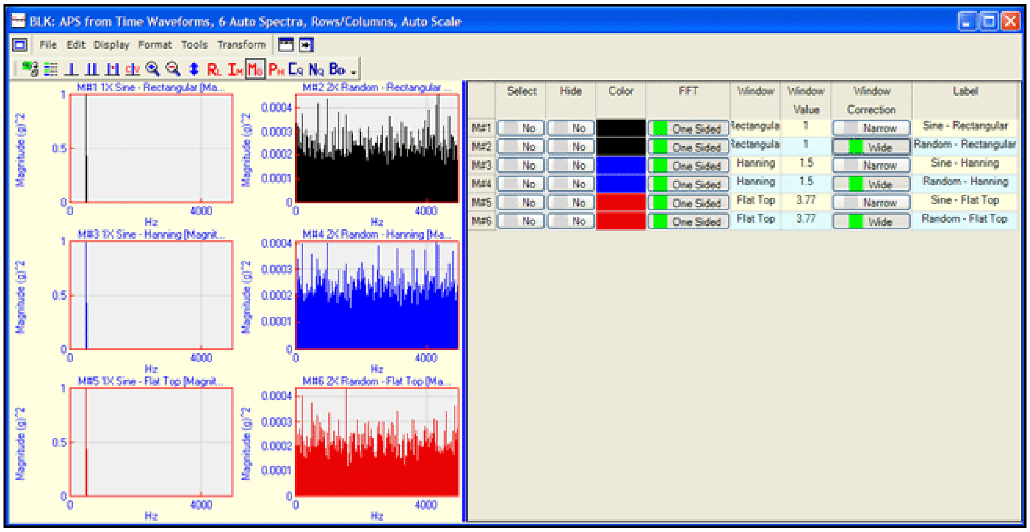
Window Correction Column

Used together with the **Window** & **Window Value columns** to correct the effects of time domain windowed from calculated spectra.

- For each **M#** containing a ***narrow band signal***, choose **Narrow Band** in the **Window Correction** column before applying a time domain window and calculating its spectrum.
- For each **M#** containing a ***wide band signal***, choose **Wide Band** in the **Window Correction** column before applying a time domain window and calculating its spectrum.

Windowing Examples

The figure below contains the spectra of 3 sine wave ***(narrow band)*** signals, and three random ***(wide band)*** signals.


BLK: APS from Time Waveforms, 6 Auto Spectra, Rows/Columns, Auto Scale
File Edit Display Format Tools Transform
M#1 1X Sine - Rectangular [Ma...
M#2 2X Random - Rectangular ...
M#3 1X Sine - Hanning [Magnit...
M#4 2X Random - Hanning [Ma...
M#5 1X Sine - Flat Top [Magnit...
M#6 2X Random - Flat Top [Ma...
Magnitude (g)^2
Hz
0
0.5
1
0.0001
0.0002
0.0003
0.0004
4000

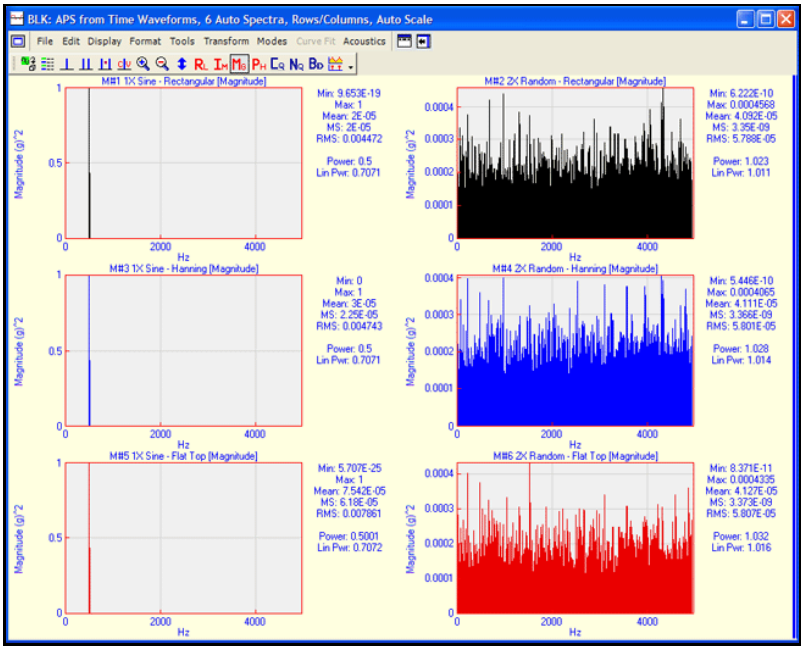
	Select	Hide	Color	FFT	Window	Window Value	Window Correction	Label
M#1	No	No	■	One Sided	Rectangula	1	Narrow	Sine - Rectangular
M#2	No	No	■	One Sided	Rectangula	1	Wide	Random - Rectangular
M#3	No	No	🟦	One Sided	Hanning	1.5	Narrow	Sine - Hanning
M#4	No	No	🟦	One Sided	Hanning	1.5	Wide	Random - Hanning
M#5	No	No	🟥	One Sided	Flat Top	3.77	Narrow	Sine - Flat Top
M#6	No	No	🟥	One Sided	Flat Top	3.77	Wide	Random - Flat Top

Narrow Band and Wide Band Spectra Amplitude Corrected for Windowing.

- Each **M#** was windowed using **Rectangular**, **Hanning**, and **Flat Top** windows before its Auto spectrum was calculated.
- All the ***magnitudes*** of the **Sine Wave** spectra (on the ***left***) are the same, even though each has been windowed with a different time domain window
- All the ***magnitudes*** of the **Random** spectra (on the ***right***) are ***approximately*** the same, even though each has been windowed with a different time domain window

The figure below shows the Power of 3 sine wave ***(narrow band)*** signals, and three random ***(wide band)*** signals.

- The **Power** in all the **Sine Wave** spectra is the same, since they have been **Narrow Band** corrected
- The **Power** in all the **Random** spectra is the same, since they have been **Wide Band** corrected


BLK: APS from Time Waveforms, 6 Auto Spectra, Rows/Columns, Auto Scale
File Edit Display Format Tools Transform Modes Curve Fit Acoustics
M#1 1X Sine - Rectangular [Magnitude]
M#2 2X Random - Rectangular [Magnitude]
M#3 1X Sine - Hanning [Magnitude]
M#4 2X Random - Hanning [Magnitude]
M#5 1X Sine - Flat Top [Magnitude]
M#6 2X Random - Flat Top [Magnitude]
Magnitude (g)^2
Hz
0
0.5
1
0.0001
0.0002
0.0003
0.0004
2000
4000

```
Min: 9.653E-19
Max: 1
Mean: 2E-05
MS: 2E-05
RMS: 0.004472

Power: 0.5
Lin Pwr: 0.7071
```

```
Min: 6.222E-10
Max: 0.0004568
Mean: 4.092E-05
MS: 3.35E-09
RMS: 5.788E-05

Power: 1.023
Lin Pwr: 1.011
```

```
Min: 0
Max: 1
Mean: 3E-05
MS: 2.25E-05
RMS: 0.004743

Power: 0.5
Lin Pwr: 0.7071
```

```
Min: 5.446E-10
Max: 0.0004065
Mean: 4.111E-05
MS: 3.366E-09
RMS: 5.801E-05

Power: 1.028
Lin Pwr: 1.014
```

```
Min: 5.707E-25
Max: 1
Mean: 7.542E-05
MS: 6.18E-05
RMS: 0.007861

Power: 0.5001
Lin Pwr: 0.7072
```

```
Min: 8.371E-11
Max: 0.0004335
Mean: 4.127E-05
MS: 3.373E-09
RMS: 5.807E-05

Power: 1.032
Lin Pwr: 1.016
```

Narrow Band and Wide Band Spectra Power Corrected for Windowing.

Z-Axis Column

This column is used to enter a Z-Axis text label for ***all*** (or ***selected***) **M#s.**

- **M#s** can be ***selected*** by their **Z-Axis label** using **M#s | Select | Select By** so that only the shape data from **M#s** with the same **Z-Axis label** is displayed together in animation.

dB Reference Column

Allows you to enter **dB reference values** that are used when **dB** is chosen for the **Y-Axis Scaling** box.

- For **Linear** quantities (such as SPL), dB units are defined as

Linear dB Units ➔ 20 log$_{10}$ (magnitude / dB Reference value)

- For **Power** quantities (such as Sound Power & Intensity), dB units are defined as

Power dB Units ➔ 10 log$_{10}$ (magnitude / dB Reference Value)

Acoustic Weight Column

Indicates the type of acoustic weighting (A, B, C) applied to each **M#**.

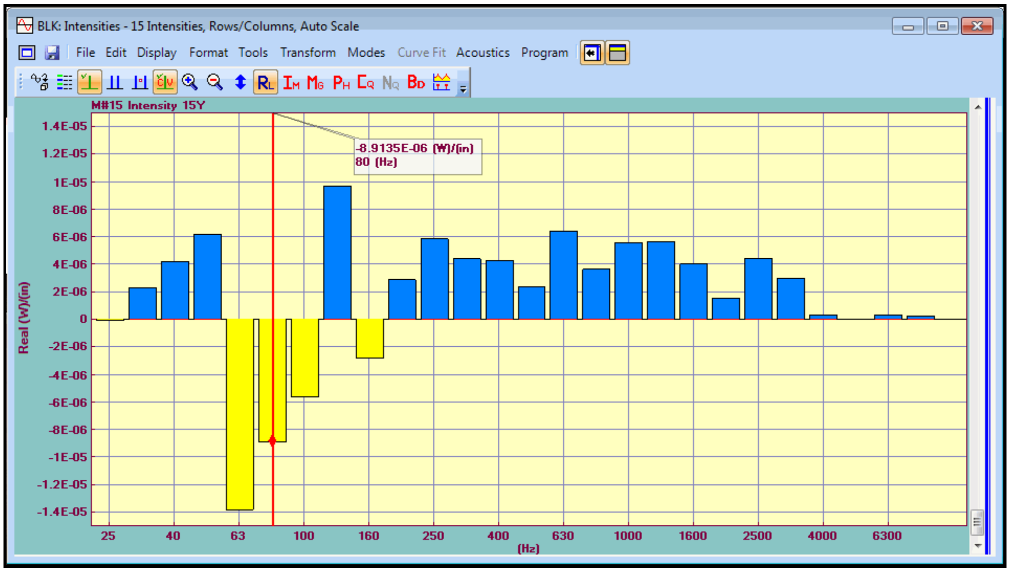
Acoustic Source Column

Used to enter a **text name** for each **M#** belonging to an acoustic source.

Data Block (BLK) Display Menu

M#s | Display | Real

Displays either **real M#** data, or the **real part of complex M# data** in **Octave** band and/or **dB** units.



*Data Block (**BLK**) Window Showing Real Part of Octave Data.*

Octave Band Data

- **Log** or **dB** formats can be chosen for displaying the Real part of Octave band data
- **Linear, Log, dB** & **decades** choices are made in the **Format | Y-Axis** dialog box
- ***Right click*** in the **M#** graphics area and execute **Format | Y-Axis** from the menu to open the Y-Axis dialog box

Real Part in dB Reference Units

- The Real part is displayed in dB units relative to a reference level if a reference level is entered in the **dB Reference column** in the **M#s** spreadsheet

- For **Linear (RMS)** data, the Real part is displayed as

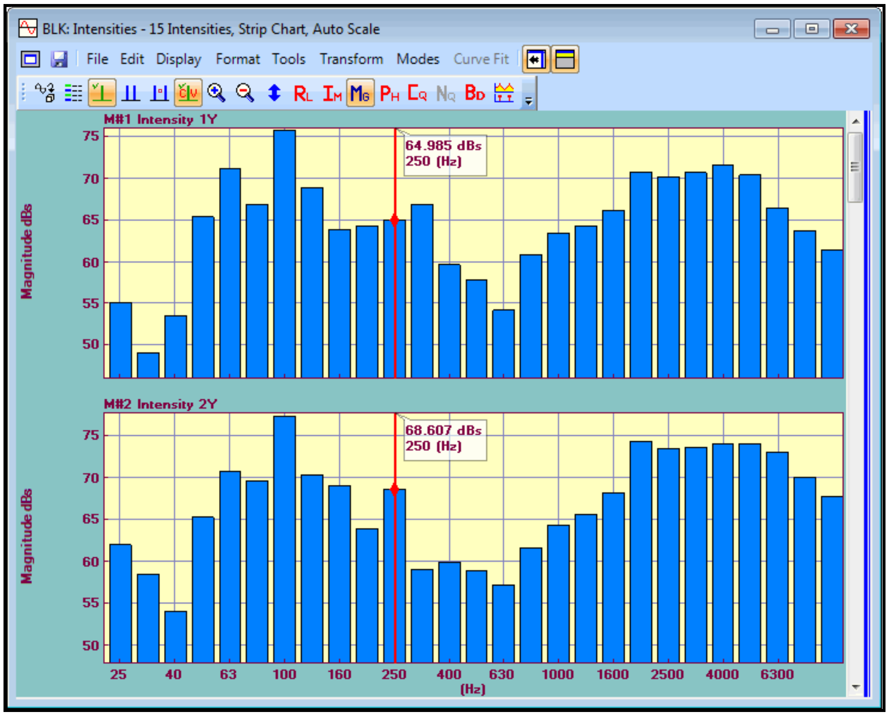
  Real part (dB Reference) = Sign (Real part) [20 Log $_{10}$ (Abs (Real part) / Linear Reference)]

- For **Power (MS)** data, the Real part is displayed as

  Real part (dB Reference) = Sign (Real part) [10 Log $_{10}$ (Abs (Real part) / Power Reference)]

M#s | Display | Magnitude

Displays the magnitude of the measurement data in **Octave** band and/or **dB** units.



*Data Block (**BLK**) Window Showing Log Magnitude of Octave Data.*

Linear, Log or dB

Magnitudes can be displayed in **Linear, Log** or **dB** format.

- When **Log** or **dB** is chosen, you can also choose **1** to **14** decades (powers of 10) to display
- **Linear, Log, dB** & **decades** choices are made in the **Format | Y-Axis** dialog box
- ***Right click*** in the **M#** graphics area and execute **Format | Y-Axis** from the menu to open the **Y-Axis** dialog box

dB Units for Linear Versus Power Quantities

Magnitudes can be displayed in dB (decibel) units.

- For **Linear** (RMS) quantities, (such as **FRFs**, Linear Spectra, etc.) the Magnitude is displayed as,

  Magnitude (dB) = 20 Log $_{10}$ (Magnitude)

- For **Power** (MS) quantities, (such as Auto Power Spectra, PSDs, etc.), the Magnitude is displayed as,

  Magnitude (dB) = 10 Log $_{10}$ (Magnitude)

Magnitude in dB Reference Units

Magnitudes can also be displayed in dB (decibel) units relative to a reference level.

- For **Linear (RMS)** quantities, (such as SPL) the Magnitude is displayed as,

  Magnitude (dB Reference) = 20 Log $_{10}$ (Magnitude / Linear Reference)

- For **Power (MS)** quantities, (such as Sound Power & Intensity), the Magnitude is displayed as,

  Magnitude (dB Reference) = 10 Log $_{10}$ (Magnitude / Power Reference)

- To display magnitudes in **dB Reference** units, the **Linear (RMS) Reference** or **Power (MS) Reference** values must be entered in the **dB Reference** column in the **M#s** spreadsheet
  - A Linear (RMS) Reference value is required for Linear (RMS) M# data
  - A Power (MS) Reference value is required for Power (MS) M# data

Data Block (BLK) Tools Menu

Tools | Integrate

Performs Integration on ***all*** (or ***selected***) **M#s** in a Data Block (**BLK**).

- All integration is done in the frequency domain
- Time domain waveforms are transformed to the frequency domain, integrated, and transformed back to the time domain.
- Frequency domain **M#s** are integrated by ***dividing the spectrum by frequency***,

$$\int x(t)dt \Leftrightarrow \frac{X_i(2\pi f_i)}{j2\pi f_i}$$

x(t) = continuous **TWF**

$X_i(2\pi f_i)$ = linear spectrum (**DFT**) of the signal for the **i**$^{\text{th}}$ sample

$2\pi f_i$ = frequency of the **i**$^{\text{th}}$ sample (**radians/second**)

f_i = frequency of the **i**$^{\text{th}}$ sample (**Hz**)

j = the imaginary operator

Integration Errors Due to DC Offset

If a time domain waveform has any **DC Offset (or bias)** in it, integration of the DC Offset will result in a ***ramp function***.

- To ***minimize errors*** due to any DC Offset, **Tools | Remove DC** is ***automatically executed*** before integration is performed

Integration Errors Due to Leakage

The FFT assumes that the signals to be transforming are ***periodic,*** or ***completely contained*** within their ***sampling window***. The ***sampling window*** is the range of samples in each **M#**.

- If a time domain waveform is ***non-periodic,*** or ***not completely contained*** within its ***sampling window***, ***smearing*** (called ***leakage***) of its spectrum will occur when it is transformed to the frequency domain
- If a frequency spectrum is ***non-periodic,*** or ***not completely contained*** within its ***sampling window***, leakage (called ***wrap around error***) of its **TWF** will occur when it is transformed to the time domain

Removing Lower Frequencies Before Integration

Integration ***amplifies*** the ***lower frequencies*** in a signal

- To reduce the harmful effects of all ***non-essential*** lower frequencies in a signal, they should be removed from its spectrum ***before integrating it***.
  - Execute **Transform | FFT** to transform time domain waveforms to the frequency domain
  - Set up the **Band cursor** to include all non-essential low frequencies
  - Execute **Transform | Window M#s** and apply the **Notch** window to remove the low frequencies (***zero*** the **M#** values)
  - Execute **Tools| Integrate** to integrate the **M#s**
  - Execute **Transform | Inverse FFT** to transform the integrated signals back to the time domain

Tools | Differentiate

Performs differentiation on ***all*** (or ***selected***) **M#s** in a Data Block (**BLK**).

- All differentiation is done in the frequency domain
- Time domain waveforms are transformed to the frequency domain, differentiated, and transformed back to the time domain
- Frequency domain **M#s** are differentiated by ***multiplying the spectrum by frequency***,

$$\frac{d\big(x(t)\big)}{dt} \Leftrightarrow j2\pi f_i\big(X_i(2\pi f_i)\big)$$

x(t) = continuous **TWF**

$X_i(2\pi f_i)$ = linear spectrum (**DFT**) of the signal for the **i**$^{\text{th}}$ sample

$2\pi f_i$ = frequency of the **i**$^{\text{th}}$ sample (**radians/second**)

f_i = frequency of the **i**$^{\text{th}}$ sample (**Hz**)

j = the imaginary operator

Tools | Remove DC

Removes the DC offset (or bias) from ***all*** (or ***selected***) **M#s** in a Data Block (**BLK**).

- The following steps are carried out on time domain waveforms,
  - Execute **Transform | FFT** to transform all **M#s** to the frequency domain
  - Zero the DC component (at frequency = 0) of the spectrum
  - Execute **Transform | Inverse FFT** to transform all **M#s** back to the time domain

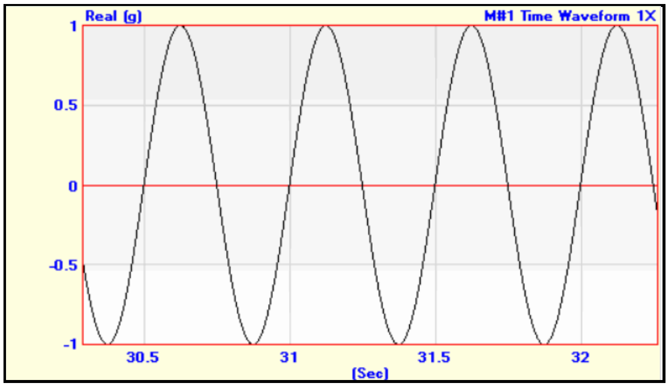
Tools | Histogram

Calculates a Histogram (or **Normal Distribution**), and its **Cumulative Distribution** of the Y-Axis values in a Data Block (**BLK**).

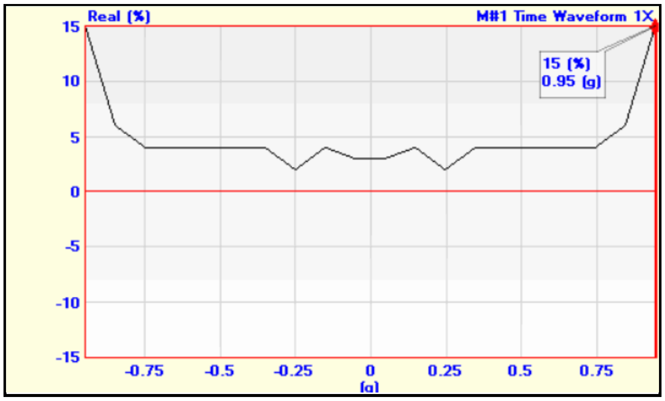
- A Histogram is a **count** of the number of Y-axis values that lie between two values, referred to as a "**bin**"
- The Y-Axis of the Histogram is displayed as a **percentage** of the total number of values in all bins
- The X-Axis of the Histogram is the limits of the Y-Axis values in the Data Block (**BLK**) divided by the number of bins
  - If the **Band** cursor is displayed, the Histogram of the data in the band is calculated
  - If the data display is **Zoomed**, the Histogram of the Zoomed data is calculated

- If the **Real** part, **Imaginary** part, or **Phase** of complex data is displayed, the Histogram of that data is calculated.
- Otherwise, the Histogram of the **Magnitude** is calculated

The figure below shows a **sine wave M# with 10000 samples** followed by its Histogram using 20 bins.

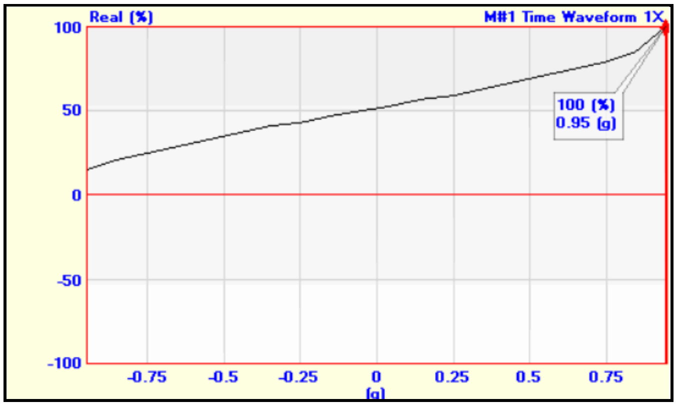


10000 Samples of a Sine Wave.



Histogram of the Sine Wave using 20 Bins.

The figure below shows the **Cumulative Distribution** of the **sine wave M# with 10000 samples** using a Histogram with 20 bins.

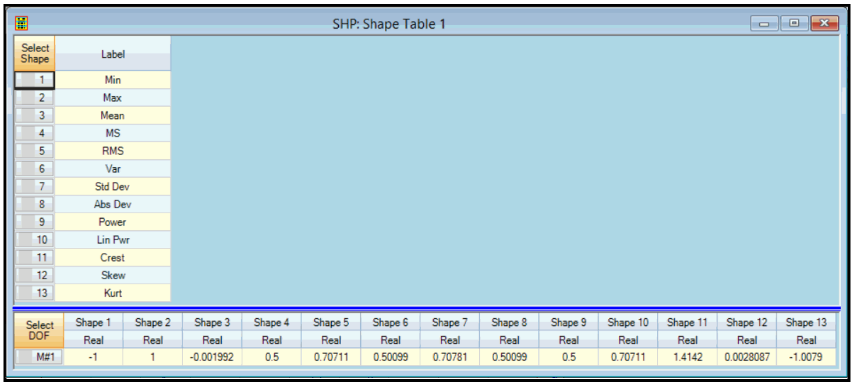


Cumulative Distribution of the Sine Wave using 20 Bins.

Tools | Save Statistics

Saves the statistics of each measurement (**M#**) in a Data Block (**BLK**) into a Shape Table (**SHP**).

- Each statistic is saved as a different shape
- Each shape **M#** is the statistics value for the ***corresponding M#*** in the Data Block (**BLK**)
- If the **Band** cursor is displayed, the statistics only for data in the band are saved
- If the data display is **Zoomed**, the statistics only for the displayed data are saved
- If the **Real** part, **Imaginary** part, or **Phase** of complex data is displayed, the statistics for that data are saved
  - Otherwise, the statistics of the Magnitude are saved



Select Shape	Label
1	Min
2	Max
3	Mean
4	MS
5	RMS
6	Var
7	Std Dev
8	Abs Dev
9	Power
10	Lin Pwr
11	Crest
12	Skew
13	Kurt

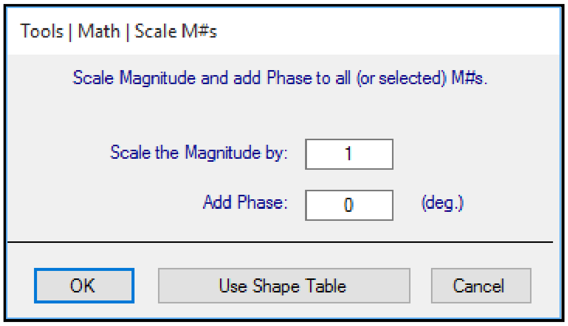
Select DOF	Shape 1	Shape 2	Shape 3	Shape 4	Shape 5	Shape 6	Shape 7	Shape 8	Shape 9	Shape 10	Shape 11	Shape 12	Shape 13
	Real	Real	Real	Real	Real	Real	Real	Real	Real	Real	Real	Real	Real
M#1	-1	1	-0.001992	0.5	0.70711	0.50099	0.70781	0.50099	0.5	0.70711	1.4142	0.0028087	-1.0079

*Data Block (**BLK**) Statistics Saved in a Shape Table (**SHP**).*

Tools | Math | Scale M#s

Multiplies ***all*** (or ***selected***) **M#s** by a ***magnitude*** and ***adds phase*** to them.

- When executed, the following dialog box opens


Tools | Math | Scale M#s

Scale Magnitude and add Phase to all (or selected) M#s.

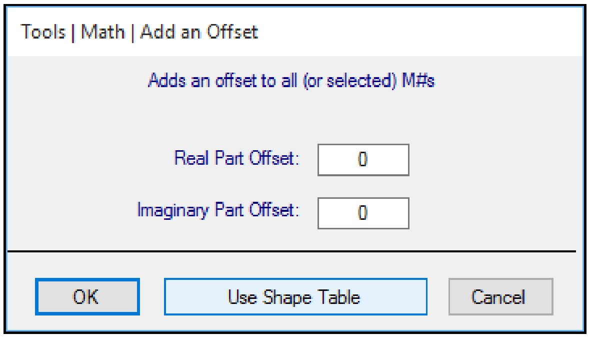
Scale the Magnitude by: 1

Add Phase: 0 (deg.)

- The **Use Shape Table** button scales each **M#** with a ***different scale factor*** from a Shape Table (**SHP**).
- The ***magnitude & phase*** of each **M#** of the ***first shape*** in the Shape Table (**SHP**) is used to scale each ***matching*** **M#** in the Data Block (**BLK**)

Tools | Math | Add an Offset

Adds a complex (real & imaginary) offset to ***all*** (or ***selected***) **M#s**.



Tools | Math | Add an Offset

Adds an offset to all (or selected) M#s

Real Part Offset: 0

Imaginary Part Offset: 0

- The **Use Shape Table** button adds a ***different offset*** from a Shape Table (**SHP**) to ***each*** **M#**.
- The ***complex*** value for each **M#** of the ***first shape*** in the Shape Table (**SHP**) is used to offset each ***matching*** **M#** in the Data Block (**BLK**).

Tools | Math | Add Random Noise

Adds random noise to each **M#**.

- The amount of random noise is a percentage of the ***maximum magnitude*** of each **M#**.

Tools | Math | Conjugate M#s

Replaces each ***complex*** measurement value with its ***complex conjugate***

- The **Real** part remains the same and the **Imaginary** part is ***multiplied*** by **"-1"**.

Tools | Math | Invert M#s

Replaces each **M#** with its ***inverse***.

Tools | Math | Square M#s

Replaces each **M#** with its ***value squared***.

Tools | Math | Square Root of M#s

Replaces each M# with the ***square root of its value***.

Tools | Math | Smooth M#s

Performs multi-point smoothing of each measurement in a Data Block (**BLK**).

- Replaces each measurement sample with the ***average value*** of **N** samples of data surrounding that sample
  - For example, for **N = 3,**

  M# (sample) = {M# (sample) + M# (sample-1) + M# (sample +1) } / 3

Tools | Math | Re-Sample M#s

Changes the number of samples in a Data Block (**BLK**) without changing the X-Axis span by ***re-sampling the*** **M#s**.

Tools | Math | Sum M#s

Sums ***all*** (or ***selected***) **M#** values at each sample and stores the result into a single **M#**.

Tools | Math | Average M#s

Divides the ***sum*** of ***all*** (or ***selected***) **M#** values at each sample by the number of **M#s** and stores the result into a single **M#**.

Tools | Math | Add (Subtract, Multiply, Divide) a selected M#

Performs the indicated operation between the **M#s** in a Data Block (**BLK**) and a ***selected*** **M#** in the same or a different Data Block (**BLK**).

- If two Data Block (**BLK**)s have the ***same number*** of **M#s**, you can choose to perform the operation ***between*** **M# pairs** in the two Data Block (**BLK**)s

Tools | M# Matrix | Add (or Subtract) M# Matrix Data Blocks

Adds a **M# Matrix** Data Block (**BLK**) to the ***host*** **M# Matrix** Data Block (**BLK**) or **subtracts** a **M# Matrix** Data Block (**BLK**) from the ***host M#*** **Matrix** Data Block (**BLK**). The ***host*** Data Block (**BLK**) is the one from which this command is executed

- A **M# Matrix** Data Block (**BLK**) is defined by the **Roving & Reference DOFs** of its **M#s**
  - The **Roving DOF** designates the ***row position*** of the **M#** in the **M#** Matrix. The **Reference DOF** designates the ***column position*** of the **M#** in the **M#** Matrix

Tools | M# Matrix | Multiply M# Matrix Data Blocks

Multiplies the ***host*** **M# Matrix** Data Block (**BLK**) by another **M# Matrix** Data Block (**BLK**). The ***host*** Data Block (**BLK**) is the one from which this command is executed.

  - A **M# Matrix** Data Block (**BLK**) is defined by the **Roving & Reference DOFs** of its **M#s**.
  - The **Roving DOF** designates the ***row*** position of the **M#** in the **M# Matrix**, The **Reference DOF** designates the ***column*** position of the **M#** in the **M# Matrix**

Tools | M# Matrix | M# Matrix Inverse

Calculates the inverse of the ***host*** **M# Matrix** Data Block (**BLK**). The ***host*** Data Block (**BLK**) is the one from which this command is executed

- A **M# Matrix** Data Block (**BLK**) is defined by the **Roving & Reference DOFs** of its **M#s**
  - The **Roving DOF** designates the ***row*** position of the **M#** in the **M# Matrix**. The **Reference DOF** designates the ***column*** position of the **M#** in the **M# Matrix**

Tools | Data Block Correlation

Calculates two measures (**MAC** & **SDI**) for comparing **M#s** in two different Data Blocks. **MAC** & **SDI** are calculated between the **M#** values at each sample in one Data Block (**BLK**) with the **M#** values at the same sample in a second Data Block (**BLK**). The results are saved as ***two*** **M#s** in a new Data Block (**BLK**).

MAC is a measure of the ***co-linearity*** of two shapes. Two shapes are co-linear if they ***"lie on the same Straight line"***.

- **MAC** has values ***between*** **0 & 1**
- **MAC = 1** ➔ the M#s in one Data Block (**BLK**) are co-linear with the M#s at the same sample in the other Data Block (**BLK**)
- **MAC *less than* 1** ➔ the M#s in one Data Block (**BLK**) are different from the M#s at the same sample in the other Data Block (**BLK**)

SDI is a measure of the ***difference*** between two shapes.

- **SDI** has values ***between*** **0 & 1**
- **SDI = 1** ➔ the **M#s** in one Data Block (**BLK**) are ***the same as*** the **M#s** at the ***same sample*** in the other Data Block (**BLK**)
- **SDI *less than* 1** ➔ the **M#s** in one Data Block (**BLK**) are ***different from*** the **M#s** at the ***same sample*** in the other Data Block (**BLK**)

Tools | M# Pairs Correlation

Calculates two measures (**MAC** & **SDI**) between **M#s** ***with matching DOFs*** in two Data Blocks. The results are saved as ***two shapes*** in a Shape Table (**SHP**). **MAC** is a measure of the ***co-linearity*** of two **M#s.** Two M#s are co-linear if their values ***"lie on the same Straight line"***

- **MAC** has values ***between* 0 & 1**
- **MAC = 1 ➔** the values of an **M#** in one Data Block (**BLK**) are ***co-linear*** with the values of the **M# *with matching DOF*** in another Data Block (**BLK**)
- **MAC *less than* 1 ➔** the values of an **M#** in one Data Block (**BLK**) are ***different from*** the values of the **M# *with matching DOF*** in another Data Block (**BLK**)

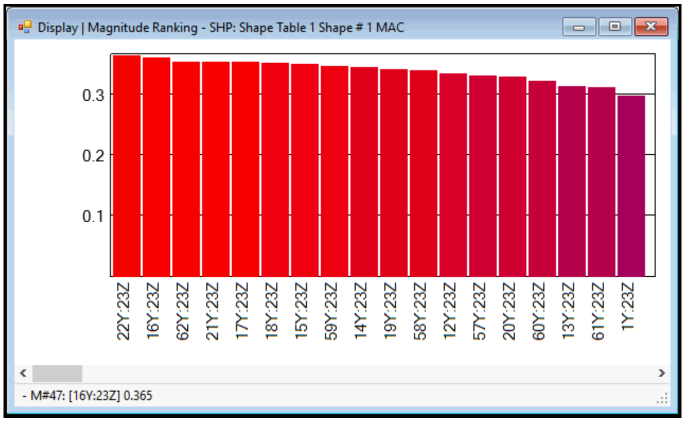
SDI is a measure of the ***difference*** between two **M#s**.

- **SDI** has values between **0 & 1**
- **SDI = 1 ➔** values of an **M#** in one Data Block (**BLK**) are ***the same as*** the values of the **M# *with matching DOF*** in another Data Block (**BLK**)
- **SDI *less than* 1 ➔** values of an **M#** in one Data Block (**BLK**) are ***different from*** the values of the **M# *with matching DOF*** in another Data Block (**BLK**)

Displaying MAC & SDI Magnitude Ranking Bars

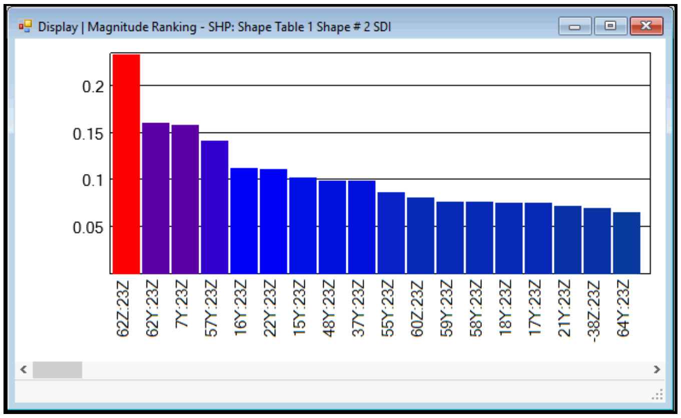
A good way to examine the MAC & SDI values that were saved in a Shape Table (**SHP**) is to use the **Display | Magnitude Ranking** command in the Shape Table (**SHP**).

- Execute **Display | Magnitude Ranking**
  - ***Select* Shape #1** to display **MAC magnitudes** as shown below
  - ***Select* Shape #2** to display **SDI magnitudes** as shown below



- M#47: [16Y:23Z] 0.365

MAC Magnitude Ranking.



SDI Magnitude Ranking.

Tools | Tachometer Peak Finder

Returns the X-Axis value of a peak when the Y-Axis value exceeds a threshold level in the ***first (or selected)*** **M#**.

Parameters

- X-Axis
  - Percentage (1 to 100 of the **Block Size)**
  - Sample (1 to the **Block Size**)
  - X-Axis Units (Hz, RPM, CPM, Sec, milli-sec, micro-sec)
- Start of X-axis search range
- End of X-axis search range
- Minimum peak value (in Y-axis units)
- Threshold (percentage of peak value in the search range)
- Script variable name

Tools | Log Decrement

Calculates the ***damping decay constant*** for each **TWF** using the **Logarithmic Decrement** method.

- The **Logarithmic Decrement** method is used to calculate the ***damping decay constant***
- A ***straight line*** is curve fit to the Log Magnitude of each **TWF**, and its slope is ***damping decay constant***
  - The ***damping decay constant*** is the coefficient of the exponential decay envelope on a ***decaying sinusoidal response***
  - For a single resonance, the ***damping decay constant*** is the same as the ***modal damping in Hz*** obtained from curve fitting the **TWF**

Tools | Save Cursor at Samples

Saves the cursor values (Line, Peak, or Band cursor) for ***all*** (or ***selected***) **M#s** of a **frequency domain Data Block** into a new Data Block and applies the **Inverse FFT** to the data.

- This command provides ***band-limited TWFs*** in the new Data Block

Tools | M# Envelope

Peak-hold averages all (or selected) M#s in a Data Block (**BLK**), displays the Envelope and adds it to the end of the M#s spreadsheet.

- **Peal-hold averaging** saves the **peak magnitude** value at each sample of all (or selected) **M#**s

Data Block (BLK) Transform Menu

Transform | Block Size

Changes the Block Size of a Data Block (**BLK**) file. When executed, the **File | Data Block** (**BLK**) **Properties** dialog box is opened, where the Block Size can be edited.

- **Block Size** is the ***number of samples*** (time or frequency) in all the **M#s** of a Data Block (**BLK**)
- ***All* M#s** in a Data Block (**BLK**) must have the ***same* Block Size** in order to support **ODS** display and animation from a Data Block (**BLK**)

Increasing the Block Size

When the Block Size is ***increased***, more samples (with ***zero Y-axis*** values) are added to the end (**right side**) of each **M#.**

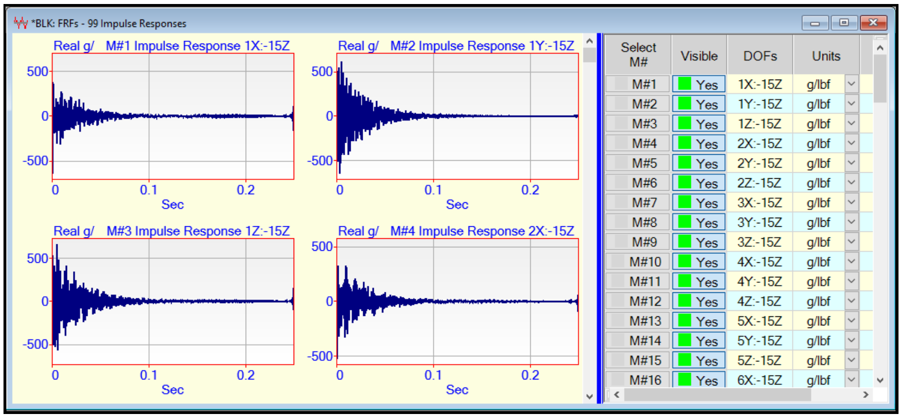
Decreasing the Block Size

When the Block Size is ***decreased***, samples are deleted from the end (**right side**) of each **M#.**

Transform | FFT

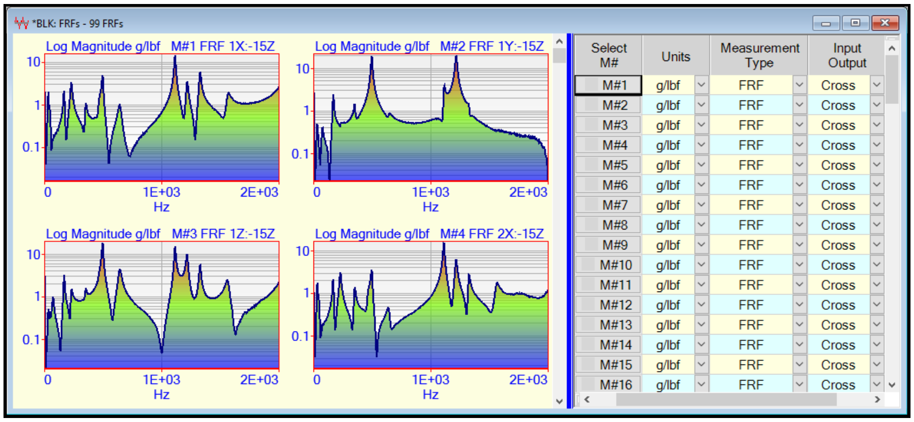
Applies the Fast Fourier Transform **(FFT)** algorithm to transform ***each* time domain M#** in a Data Block (**BLK**) into its **frequency spectrum (DFT)**.

- The FFT is a ***loss-less*** (also called ***one-to-one & onto***) transformation from one domain (time or frequency) to the other
- An original **TWF** can ***always be recovered*** by applying the ***Inverse FFT*** to its DFT


*BLK: FRFs - 99 Impulse Responses
Real g/ M#1 Impulse Response 1X:-15Z
Real g/ M#2 Impulse Response 1Y:-15Z
Real g/ M#3 Impulse Response 1Z:-15Z
Real g/ M#4 Impulse Response 2X:-15Z
500
0
-500
0
0.1
0.2
Sec

Select M#	Visible	DOFs	Units
M#1	🟩 Yes	1X:-15Z	g/lbf
M#2	🟩 Yes	1Y:-15Z	g/lbf
M#3	🟩 Yes	1Z:-15Z	g/lbf
M#4	🟩 Yes	2X:-15Z	g/lbf
M#5	🟩 Yes	2Y:-15Z	g/lbf
M#6	🟩 Yes	2Z:-15Z	g/lbf
M#7	🟩 Yes	3X:-15Z	g/lbf
M#8	🟩 Yes	3Y:-15Z	g/lbf
M#9	🟩 Yes	3Z:-15Z	g/lbf
M#10	🟩 Yes	4X:-15Z	g/lbf
M#11	🟩 Yes	4Y:-15Z	g/lbf
M#12	🟩 Yes	4Z:-15Z	g/lbf
M#13	🟩 Yes	5X:-15Z	g/lbf
M#14	🟩 Yes	5Y:-15Z	g/lbf
M#15	🟩 Yes	5Z:-15Z	g/lbf
M#16	🟩 Yes	6X:-15Z	g/lbf

*Data Block (**BLK**) Before FFT.*


*BLK: FRFs - 99 FRFs
Log Magnitude g/lbf M#1 FRF 1X:-15Z
Log Magnitude g/lbf M#2 FRF 1Y:-15Z
Log Magnitude g/lbf M#3 FRF 1Z:-15Z
Log Magnitude g/lbf M#4 FRF 2X:-15Z
10
1
0.1
0
1E+03
2E+03
Hz

Select M#	Units	Measurement Type	Input Output
M#1	g/lbf	FRF	Cross
M#2	g/lbf	FRF	Cross
M#3	g/lbf	FRF	Cross
M#4	g/lbf	FRF	Cross
M#5	g/lbf	FRF	Cross
M#6	g/lbf	FRF	Cross
M#7	g/lbf	FRF	Cross
M#8	g/lbf	FRF	Cross
M#9	g/lbf	FRF	Cross
M#10	g/lbf	FRF	Cross
M#11	g/lbf	FRF	Cross
M#12	g/lbf	FRF	Cross
M#13	g/lbf	FRF	Cross
M#14	g/lbf	FRF	Cross
M#15	g/lbf	FRF	Cross
M#16	g/lbf	FRF	Cross

*Data Block (**BLK**) After FFT.*

Prime Number FFT

MEscope uses a ***prime number*** **FFT**, which ***does not require*** that the **Block Size** (number of samples) be ***equal to a power of 2***.

One-Sided Versus Two-Sided FFT

All the energy in a time domain signal is spread of ***all*** frequencies, including both ***positive*** & ***negative*** frequencies in its DFT.

- The FFT always calculates a **Two-Sided FFT**, where ***half*** of a signal is represented by ***positive*** frequencies, and ***half*** by ***negative*** frequencies in its spectrum
- A **One-Sided FFT** yields spectrum values ***that are twice*** the values of a **Two-Sided FFT**
- The frequency spectrum of a ***real*** valued **TWF** is ***symmetric*** about zero frequency **(DC)**, so only the ***positive frequency*** half of the spectrum is displayed
- The ***amplitude & power*** values of a **DFT** calculated with a **Two-Sided FFT *are half*** of the values of the its corresponding **TWF**
- The ***amplitude*** & ***power*** values of a **DFT** calculated with a **One-Sided** FFT ***are the same*** values as its corresponding **TWF**

Transform | Inverse FFT

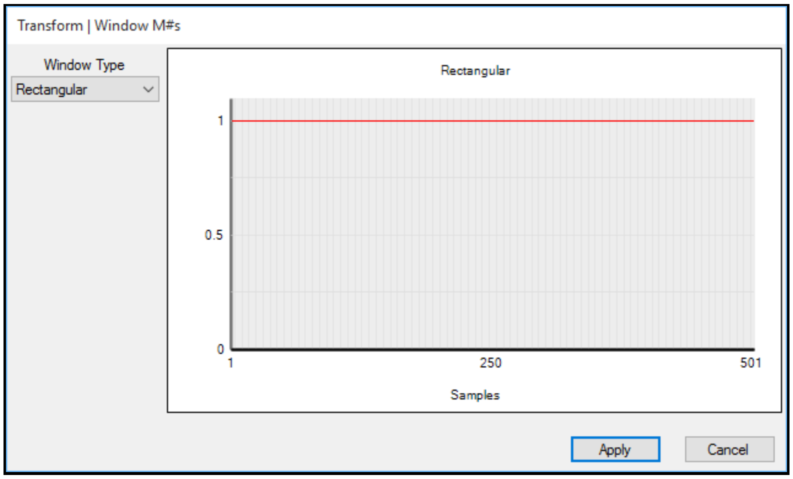
Applies the **Inverse Fast Fourier Transform (IFFT)** to ***each*** **frequency domain M#** in a Data Block (**BLK**) yielding its corresponding **TWF**.

- The FFT is a ***loss-less*** (also called ***one-to-one & onto***) transformation from one domain (time or frequency) to the other
- An original **TWF** can ***always be recovered*** by applying the **Inverse FFT** to its **DFT**

Transform | Window M#s

Multiplies ***all*** (or ***selected***) **M#s** by one of several windowing functions.

- When executed, the following window is opened,

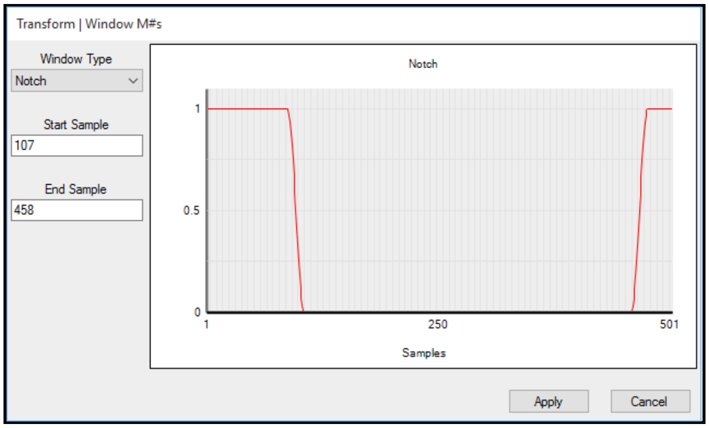


*Window **M#s** Dialog Box Showing the Rectangular Window.*

Notch Window

The **Notch** window is useful for ***removing (zeroing) unwanted*** samples of data. It uses a **Cosine function** to transition the data ***smoothly to zero inside*** the cursor band. The **Notch** window is defined as follows,

- Outside the cursor band, **Notch ➔ 1.0**
- From **0% to 5% inside** the cursor band, **Notch ➔ Cos(0) =1.0** to **Cos(90) = 0.0**
- From **5% to 95% inside** the cursor band **Notch ➔ 0.0**
- From **95% to 100% inside** the cursor band **Notch ➔ Cos(90) = 0.0** to **Cos(0) = 1.0**


Transform | Window M#s

Window Type: Notch

Start Sample: 107

End Sample: 458

Notch Window.

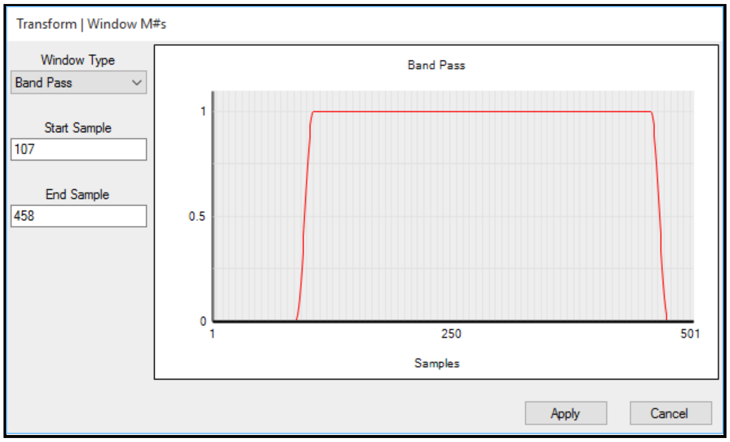
To apply a Notch window,

- ***Select*** the **M#s** to be windowed
- Display the **Band** cursor and position the band to enclose the data to be notched (or zeroed)
- Execute **Transform | Window M#s**, select the Notch window, and ***press* Apply**

Band Pass Window

The **Band Pass** window is useful for preserving certain samples of data and setting the rest to zero. It uses a Cosine function to transition the data ***smoothly to zero outside the cursor band***. The **Band Pass** window is defined as follows,

- **Inside** the cursor band, **Band Pass ➔ 1.0**
- For **5% of the cursor band prior to the lower edge, Band Pass ➔ Cos (90) = 0.0** to **Cos (0) = 1.0**
- For **5% of the cursor band following the upper edge**, **Band Pass ➔ Cos (0) = 1.0** to **Cos (90) = 0.0**
- **Otherwise**, **Band Pass ➔ 0.0**


Transform | Window M#s

Window Type: Band Pass

Start Sample: 107

End Sample: 458

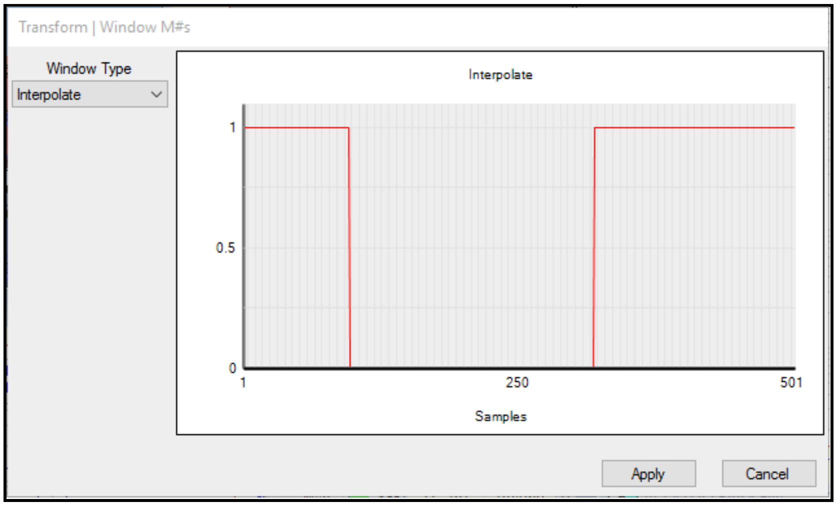
Band Pass Window.

To apply the Band Pass window,

- ***Select*** the **M#s** to be windowed
- Display the **Band** cursor, and position the band to enclose the data to be preserved
- Execute **Transform | Window M#s**, select the Band Pass window, and ***press* Apply**

Interpolation Window

This window is used for replacing ***unwanted data*** with ***interpolated data*** in a band of samples. Data in the cursor Band is replaced with a ***Straight Line of data*** between the values at the ends of the band

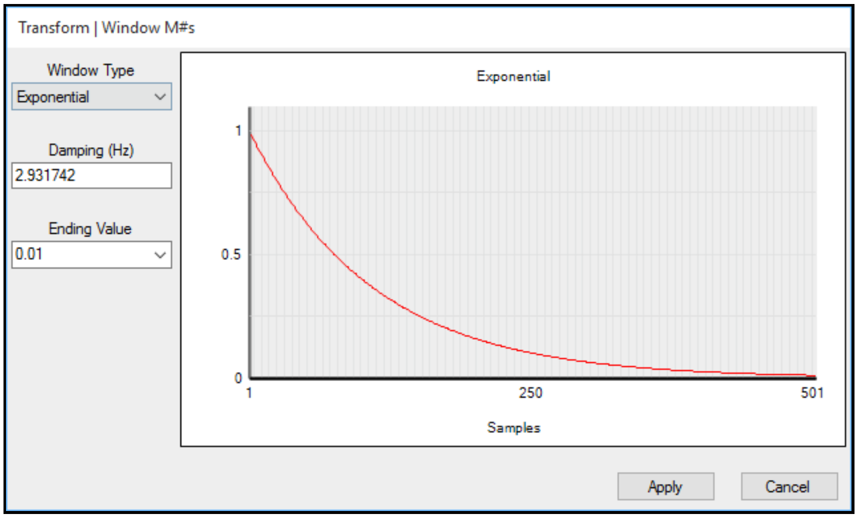


Interpolation Window.

Exponential Window

This window multiplies ***each*** **TWF M#** by a ***decreasing*** (or ***increasing***) exponential curve.

- The **beginning value** of the exponential window is **"1"**
- **Ending value *greater than "0"*** & ***less than "1"*** ➔ decreasing exponential window is applied
- **Ending value *greater than "1"*** ➔ increasing exponential window is applied


Window Type: Exponential

Damping (Hz): 2.931742

Ending Value: 0.01

Exponential Window.

Exponential Windowing of Frequency Domain M#s

When the exponential window is applied to **frequency domain M#s**, the following steps are carried out

- ***All*** (or ***selected***) **M#s** are transformed to the time domain using the Inverse FFT
- The **Exponential** window is applied
- The **M#s** are transformed back to the frequency domain using the FFT

Decreasing Exponential Reduces Noise & Leakage

A ***deceasing*** exponential ***modifies each TWF*** in several ways.

- ***Noise is suppressed*** in each **TWF**
- A windowed waveform is ***more completely contained*** within its sampling window, so its spectrum ***has less leakage***
- The damping of all modes is ***artificially increased*** by a known amount of damping
- All ***resonance peaks become wider***, meaning that tightly-coupled modes are less widely-separated

Increasing Exponential Narrows Resonance Peaks

An **in*creasing*** exponential modifies **each TWF** in several ways.

- ***Noise is amplified*** in each **TWF**
- The waveform is ***less completely contained*** within its sampling window, so its **Digital Fourier Transform *has more leakage***
- The damping of all modes is ***artificially decreased*** by a known amount of damping
- All ***resonance peaks become narrower***, meaning that tightly-coupled modes are more widely-separated

Modal Damping

Applying an exponential window to **M#s** that contain resonant vibration ***adds or subtracts a known amount of damping*** to each of the modes represented in the data.

Following curve fitting, the exponential window damping is ***added to or subtracted from the damping*** of each mode shape when it is are saved into a Shape Table (**SHP**)

- A ***decreasing* exponential** window ***adds damping*** to each mode, which is ***subtracted*** from their modal damping when mode shapes are saved into a Shape Table (**SHP**)
- An ***increasing* exponential** window ***subtracts damping*** from each mode, which is ***added*** to their modal damping when mode shapes are saved into a Shape Table (**SHP**)

The amount of modal damping added by the Exponential window ***is cumulative***

- If the Exponential window is ***applied several times*** to the same data, the amount of damping is the ***sum of the damping amounts*** added with each application of the window

The ***damping*** added by an Exponential window to the modes is listed in the **Transform | Window M#s** dialog box, and in the **Window Value** column of the **M#s** spreadsheet

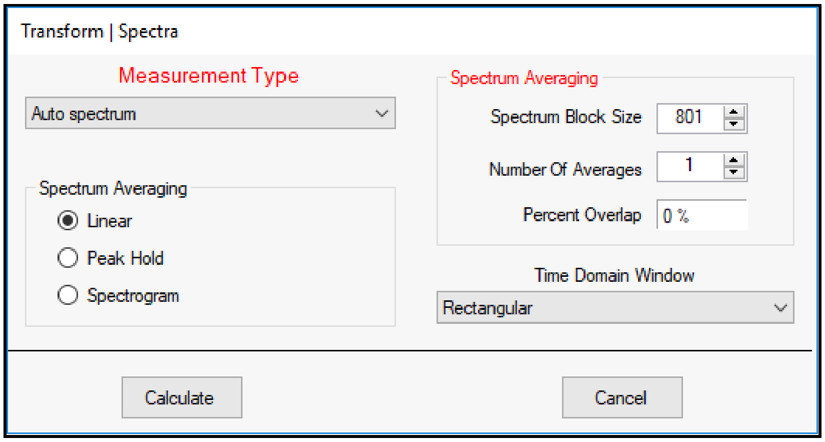
Modal Damping Change Following Curve Fitting

The damping of each mode is either ***decreased or increased*** when one of the following commands is executed,

- **Save Shapes** button on the **Residues Save Shapes** tab
- **Curve Fit | Shapes | Save Shapes**

Transform | Spectra

Calculates **Fourier spectra**, **Auto & Cross spectra, PSDs** or **ESDs** from **TWF**s or frequency spectra. When this command is executed, the dialog box below is opened



Transform | Spectra

Measurement Type: Auto spectrum

Spectrum Averaging
● Linear
○ Peak Hold
○ Spectrogram

Spectrum Averaging
Spectrum Block Size: 801
Number Of Averages: 1
Percent Overlap: 0 %

Time Domain Window: Rectangular

Digital Fourier Transform (DFT)

A **Digital Fourier Transform** is also called the **DFT** of a **TWF**.

- The FFT calculates the **Digital Fourier Transform (DFT)** of each **M#** in a Data Block (**BLK**)

Auto spectrum (APS)

Each Auto spectrum is calculated by multiplying the **DFT** of a **TWF** by the ***complex conjugate*** of its **DFT**.

- The Auto spectrum is **Real valued** (magnitude only)

Cross spectrum (XPS)

Each Cross-spectrum is calculated by multiplying the **DFT** of a **TWF** labeled as an **Output** by the ***complex conjugate*** of the **DFT** of a **TWF** labeled as an **Input**.

- Each Input & Output is designated in the **Input Output** column of the **M#s** spreadsheet in a Data Block (**BLK**) window.
- The Cross spectrum is complex valued with **magnitude & phase**

Power Spectral Density (PSD)

A **PSD** is an Auto spectrum that has been ***"normalized"*** by dividing it by the frequency resolution of the Auto spectrum.

- If the units of an Auto spectrum are **g^2**, the units of its corresponding **PSD** are **g^2 / Hz**

Energy Spectral Density (ESD)

An **ESD** is a **PSD** ***multiplied by the time length*** **(T)** of the **TWF** used to create the **PSD**. An **ESD** is used to characterize **transient signals**.

- Units of a **PSD ➔ g^2 / Hz**
- Units of its **ESD ➔ (g^2 - sec) / Hz**

Spectrogram

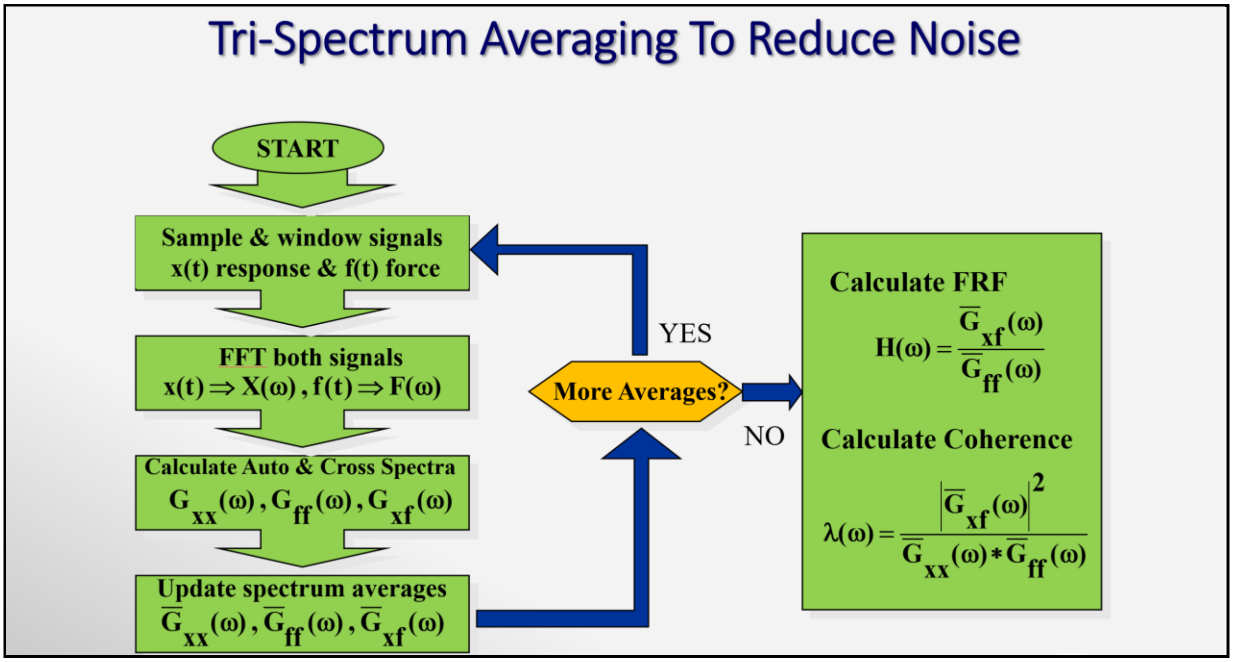
A Spectrogram is a series of spectra that are calculated from ***short time portions*** of a **TWF**.

- If **Number of Spectrum Averages = 10 ➔** the Spectrogram contains 10 individual spectrum estimates

Spectrum Averaging

Spectrum averaging is done to remove extraneous noise from vibration signals. Spectrum averaging can be used to calculate Auto & Cross spectra as well as **ODS-FRFs** and **FRFs**, (which are both calculated from Auto & Cross spectra). A spectrum averaging loop is depicted in the diagram below

- An **average Auto spectrum** is calculated by averaging together multiple Auto spectrum estimates
- An **average Cross spectrum** is calculated by averaging together multiple Cross spectrum estimates
- **ODS-FRFs** & **FRFs** are calculated from **averaged Auto & Cross spectra**.



Tri-Spectrum Averaging To Reduce Noise

START

Sample & window signals x(t) response & f(t) force

FFT both signals $x(t)\Rightarrow X(\omega)\,,\,f(t)\Rightarrow F(\omega)$

Calculate Auto & Cross Spectra $G_{xx}(\omega)\,,G_{ff}(\omega)\,,G_{xf}(\omega)$

Update spectrum averages $\overline{G}_{xx}(\omega)\,,\overline{G}_{ff}(\omega)\,,\overline{G}_{xf}(\omega)$

More Averages?

YES

NO

Calculate FRF

$$H(\omega)=\frac{\overline{G}_{xf}(\omega)}{\overline{G}_{ff}(\omega)}$$

Calculate Coherence

$$\lambda(\omega)=\frac{\left|\overline{G}_{xf}(\omega)\right|^2}{\overline{G}_{xx}(\omega)*\overline{G}_{ff}(\omega)}$$

Block Diagram of a Spectrum Averaging Loop.

Total Samples Required

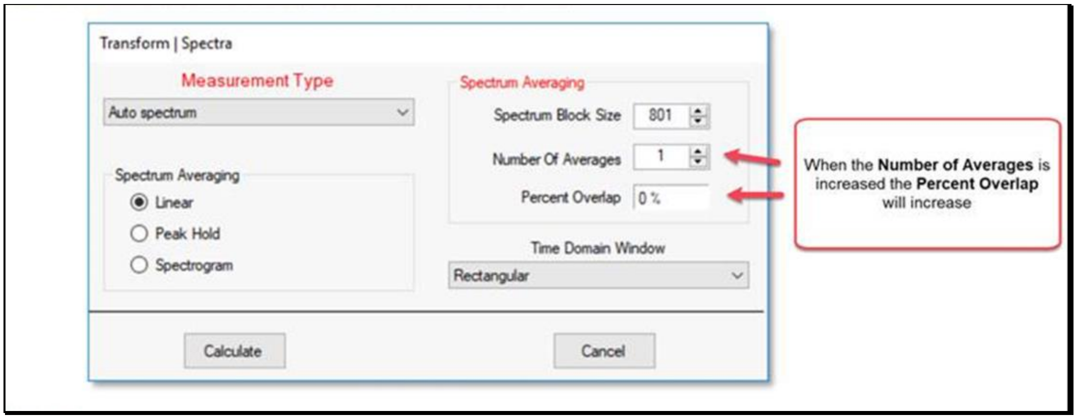
The total number of samples required for spectrum averaging is,

Total Samples Required = [2 x Spectrum Block Size x Number of Averages]

Overlap Processing

If the **Total Samples Required** ***exceeds the time domain Block Size***, Overlap Processing will be used during spectrum averaging

- During Overlap Processing, each sampling window of **TWF**s used to calculate a spectrum estimate overlaps with the sampling window used to calculate the previous spectrum estimate



Transform | Spectra

Measurement Type: Auto spectrum

Spectrum Averaging
● Linear
○ Peak Hold
○ Spectrogram

Spectrum Averaging
Spectrum Block Size: 801
Number Of Averages: 1
Percent Overlap: 0 %

Time Domain Window: Rectangular

When the **Number of Averages** is increased the **Percent Overlap** will increase

Transform | Seed TRN Chain

Seeds a **Transmissibility (TRN) chain** with a single measurement (Auto spectrum, Cross spectrum, **FRF**) to yield a set of ***single reference*** **ODS-FRFs, Cross spectra, or FRFs**.

- A **Transmissibility** is defined as the **DFT** of a vibration response divided by the **DFT** of another vibration response (acceleration, velocity, or displacement)

A **TRN Chain** is a series of Transmissibility's chained together by their DOFs, the **Roving DOF** of one Transmissibility matching the **Reference DOF** on another

- For example, the following is a **TRN Chain**; **TRN (1Z:2Z)**, **TRN (2Z:3Z)**, **TRN (3Z:4Z)**, **TRN (4Z:5Z)**,...

A **TRN Chain** has several advantages,

- Only Structural responses are required to form a **TRN Chain**
- Data can be acquired with ***two sensors attached close to each other*** throughout the test
- ***Either or both*** **sensors** can be moved between acquisitions
- A **TRN Chain** can be formed from data acquired from an ***operating machine*** or from any structure where the ***excitation forces are not measured***
- A **TRN Chain** accounts for changes in excitation force levels during data acquisition
- Before executing this command, the **M#** used to seed a **TRN Chain** ***must be stored in the same*** **Data Block (BLK)** as the **TRN Chain**

Seeding a TRN Chain

Seeding a **TRN** Chain will give several different single reference functions

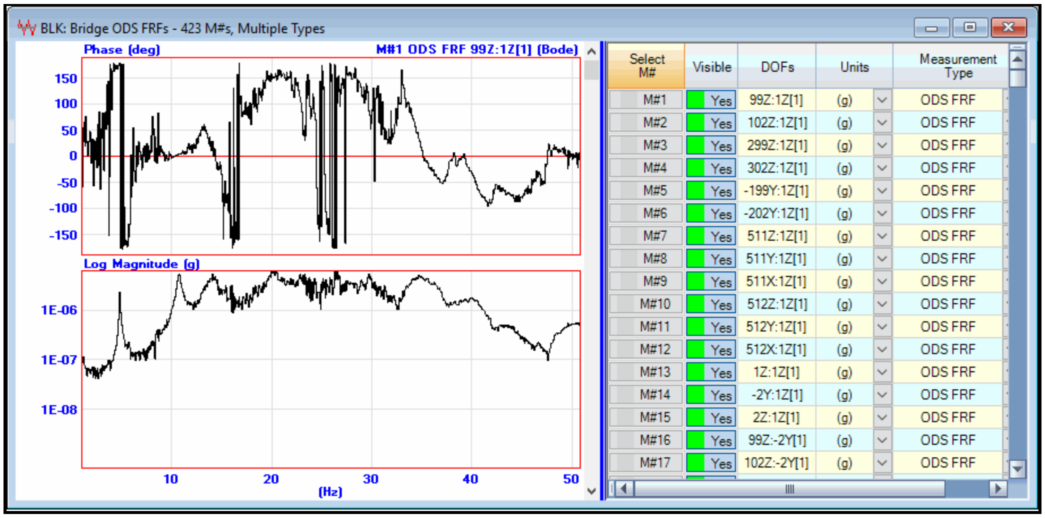
- Seeding (multiplying) a **TRN** Chain by an Auto spectrum ➔ a set **of *single reference* ODS-FRFs**
- Seeding (multiplying) a **TRN** Chain by a Cross spectrum ➔ a set of ***single reference*** **Cross spectra**
- Seeding (multiplying) a **TRN** Chain by an **FRF** ➔ a set of ***single reference*** **FRFs**

Transform | ODS-FRFs

Calculates a set of **ODS-FRFs** from operational (or **output-only**) data.

What is an ODS-FRF?

An **ODS-FRF** has a magnitude equal to the Auto spectrum of a Roving response and the phase between the Roving response and a **(fixed) Reference** response. An **ODS-FRF** is a ***complex valued frequency domain function*** that is like an **FRF**.



Select M#	Visible	DOFs	Units	Measurement Type
M#1	Yes	99Z:1Z[1]	(g)	ODS FRF
M#2	Yes	102Z:1Z[1]	(g)	ODS FRF
M#3	Yes	299Z:1Z[1]	(g)	ODS FRF
M#4	Yes	302Z:1Z[1]	(g)	ODS FRF
M#5	Yes	-199Y:1Z[1]	(g)	ODS FRF
M#6	Yes	-202Y:1Z[1]	(g)	ODS FRF
M#7	Yes	511Z:1Z[1]	(g)	ODS FRF
M#8	Yes	511Y:1Z[1]	(g)	ODS FRF
M#9	Yes	511X:1Z[1]	(g)	ODS FRF
M#10	Yes	512Z:1Z[1]	(g)	ODS FRF
M#11	Yes	512Y:1Z[1]	(g)	ODS FRF
M#12	Yes	512X:1Z[1]	(g)	ODS FRF
M#13	Yes	1Z:1Z[1]	(g)	ODS FRF
M#14	Yes	-2Y:1Z[1]	(g)	ODS FRF
M#15	Yes	2Z:1Z[1]	(g)	ODS FRF
M#16	Yes	99Z:-2Y[1]	(g)	ODS FRF
M#17	Yes	102Z:-2Y[1]	(g)	ODS FRF

Typical ***ODS-FRF****.*

Advantages of ODS-FRFs

The **ODS-FRF** provides the true response (in displacement, velocity, or acceleration units) at each DOF of a machine or structure, together with its phase relative to a Reference response.

- An **ODS-FRF *contains a peak at each resonant frequency***
- **ODS's** can be displayed in animation from set of **ODS-FRFs**
- **OMA mode shapes** can be extracted by ***curve fitting*** a set of **ODS-FRFs**

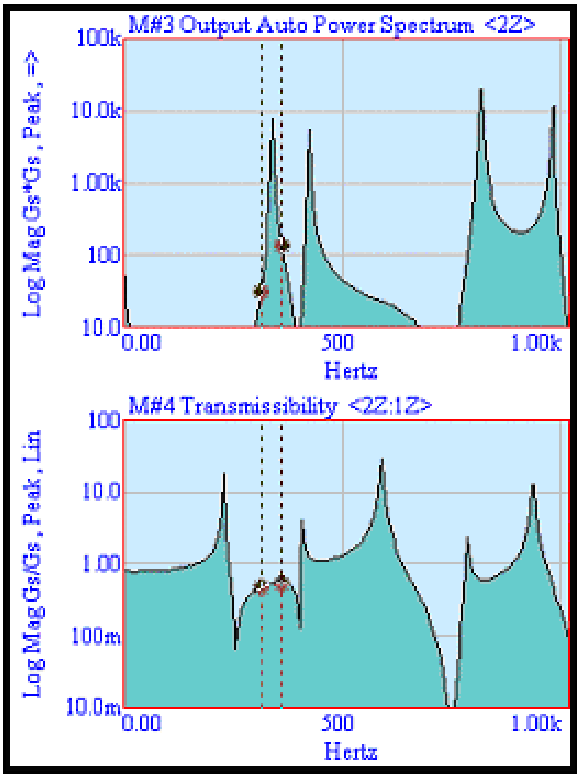
ODS's From a Set of ODS-FRFs

If shape data from the cursor position in two or more **ODS-FRFs** is displayed in animation on a model of the test article, the resulting **ODS *is the true overall response*** of the structure at each DOF, with the ***correct phase*** relative to all other DOFs.

What is Transmissibility?

Transmissibility is the **DFT** of a Roving response divided by the **DFT** of a Reference response. Transmissibility is calculated in the same way as an **FRF**, but a ***(fixed) Reference*** response is used instead of the unmeasured excitation force(s)

- **Advantage of Transmissibility:** If the excitation force varies between Measurement Sets, the transmissibility ***is not affected***
  - For a linear dynamic system, any change in both the Roving & Reference responses is ***"canceled out"*** in a Transmissibility
- **Difficulty with Transmissibility:** A Transmissibility has a ***"flat spot" instead of a peak*** in the vicinity of each resonant frequency, as shown below



Roving Auto Spectrum & Transmissibility.

Transmissibility's Multiplied by Reference Auto Spectrum

When a set of Transmissibility's is multiplied by a ***single Reference Auto spectrum***, the result is a set of **ODS-FRFs**.

(Transmissibility's x Reference Auto Spectrum) ➔ ODS-FRFs

Operating Mode Shapes from ODS-FRFs

At or near a resonant frequency, the **ODS** obtained from a set of **ODS-FRFs *is often dominated*** by the mode shape of that resonance.

- A windowed set of **ODS-FRFs** can be curve fit using a **FRF-based curve fitting method** to obtain an **OMA mode shape** for each resonance

Data for Calculating ODS-FRFs

Before executing this command, all the data necessary for calculating **ODS-FRFs** much be **contained in one Data Block.**

The **Transform | ODS-FRFs** command can calculate **ODS-FRFs** from ***three different kinds of data***.

1. **TWFs ➔** Multiple Roving responses and a Reference response.
2. **Auto & Cross Spectra ➔** Roving response Auto spectra and Cross spectra between each Roving response and a Reference response.
3. **TRNs & Reference Auto Spectrum ➔** Transmissibility's between each Roving response and a Reference response and the Reference Auto spectrum.

TWFs ➔ ODS-FRFs

Each **TWF M#** must contain the **DOF** (point & direction) from which it was acquired including its [**measurement set**]

- Roving responses must be defined as **Outputs** in the **Input Output** column of the **M#s** spreadsheet
- Reference responses must be defined as **Inputs** in the **Input Output** column of the **M#s** spreadsheet

Auto & Cross spectra ➔ ODS-FRFs

Each Auto spectrum **DOF** must match the **Roving DOF** of a Cross spectrum

- Auto spectra must be defined as **Outputs** in the **Input Output** column of the **M#s** spreadsheet
- Cross spectra must be defined as **Cross** in the **Input Output** column of the **M#s** spreadsheet

Transmissibility's ➔ ODS-FRFs

- Transmissibility's must be defined as **Cross** in the **Input Output** column of the **M#s** spreadsheet
- The Reference Auto spectrum must be defined as an **Input** in the **Input Output** column of the **M#s** spreadsheet

Multiple Measurement Sets

If the **M# DOFs** contain [**Measurement Set]** numbers, each Measurement Set is processed independently of the other Measurement Sets.

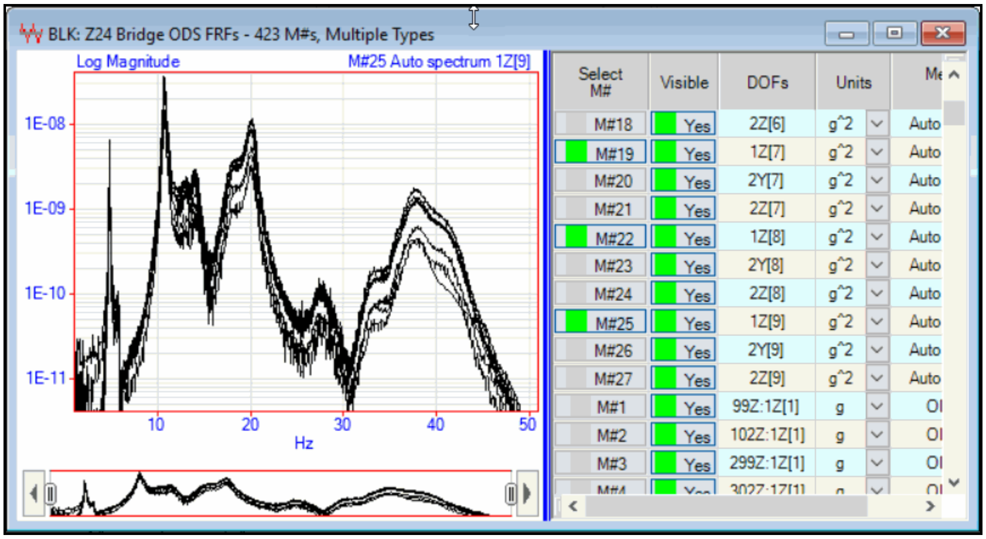
Transform | Scale ODS-FRFs

Re-scales* ODS-FRFs** to correct for changes in the response levels between ***multiple Measurement Sets.

- This command is only required when **ODS-FRFs** are calculated from ***multiple Measurement Sets*** of data

Overlaid Reference Auto Spectra

If the Reference Auto Spectra ***from all Measurement Sets*** are overlaid as shown below, changes of response levels between Measurement Sets will be apparent.



Select M#	Visible	DOFs	Units		Me
M#18	🟩 Yes	2Z[6]	g^2	⌄	Auto
🟩 M#19	🟩 Yes	1Z[7]	g^2	⌄	Auto
M#20	🟩 Yes	2Y[7]	g^2	⌄	Auto
M#21	🟩 Yes	2Z[7]	g^2	⌄	Auto
🟩 M#22	🟩 Yes	1Z[8]	g^2	⌄	Auto
M#23	🟩 Yes	2Y[8]	g^2	⌄	Auto
M#24	🟩 Yes	2Z[8]	g^2	⌄	Auto
🟩 M#25	🟩 Yes	1Z[9]	g^2	⌄	Auto
M#26	🟩 Yes	2Y[9]	g^2	⌄	Auto
M#27	🟩 Yes	2Z[9]	g^2	⌄	Auto
M#1	🟩 Yes	99Z:1Z[1]	g	⌄	Ol
M#2	🟩 Yes	102Z:1Z[1]	g	⌄	Ol
M#3	🟩 Yes	299Z:1Z[1]	g	⌄	Ol
M#4	🟩 Yes	302Z:1Z[1]	g	⌄	Ol

*Overlaid **Reference Auto Spectra** from Multiple Measurement Sets.*

ODS-FRF Scale Factor

To re-scale the **ODS-FRFs**, all **ODS-FRFs** in **Measurement Set [i]** are multiplied by the **Scale Factor (i)**

$$\mathrm{ScaleFactor(i)} = \frac{1}{\mathrm{N}}\left(\frac{\sum\limits_{i=1}^{N}\mathrm{ARM(i)}}{\mathrm{ARM(i)}}\right)$$

N = Number of Measurement Sets

ARM(i) = **Average Magnitude** of the **Reference Auto spectrum** for **Measurement Set [i]**

- If the **Line** cursor is displayed, **ARM(i)** is calculated at the **Line** cursor position
- If the **Band** or **Peak** cursor is displayed, **ARM(i)** is calculated using all the samples in the band
- If no cursors are displayed, **ARM(i)** is calculated using ***all samples*** of each Reference Auto spectrum

What is a Multi-Input Multi-Output (MIMO) Model?

A **MIMO** model is a frequency domain model where the **DFTs** of ***multiple*** Inputs are multiplied by elements of an **FRF *matrix*** to yield the **DFTs** of ***multiple*** Outputs. A **Multi-Input Multi-Output (MIMO)** dynamic model is used to calculate multiple **Inputs**, **Outputs & FRFs** of a structure.

- The **MIMO** Model is written as,

  {X(ω)} = [H(ω)] {F(ω)}

  {F(ω)} ➔ Input **DFT** (**m - vector**)

  [H(ω)] ➔ **FRF** matrix (**n by m**)

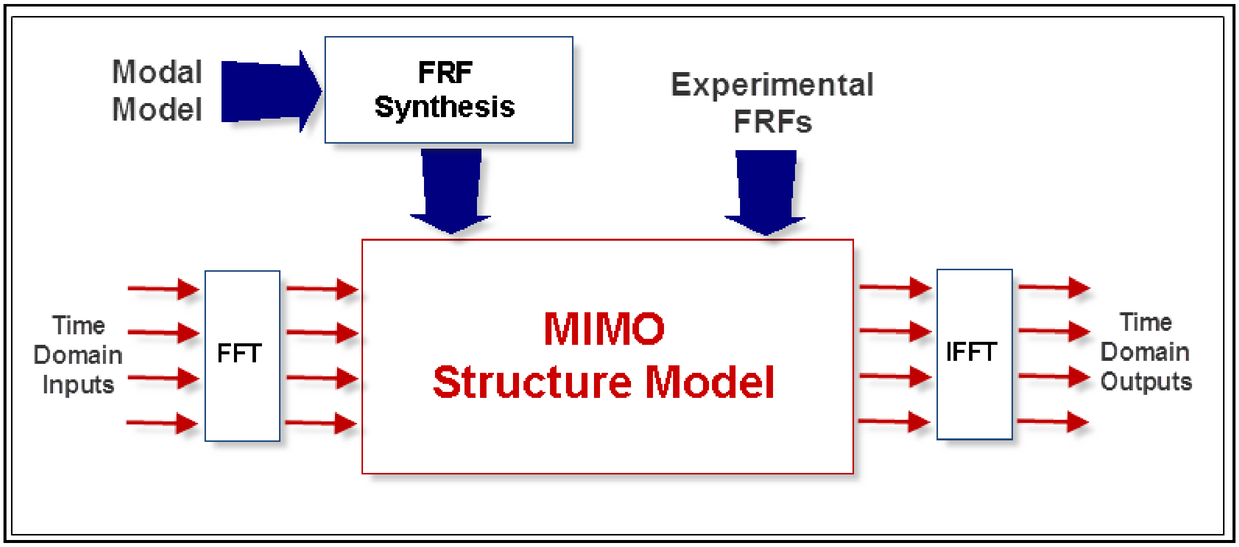
  {X(ω)} ➔ Output **DFT** (**n - vector**)

  m ➔ number of Inputs

  n ➔ number of Outputs

  ω ➔ frequency variable (radians per second)

- ***Rows*** of the **FRF** matrix correspond to **Outputs** and ***columns*** correspond to **Inputs**
- **Each Input** and **each Output** has a DOF (point & direction)
- **Each FRF** is a ***cross-channel measurement*** between an Input DOF and an Output DOF



MIMO Model Block Diagram

Each part of a **MIMO** model (**Inputs**, **Outputs**, **FRFs**) ***is calculated from the other two parts***.

- Inputs & Outputs can be either **TWFs** or **frequency domain functions**
- Frequency domain functions can be **DFTs, Auto & Cross spectra, or PSDs**
- **FRFs** can be either **measured or synthesized** from a **modal model**

Frequency Response Function (FRF)

An **FRF** is defined as the **DFT** of a ***displacement, velocity, or acceleration*** response ***divided by*** the **DFT** of the ***excitation force*** that caused the response.

Transmissibility (TRN)

A **Transmissibility** is defined as the **DFT** of an Output divided by the **DFT** of a Reference Output

M# Input Output Properties

Before using one of the **Transform** commands, ***each*** **M#** must be designated as either an **Input**, **Output**, **Both** or **Cross** in the **Input Output** column of the **M#s** spreadsheet.

- **Input M#s** must be designated as **Input** or **Both** in the **Input Output** column of the **M#s** spreadsheet
- **Output M#s** must be designated as **Output** or **Both** in the **Input Output** column of the **M#s** spreadsheet
- **Transfer Function M#s** must be designated as **Cross** in the **Input Output** column of the **M#s** spreadsheet

M# DOFs and Units

Before using one of the **Transform** commands, each M# must have correct DOFs and engineering units.

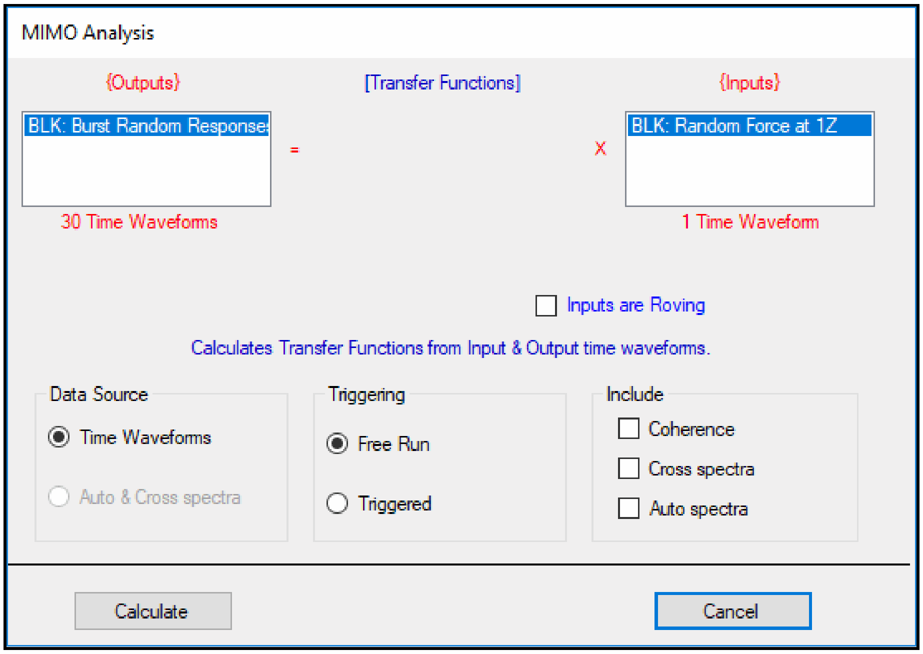
- ***Each*** **M#** must have a **DOF** in the **DOFs** column of the **M#s** spreadsheet that designates the Point & direction of its measurement
- ***Each*** **M#** must have ***correct engineering units*** in the **Units** column of the **M#s** spreadsheet

Transform | H1 FRF

Calculates **H1 FRFs** from **TWF**s or frequency spectra in a Data Block (**BLK**).

- H1 **FRFs** can be calculated from two sources
  - **Input** & **Output TWF**s
  - **Input Auto spectra** and **Cross spectra** between Inputs & Outputs

When this command is executed, the following dialog box will open.



MIMO Analysis

{Outputs} = [Transfer Functions] X {Inputs}

Outputs: BLK: Burst Random Response — 30 Time Waveforms

Inputs: BLK: Random Force at 1Z — 1 Time Waveform

□ Inputs are Roving

Calculates Transfer Functions from Input & Output time waveforms.

Data Source: ● Time Waveforms ○ Auto & Cross spectra

Triggering: ● Free Run ○ Triggered

Include: □ Coherence □ Cross spectra □ Auto spectra

H1 FRFs Using Auto & Cross Spectra

An H1 **FRF** matrix is calculated from **Auto & Cross spectra** using the following formula,

$$[\text{H1 FRF}(\omega)] = [\{X(\omega)\}\ \{F(\omega)\}^{t}]\ [\{F(\omega)\}\ \{F(\omega)\}^{t}]^{-1}$$

$[\text{H1 FRF}(\omega)]$ ➔ **H1 FRF** matrix (**n by m**)

$[\{X(\omega)\}\ \{F(\omega)\}^{t}]$ ➔ Cross spectrum matrix between Outputs & Inputs (**n by m**)

$[\{F(\omega)\}\ \{F(\omega)\}^{t}]$ ➔ Input Auto spectrum matrix (**m by m**)

$\{F(\omega)\}$ ➔ **DFTs** of Inputs (**m-vector**)

$\{X(\omega)\}$ ➔ **DFTs** of Outputs (**n-vector**)

m ➔ number of Inputs

n ➔ number of Outputs

ω ➔ frequency variable (radians per second)

t ➔ denotes conjugate transposed

-1 ➔ denotes the matrix inverse

H1 FRFs Using TWFs

If **TWFs** are used to calculate **FRFs**, ***time domain windowing, overlap processing***, and ***spectrum averaging*** can be used to calculate Auto & Cross spectra, which are then used to calculate the **FRFs** using the formula above.

- **Coherences, Auto spectra & Cross spectra** can also be calculated and saved with the **FRFs** by ***checking*** them in the **Include** section of the dialog box

Time Domain Windowing

Sampled **TWF**s can have different windows applied to them before the FFT is applied. Each window is most effective when used on a specific type of data, as described below.

- **Rectangular** (for signals that are ***periodic in the time domain sampling window***)
- **Hanning** (for ***broad band*** signals that are ***not completely contained in the time domain sampling window***)
- **Flat Top** (for ***narrow band*** signals)

Transform | H2 FRFs

Calculates **H2 FRFs** from **TWF**s or frequency spectra in a Data Block (**BLK**).

- H2 **FRFs** can be calculated from
  - **Input** & **Output TWF**s
  - **Output Auto spectra** and **Cross spectra** between Inputs & Outputs

An **H2 FRF** matrix is calculated using the following formula.

$$[\mathbf{H2\ FRF}(\omega)] = [\mathbf{X}(\omega)^t\, \mathbf{X}(\omega)] \,/\, [\mathbf{X}(\omega)^t\, \mathbf{F}(\omega)]$$

$[\mathbf{H2\ FRF}(\omega)]$ ➔ H2 **FRF** matrix (**n by m**)

$[\mathbf{X}(\omega)^t\, \mathbf{F}(\omega)]$ ➔ Cross spectrum between Output & Input (**n by m**)

$[\mathbf{X}(\omega)^t\, \mathbf{X}(\omega)]$ ➔ Output Auto spectrum (**n by n**)

$\{\mathbf{F}(\omega)\}$ ➔ **DFTs** of Inputs (**m-vector**)

$\{\mathbf{X}(\omega)\}$ ➔ **DFTs** of Outputs (**n-vector**)

ω ➔ frequency variable (radians per second)

$\mathbf{t}$ ➔ denotes complex conjugate

Transform | Outputs

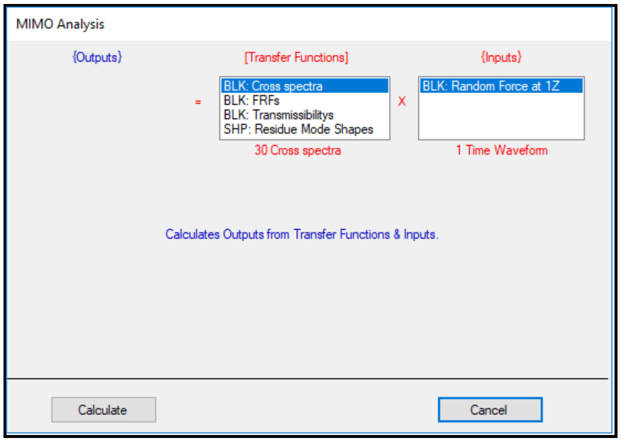
Calculates ***multiple*** **Outputs** from **FRFs** & **Inputs**. Different types of **Inputs** can be used for this calculation,

- Input **TWF**s
- Input Auto spectra or Fourier spectra

Before using this command,

- Inputs must be designated as **Input** (or **Both**) in the **Input Output** column of the **M#s** spreadsheet
- **FRFs** must be designated as **Cross** in the **Input Output** column of the **M#s** spreadsheet
- Residue mode shapes or UMM mode shapes can also be used to ***synthesize*** the required **FRFs**

When this command is executed, the following dialog box is opened,



BLK: Cross spectra
BLK: FRFs
BLK: Transmissibilitys
SHP: Residue Mode Shapes

BLK: Random Force at 1Z

30 Cross spectra

1 Time Waveform

Calculates Outputs from Transfer Functions & Inputs.

- The Data Block (**BLK**) containing the **Inputs** is chosen from the **Inputs** list box
- The Data Block (**BLK**) containing the Transfer Functions (**FRFs**, **Cross** measurements, **Mode Shapes**) is chosen from the **Transfer Functions** list box

Outputs from FRFs & Inputs

Outputs are calculated from **FRFs** & **Inputs** in three different ways

1. Output **TWFs** or **Fourier spectra** are calculated from Input **TWF**s or Fourier spectra & **FRFs**.
2. **Cross spectra** are calculated between Inputs & Outputs
3. Output **Auto spectra** or **PSDs** are calculated from Auto spectra or PSDs & **FRFs**

Output DFTs and TWFs

Output **DFTs** are calculated from **FRFs** and **Input DFTs** using the formula,

$\{X(\omega)\} = [H(\omega)]\,\{F(\omega)\}$

$\{F(\omega)\}$ ➔ **DFTs** of Inputs (**m - vector**)

$[H(\omega)]$ ➔ **FRF** matrix (**n by m**)

$\{X(\omega)\}$ ➔ **DFTs** of Outputs (**n - vector**)

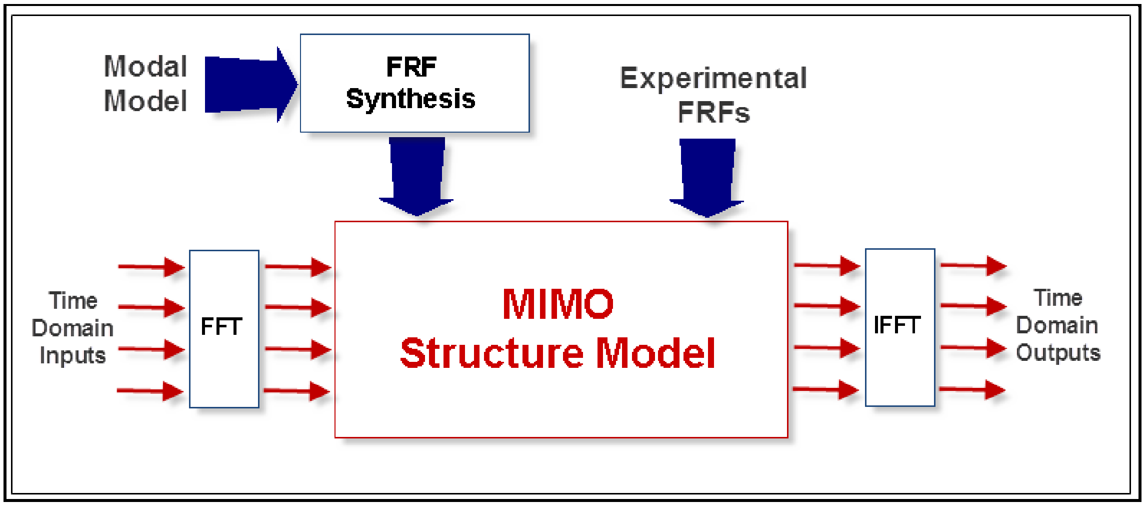
m ➔ number of Inputs

n ➔ number of Outputs

ω ➔ frequency variable (radians per second)

- If **Input TWF**s are provided as a Source, they are transformed to **DFTs** before calculating **Output DFTs**
- The calculated **Output DFTs** are then transformed to **Output TWF**s

The block diagram below depicts Outputs calculation when Inputs are provided as **TWF**s, and either a Modal Model or Experimental **FRFs** are provided as the MIMO matrix.



MIMO Output Calculation.

Cross Spectra

Cross spectra between Inputs & Outputs are calculated from **Input** Auto spectra and **FRFs** using the formula,

$[\{X(\omega)\}\ \{F(\omega)\}^t] = [H(\omega)]\ [\{F(\omega)\}\ \{F(\omega)\}^t]$

$[\{X(\omega)\}\ \{F(\omega)\}^t]$ ➔ Cross spectrum matrix between Inputs & Outputs (**n by m**)

$[\{F(\omega)\}\ \{F(\omega)\}^t]$ ➔ Input Auto spectrum matrix (**m by m**)

$[H(\omega)]$ ➔ **FRF** matrix (**n by m**)

m ➔ number of Inputs

n ➔ number of Outputs

ω ➔ frequency variable (radians per second)

t ➔ denotes transposed conjugate

Output Auto Spectra

Output Auto spectra or PSDs are calculated from **Input** Auto spectra or PSDs and **FRFs** using the formula,

$[\{X(\omega)\}\ \{X(\omega)\}^t] = [H(\omega)]\ [\{F(\omega)\}\ \{F(\omega)\}^t]\ [H(\omega)]^t$

$[\{X(\omega)\}\ \{X(\omega)\}^t]$ ➔Output Auto spectrum matrix (**n by n**)

$[\{F(\omega)\}\ \{F(\omega)\}^t]$ ➔ Input Auto spectrum matrix (**m by m**)

$[H(\omega)]$ ➔**FRF** matrix (**n by m**)

m ➔ number of Inputs

n ➔ number of Outputs

ω ➔ frequency variable (radians per second)

t ➔ denotes transposed conjugate

- ***Only the diagonal elements*** of the **Output** Auto spectrum matrix are calculated

Input TWFs

TWFs can be imported or synthesized using **File | New | Data Block** in the MEscope window.

- **Input TWF**s are transformed to **DFTs** before being multiplied by the **FRFs** to yield **Output DFTs**
  - The Output **DFTs** are then transformed to **TWF**s

FRFs Synthesized from Modal Parameters

FRFs can be ***imported*** or ***acquired*** with an **Acquisition** window, or ***synthesized*** from a modal model.

If a Shape Table (**SHP**) with a modal model in it is chosen instead of an **FRF** Data Block (**BLK**), the required **FRFs** are ***synthesized from modal parameters***.

The frequency axis parameters of the **Input DFTs** are used for the **FRF** synthesis

- If **Residue mode shapes** are used, **FRFs *can only be synthesized with the same* DOFs** as the Residue mode shapes.
- If **UMM mode shapes** are used, **FRFs *are synthesized*** with **Reference DOFs** to match the DOFs of the **Inputs**

FRF DOFs and the MIMO Matrix

Each **FRF** is assembled into an **FRF matrix** based on its **Output & Input DOFs**.

- The **Output DOF** of an **FRF** designates its ***row position*** in the **MIMO matrix**
- The **Input DOF** of an **FRF** designates its ***column position*** in the **MIMO matrix**
- The DOF of each **Input** must match with an **Input DOF** (***column***) of the **MIMO matrix**
- Each calculated **Output** is given the **Output DOF** (***row***) of the **MIMO matrix**

Transform | Inputs

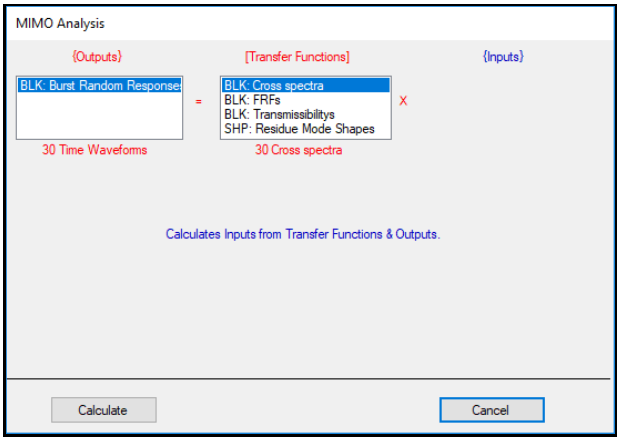
Calculates ***multiple*** **Inputs** from **FRFs** and **Outputs**. Different types of **Output** measurements can be used for this calculation.

- **Output TWF**s
- **Output** Auto spectra, **DFTs**, or **Cross** spectra between Inputs & Outputs

Before using this command

- Outputs must be designated as **Output** (or **Both**) in the **Input Output** column of the **M#s** spreadsheet
- **FRFs** must be designated as **Cross** in the **Input Output** column of the **M#s** spreadsheet
- **Residue mode shapes** or **UMM mode shapes** can also be used ***to synthesize the required*** **FRFs**

When this command is executed, the following dialog box is opened,



MIMO Analysis

{Outputs} [Transfer Functions] {Inputs}

BLK: Burst Random Response = BLK: Cross spectra X

BLK: FRFs

BLK: Transmissibilitys

SHP: Residue Mode Shapes

30 Time Waveforms 30 Cross spectra

Calculates Inputs from Transfer Functions & Outputs.

Input DFTs or TWFs

Input **DFTs** are calculated from **Output DFTs** and **FRFs** using the formula,

$$\{F(\omega)\} = [T(\omega)]\ \{X(\omega)\}$$

$[T(\omega)]$ ➔ $[[H(\omega)]^t\ [H(\omega)]]^{-1}\ [H(\omega)]^t$ (m by n) matrix

$[H(\omega)]$ ➔ **FRF** matrix (**n by m**)

$\{F(\omega)\}$ ➔ Input **DFTs** (**m - vector**)

$\{X(\omega)\}$ ➔ Output **DFTs** (**n - vector**)

m ➔ number of Inputs

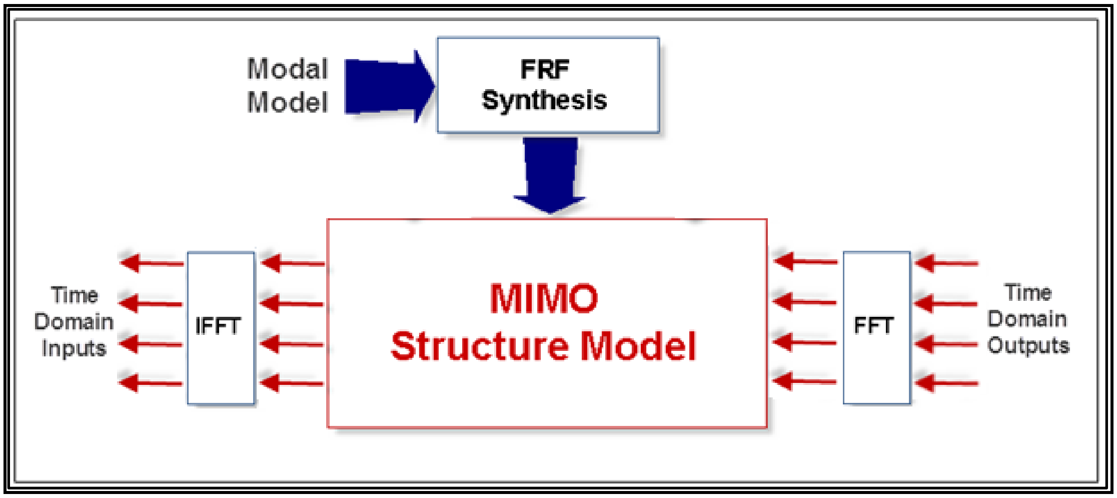
n ➔ number of Outputs

ω ➔ frequency variable (radians per second)

t ➔- denotes transposed conjugate

-1 ➔ denotes matrix inverse

- If **Output TWF**s are provided, they are transformed to **DFTs** before solving the above equation.
- The calculated **Input DFTs** are then transformed to **Input TWF**s.



Input Auto spectra From Cross spectra

Input Auto spectra are calculated from **FRFs** and Cross spectra using the formula,

$[\{F(\omega)\}\,\{F(\omega)\}^t] = [T(\omega)]\,\{X(\omega)\}\,\{F(\omega)\}^t$

$[\{F(\omega)\}\,\{F(\omega)\}^t]$ ➔ Input Auto spectrum matrix (**m by m**)

$[T(\omega)]$ ➔ $[[H(\omega)]^t\,[H(\omega)]]^{-1}\,[H(\omega)]^t$ (**m by n**) matrix

$[H(\omega)]$ ➔ **FRF** matrix (**n by m**)

$[\{X(\omega)\}\,\{F(\omega)\}^t]$ ➔ Cross spectrum matrix (**n by m**)

m ➔ number of Inputs

n ➔ number of Outputs

ω ➔ frequency variable (radians per second)

t ➔ denotes transposed conjugate

-1 ➔ denotes matrix inverse

Input Auto spectra from Output Auto spectra

Input Auto spectra or PSDs are calculated from **Output** Auto spectra or PSDs and **FRFs** using the formula,

$[\{F(\omega)\}\,\{F(\omega)\}^t] = [T(\omega)]\,[\{X(\omega)\}\,\{X(\omega)\}^t]\,[T(\omega)]^t$

$[\{F(\omega)\}\,\{F(\omega)\}^t\,]$ ➔ Input Auto spectrum matrix (**m by m**)

$[T(\omega)]$ ➔ $[[H(\omega)]^t\,[H(\omega)]]^{-1}\,[H(\omega)]^t$ (**m by n**) matrix

$[H(\omega)]$ ➔ **FRF** matrix (**n by m**)

$[\{X(\omega)\}\,\{X(\omega)\}^t]$ ➔ Output Auto spectrum matrix (**n by n**)

m ➔ number of Inputs

n ➔ number of Outputs

ω ➔ frequency variable (radians per second)

t ➔ denotes transposed conjugate

-1 ➔ denotes matrix inverse

- ***Only the diagonal elements*** of the **Output** Auto spectrum matrix are used for this calculation

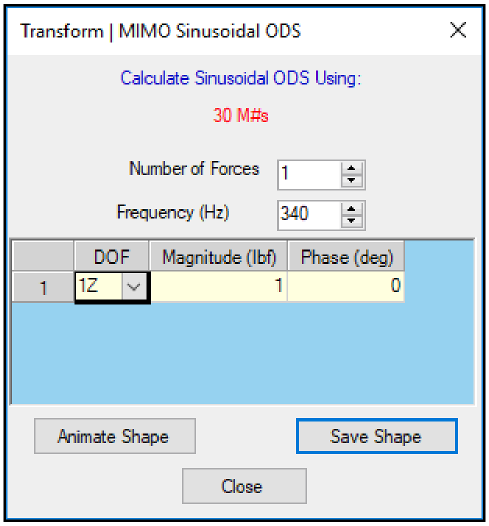
Transform | Sinusoidal ODS

Calculates a ***single frequency*** **ODS** ***from multiple sinusoidal*** excitation forces.

The Sinusoidal **ODS** can be ***saved*** in a Shape Table (**SHP**) or ***displayed in animation*** in a ***connected*** Structure (**STR**) window.

- The **ODS** is calculated by multiplying **FRFs** by the **DFTs** of excitation forces at a single frequency.
- Forces can be ***applied at any*** **Reference DOF** of the **FRFs**
- Each force is defined by its **magnitude & phase**, and the **Reference DOF** at which it is applied to the structure
- The **DOFs** of the Sinusoidal **ODS** are determined from the **Roving DOFs** of the **FRFs**

When this command is executed, the following dialog box is opened.



Transform | MIMO Sinusoidal ODS

Calculate Sinusoidal ODS Using:

30 M#s

Number of Forces: 1

Frequency (Hz): 340

	DOF	Magnitude (lbf)	Phase (deg)
1	1Z	1	0

Animating the Sinusoidal ODS

- ***Press*** the **Animate Shape** button to display the Sinusoidal **ODS** in animation on the structure model in a ***connected*** Structure (**STR**) window

The **M# Links** in the ***connected*** structure ***must be compatible with the M#s*** of the Sinusoidal **ODS** in order to display it in animation. To ensure that the Sinusoidal **ODS** will deflect the structure model correctly,

- ***Press*** **Save Shape** to save the **ODS** into a Shape Table (**SHP**)
- Execute **M# Links | Create M# Links** from the ***connected*** Structure (**STR**) window to create **new M# Links** to the Sinusoidal **ODS** into a Shape Table (**SHP**)

Acoustic Surfaces

An Acoustic Surface is a special type of Substructure that is used to display acoustic data in a Structure (**STR**) window.

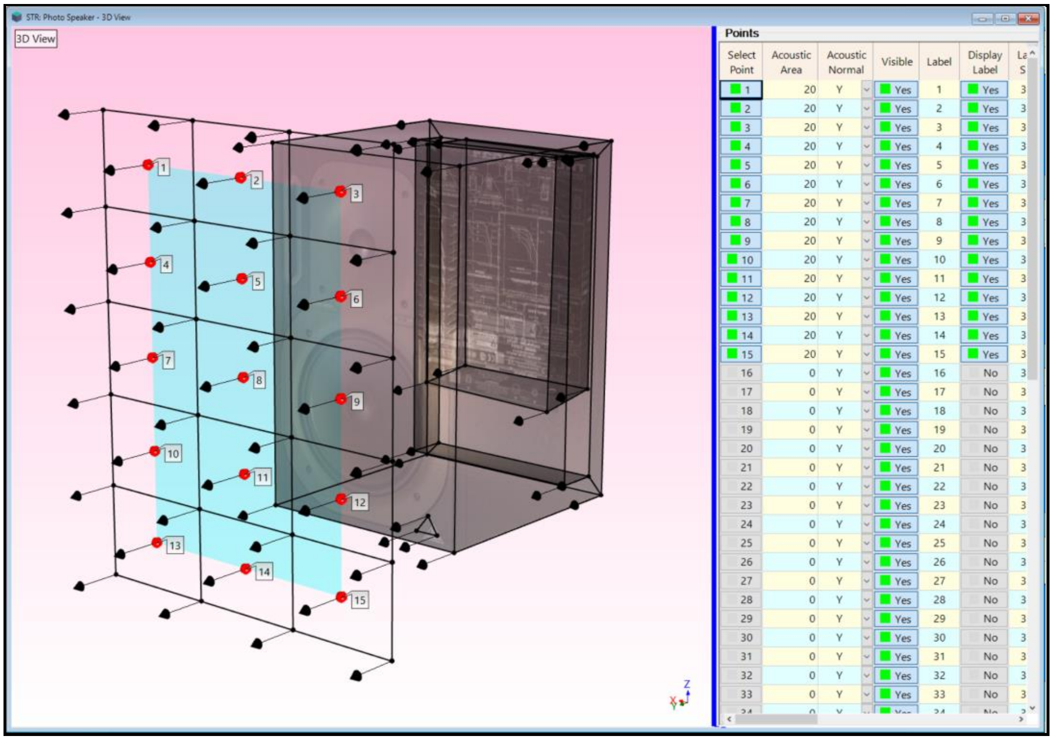
Acoustic data is typically taken on a grid of spatial Points in the vicinity of one or more noise sources.

- **SPL**, **Sound Power** & **Acoustic Intensity** is typically displayed on an Acoustic surface
- Acoustic surfaces are easily created by using the **Drawing Assistant** in the Structure (**STR**) window
- Each measurement Point on an acoustic surface ***is surrounded by an area*** that is determined when the surface is created.

The **Acoustic area** surrounding a Point and the **Acoustic Normal** to the Point are used to calculate **Sound Power** through the surface from **Intensity** data

- **Acoustic area & normal** are calculated when an acoustic surface is created in the Drawing Assistant

- **Acoustic area & normal** are listed in the **Points** spreadsheet and must be edited if the Point coordinates are changed.
- **Acoustic area** is displayed in the **Acoustic Area** column of the **Points** spreadsheet.
- The **Acoustic normal *vector*** (in the Global X, Y, Z direction) is defined in the **Acoustic Normal** column of the **Points** spreadsheet.
- Each of the bold red Points in the figure above is surrounded by 4 Points which define its **Acoustic area.**



Points

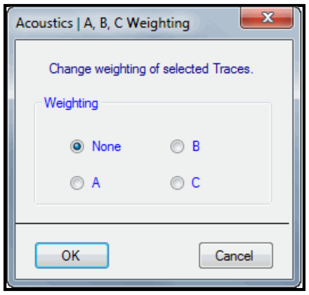
Select Point	Acoustic Area	Acoustic Normal	Visible	Label	Display Label	La S
🟩 1	20	Y	🟩 Yes	1	🟩 Yes	3
🟩 2	20	Y	🟩 Yes	2	🟩 Yes	3
🟩 3	20	Y	🟩 Yes	3	🟩 Yes	3
🟩 4	20	Y	🟩 Yes	4	🟩 Yes	3
🟩 5	20	Y	🟩 Yes	5	🟩 Yes	3
🟩 6	20	Y	🟩 Yes	6	🟩 Yes	3
🟩 7	20	Y	🟩 Yes	7	🟩 Yes	3
🟩 8	20	Y	🟩 Yes	8	🟩 Yes	3
🟩 9	20	Y	🟩 Yes	9	🟩 Yes	3
🟩 10	20	Y	🟩 Yes	10	🟩 Yes	3
🟩 11	20	Y	🟩 Yes	11	🟩 Yes	3
🟩 12	20	Y	🟩 Yes	12	🟩 Yes	3
🟩 13	20	Y	🟩 Yes	13	🟩 Yes	3
🟩 14	20	Y	🟩 Yes	14	🟩 Yes	3
🟩 15	20	Y	🟩 Yes	15	🟩 Yes	3
16	0	Y	🟩 Yes	16	No	3
17	0	Y	🟩 Yes	17	No	3
18	0	Y	🟩 Yes	18	No	3
19	0	Y	🟩 Yes	19	No	3
20	0	Y	🟩 Yes	20	No	3
21	0	Y	🟩 Yes	21	No	3
22	0	Y	🟩 Yes	22	No	3
23	0	Y	🟩 Yes	23	No	3
24	0	Y	🟩 Yes	24	No	3
25	0	Y	🟩 Yes	25	No	3
26	0	Y	🟩 Yes	26	No	3
27	0	Y	🟩 Yes	27	No	3
28	0	Y	🟩 Yes	28	No	3
29	0	Y	🟩 Yes	29	No	3
30	0	Y	🟩 Yes	30	No	3
31	0	Y	🟩 Yes	31	No	3
32	0	Y	🟩 Yes	32	No	3
33	0	Y	🟩 Yes	33	No	3
34	0	Y	🟩 Yes	34	No	3

Acoustic Surface Showing Areas & Normal Vectors.

Data Block (BLK) Acoustics Menu

Acoustics | ABC Weighting

Applies A, B or C weighting to ***all*** (or ***selected***) ***frequency domain measurements*** in a Data Block (**BLK**). When it is executed, a dialog box is opened.



Acoustics | A, B, C Weighting

Change weighting of selected Traces.

Weighting

● None ○ B

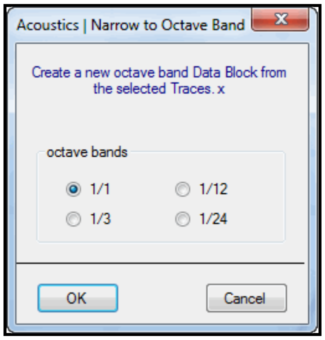
○ A ○ C

OK Cancel

- Choose the type of weighting to be applied and ***click*** on **OK** to apply the weighting

Acoustics | Narrow to Octave Band

Creates a new Data Block (**BLK**) of ***octave band measurements*** from a Data Block (**BLK**) of ***narrow band frequency domain measurements***. When it is executed, a dialog box is opened.



Acoustics | Narrow to Octave Band

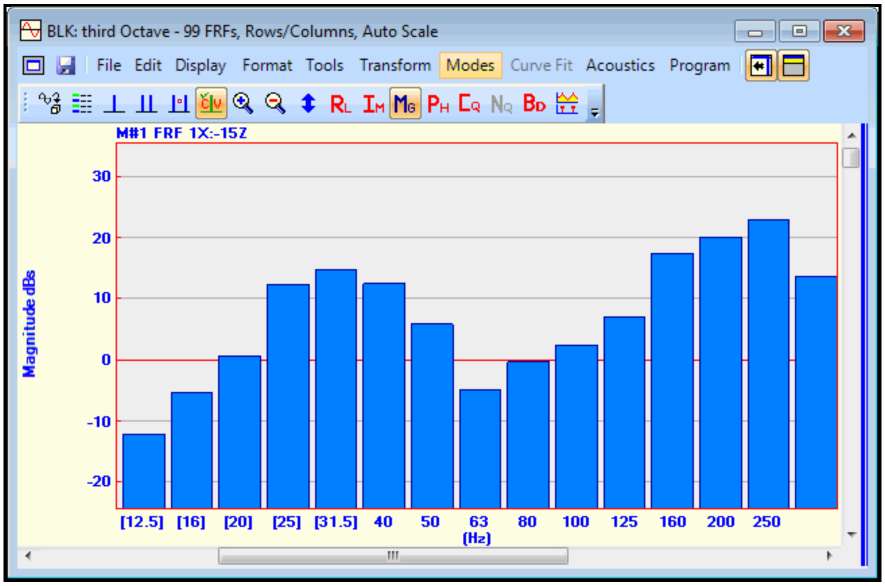
Create a new octave band Data Block from the selected Traces. x

octave bands

- ● 1/1
- ○ 1/3
- ○ 1/12
- ○ 1/24

- Choose the octave band in the dialog box and ***click*** on **OK**.

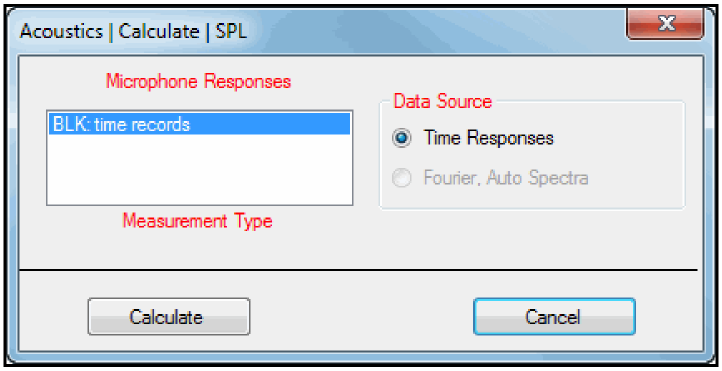
If ***less than 5 samples*** of narrow band data were used to create an octave band, the octave band frequency is enclosed in **brackets [ ]**. In the figure below, several Octave bands were created with ***less than 5 samples***.



Octave Band Measurement Showing Bands Created from Less Than 5 Samples.

Acoustics | Calculate | SPL

Creates a new Data Block (**BLK**) of **Sound Pressure Level (SPL)** measurements from microphone **TWF**s, **DFTs** or Auto spectra. When this command is executed, the following dialog box will open.



Acoustics | Calculate | SPL

Microphone Responses

BLK: time records

Measurement Type

Data Source

- ● Time Responses
- ○ Fourier, Auto Spectra

Time Responses

If **Time Responses** is chosen as the **Data Source**, all open Data Blocks (**BLK**s) **with TWFs** in them are listed in the dialog box.

DFTs and Auto Spectra

If **Fourier, Auto Spectra** is chosen as the **Data Source**, all open Data Blocks (**BLK**s) with **Fourier spectra** (**DFTs**) or **Auto spectra** in them are listed in the dialog box.

SPL spectra are calculated in the following ways,

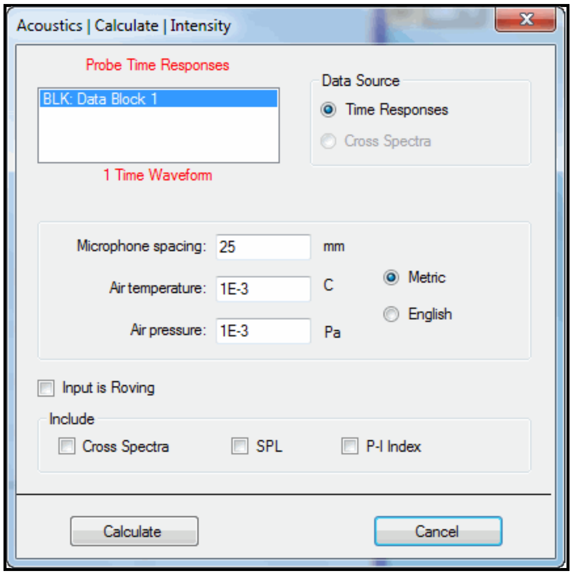
- **DFT *magnitude* ➔ SPL** spectrum
- ***Square root*** of an Auto spectrum with ***power units*** ➔ **SPL** spectrum
- Auto spectrum with ***linear units*** ➔ **SPL** spectrum

Acoustics | Calculate | Intensity

Creates a new Data Block (**BLK**) of Acoustic Intensity measurements **from TWFs** or a **Cross spectrum** calculated from data acquired with a **two**-microphone Acoustic Probe.

- Four-microphone data (taken with 3 Responses & 1 Reference) can also be used with this command

When this command is executed, a dialog box is opened



Acoustics | Calculate | Intensity

Probe Time Responses

BLK: Data Block 1

1 Time Waveform

Data Source

● Time Responses

○ Cross Spectra

Microphone spacing: 25 mm

Air temperature: 1E-3 C

Air pressure: 1E-3 Pa

● Metric

○ English

□ Input is Roving

Include

□ Cross Spectra □ SPL □ P-I Index

Time Responses

If **Time Responses** is chosen as the **Data Source**, all open Data Blocks (**BLK**s) **with TWFs** in them are listed in the dialog box.

- **Roving waveforms** must be identified as (**Output** or **Both**) in the **Input Output** column of the **M#s** spreadsheet
- **Fixed Reference waveforms** must be identified as (**Input** or **Both***)* in the **Input Output** column of the **M#s** spreadsheet

Cross Spectra

If **Cross Spectra** is chosen as the **Data Source**, all the open Data Blocks (**BLK**s) **with Cross spectra** in them are listed in the dialog box.

Acoustic Intensity is calculated from the Cross spectrum between a pair of microphone responses with the formula,

$$\text{Intensity} = \frac{-(\text{Imaginary Part}(\text{XPS}))}{\rho \Delta X \omega}$$

$\text{XPS} = \text{Cross Power Spectrum}$

$\rho = \text{Air Density}$

$\Delta X = \text{Microphone Spacing}$

$\omega = \text{Frequency}$

- Air density is calculated from the air pressure and temperature values

SPL and P-I Index

Both **SPL** and **P-I Index** measurements can be calculated at the ***same time as*** **Acoustic Intensity** by ***checking*** these selections in the **Calculate Intensity** dialog box.

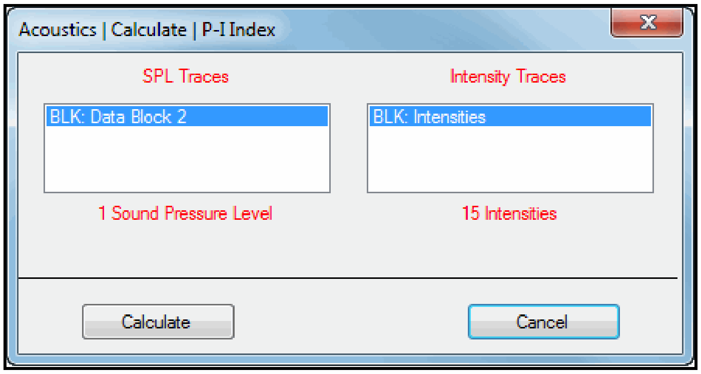
Acoustics | Calculate | P-I Index

Calculates the **Pressure-Intensity (P-I) Index** from SPL and Intensity functions.

The P-I Index is calculated as,

P-I Index (dB) = (SPL (dB Reference 20 ω PA) - Intensity (dB Reference (e-12 watts/m^2))

When this command is executed, a dialog box is opened



Acoustics | Calculate | P-I Index

SPL Traces

BLK: Data Block 2

1 Sound Pressure Level

Intensity Traces

BLK: Intensities

15 Intensities

- When the **Calculate** button is ***pressed***, a new Data Block (**BLK**) file with **P-I Index M#s** is created

Acoustics | Intensity to Power

Calculates **Sound Power M#s** from a Data Block (**BLK**) containing **Acoustic Intensity M#s**.

Sound Power is calculated by ***multiplying*** **Acoustic Intensity** by the **surface area** surrounding its corresponding measurement Point on an Acoustic Surface in a ***connected*** Structure (**STR**) window.

- The ***connected*** Structure (**STR**) window must have an Acoustic Surface with ***uniquely numbered*** **Points** that match the Point numbers in the **Roving DOFs** of the Intensity measurements
    - ***Each matching*** **Point** must also have a **non-zero** surface area associated with it
- The calculated **Sound Power M#s** are ***added*** to the **Acoustic Intensity M#s** in the same Data Block (**BLK**)

Animating Sound Power & Intensity Together

Sound Power and Acoustic Intensity shapes must be scaled differently in order to display them together in animation. This is done by ***defining two Groups*** of **M#s**

- Execute **Edit | Select M#s | Select By** and choose **Sound Power** from the Measurement Type drop-down list
  - ***Press*** the **Select button** to ***select*** the **Sound Power M#s** and press ***Close***
- ***Double click*** on the **Group** column heading in the **M#s** spreadsheet, and type ***"Sound Power"*** into the dialog box
- Execute **Edit | Select M#s | Select By** again, and choose **Intensity** from the Measurement Type drop-down list, and.
  - ***Press*** the **Select** button to ***select*** the Intensity **M#s** and press ***Close***
- ***Double click*** on the **Group** column heading in the **M#s** spreadsheet, and type **"Intensity"** into the dialog box

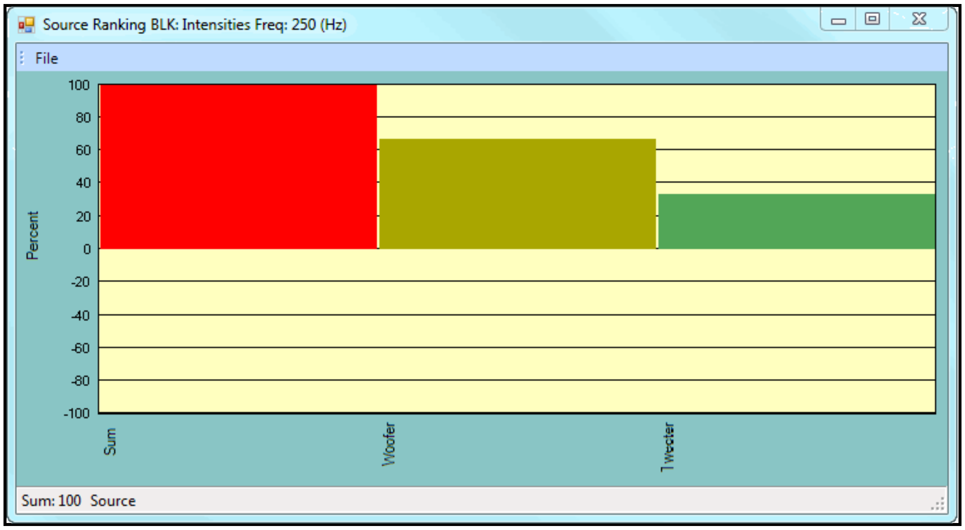
To animate the Sound Power & Acoustic Intensity data together,

- Execute **Deflection | Animate Using | Groups** in the Structure (**STR**) window

Acoustics | Source Ranking | Chart

Opens the Acoustic Source Ranking bar chart window. This window displays a bar chart ranking the relative strengths of the **Acoustic Sources** at the cursor position for ***all*** (or ***selected***) **M#s.**

- In this bar chart, Source ***percentages*** are plotted on the ***vertical axis*** and **Source Names** on the ***horizontal axis***
- Acoustic Sources are defined in the **Acoustic Source** column of the **M#s** spreadsheet



Source Ranking Chart

Values at Cursor Position

The Source Ranking bar chart is updated whenever the Data Block (**BLK**) cursor is moved.

- If the **Line** or **Peak** cursor is displayed, the **M#** values at the cursor position are Source ranked
- If the **Band** cursor is displayed, the ***sum* of the M# values** in the band are Source ranked
- The first bar is the ***Sum*** of all sources and is always **100%**

Which Magnitudes Are Ranked?

- If the **Real** part of the data is displayed, the ***absolute values*** of the **Real** parts are ranked

- If the **Imaginary** part of the data is displayed, the ***absolute values*** of the **Imaginary** parts are ranked
- **Otherwise,** the ***magnitudes*** of the data are ranked

Status Bar

- ***Hover*** the mouse pointer over the Source Rank **bar** of a source to display information for that source on the Status Bar at the bottom of the window

Source Ranking

Measurements are associated with an acoustic source by giving them a common **Acoustic Source** name. An acoustic source would typically be a physical source which is nearest to the Points associated with a group of **M#s**

- Source ranking ***sums the data*** from all Points associated with each Acoustic Source
- After each Source value is calculated, it is ***normalized*** by the total of the magnitudes of all Sources, yielding a **percentage** value for each Source

Source names are entered as text into the **Acoustic Source** column of the **M#s** spreadsheet. Source ranked data can be,

- Displayed in a bar chart
- Animated on an acoustic surface by executing **Deflection | Animate Using | Acoustic Source** in the ***connected*** Structure (**STR**) window
- Saved in a Shape Table (**SHP**) by executing **Acoustics | Source Ranking | Save Shape by Source**

Naming Acoustic Sources

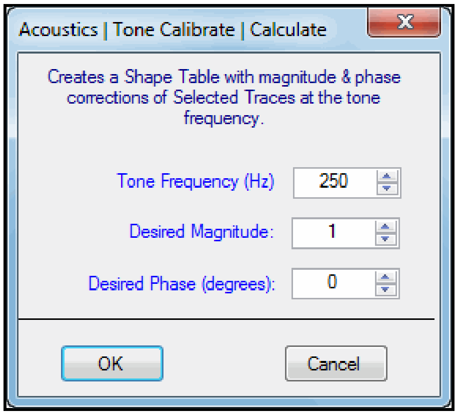
To give the ***same name*** to a group of **M#s linked to Points** on an acoustic surface,

1. Execute **M# Links | Create M# Links** to create **M# Links** in a ***connected*** Structure (**STR**) window containing the structure model with **acoustic surfaces**
2. ***Select*** a **Substructure** on the model that defines ***a single*** **Acoustic Source**
3. Execute **M# Links | Select Source M#s** to select the **M#s** in the Data Block (**BLK**) that are linked to the Source
4. ***Double click*** on the **Acoustic Source** column in the **M#s** spreadsheet
5. Enter an Acoustic Source **name** into the **Acoustic Source** column in the **M#s** spreadsheet

Repeat the above steps to name other Acoustic Sources

Acoustics | Tone Calibration | Calculate

Creates a Shape Table (**SHP**) of scale factors that can be used to calibrate acoustic measurements. When this command is executed, a dialog box is opened.



Acoustics | Tone Calibrate | Calculate

Creates a Shape Table with magnitude & phase corrections of Selected Traces at the tone frequency.

Tone Frequency (Hz) 250

Desired Magnitude: 1

Desired Phase (degrees): 0

- Enter the **Tone Frequency**, **Desired Magnitude**, & **Desired Phase** into the dialog box, and ***click*** on OK

Acoustics | Tone Calibration | Apply

Applies the tone calibration scale factors stored in a Shape Table (**SHP**) to the acoustic **M#s** in a Data Block (**BLK**).

- The scale factor for ***each* M#** in the **M#s** spreadsheet in the Shape Table (**SHP**) is applied to the **M#** with ***matching* DOF** in the Data Block (**BLK**)

Acoustics | Save Ln

Calculates **Ln** values for ***all*** (or ***selected***) **M#s** in a Data Block (**BLK**) and stores them in a Shape Table (**SHP**).

Because noise levels often fluctuate over a wide range and over time, a single value descriptor called the **Leq - Equivalent Level** is often used to characterize the noise level statistics of a signal.

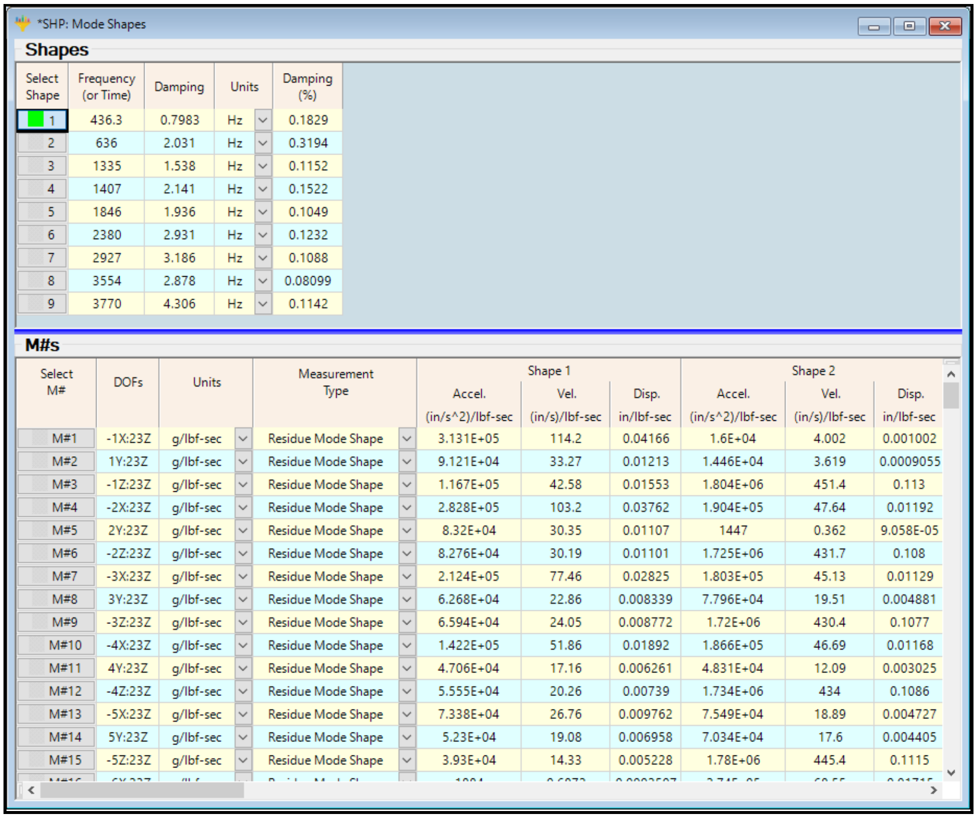
A useful set of **Statistical Noise Levels** are the **Ln** values of an acoustic signal. Any statistical value between 0.01% and 99.99% can be calculated, but the widely used ones are L10, L90 & L95.

- If the **Line** or **Peak** cursor is displayed, **Ln** values are calculated at the **Line** cursor position
- If the **Band** is displayed, **Ln** values are calculated using all the samples in the band

Shape Table (SHP) Display | M#s Menu

Display | M#s | Accel, Vel, Disp

Displays the shape data in the **M#s** spreadsheet in Acceleration, Velocity or Displacement units.



*SHP: Mode Shapes

Shapes

Select Shape	Frequency (or Time)	Damping	Units	Damping (%)
🟩 1	436.3	0.7983	Hz	0.1829
2	636	2.031	Hz	0.3194
3	1335	1.538	Hz	0.1152
4	1407	2.141	Hz	0.1522
5	1846	1.936	Hz	0.1049
6	2380	2.931	Hz	0.1232
7	2927	3.186	Hz	0.1088
8	3554	2.878	Hz	0.08099
9	3770	4.306	Hz	0.1142

M#s

Select M#	DOFs	Units	Measurement Type	Shape 1			Shape 2		
				Accel. (in/s^2)/lbf-sec	Vel. (in/s)/lbf-sec	Disp. in/lbf-sec	Accel. (in/s^2)/lbf-sec	Vel. (in/s)/lbf-sec	Disp. in/lbf-sec
M#1	-1X:23Z	g/lbf-sec	Residue Mode Shape	3.131E+05	114.2	0.04166	1.6E+04	4.002	0.001002
M#2	1Y:23Z	g/lbf-sec	Residue Mode Shape	9.121E+04	33.27	0.01213	1.446E+04	3.619	0.0009055
M#3	-1Z:23Z	g/lbf-sec	Residue Mode Shape	1.167E+05	42.58	0.01553	1.804E+06	451.4	0.113
M#4	-2X:23Z	g/lbf-sec	Residue Mode Shape	2.828E+05	103.2	0.03762	1.904E+05	47.64	0.01192
M#5	2Y:23Z	g/lbf-sec	Residue Mode Shape	8.32E+04	30.35	0.01107	1447	0.362	9.058E-05
M#6	-2Z:23Z	g/lbf-sec	Residue Mode Shape	8.276E+04	30.19	0.01101	1.725E+06	431.7	0.108
M#7	-3X:23Z	g/lbf-sec	Residue Mode Shape	2.124E+05	77.46	0.02825	1.803E+05	45.13	0.01129
M#8	3Y:23Z	g/lbf-sec	Residue Mode Shape	6.268E+04	22.86	0.008339	7.796E+04	19.51	0.004881
M#9	-3Z:23Z	g/lbf-sec	Residue Mode Shape	6.594E+04	24.05	0.008772	1.72E+06	430.4	0.1077
M#10	-4X:23Z	g/lbf-sec	Residue Mode Shape	1.422E+05	51.86	0.01892	1.866E+05	46.69	0.01168
M#11	4Y:23Z	g/lbf-sec	Residue Mode Shape	4.706E+04	17.16	0.006261	4.831E+04	12.09	0.003025
M#12	-4Z:23Z	g/lbf-sec	Residue Mode Shape	5.555E+04	20.26	0.00739	1.734E+06	434	0.1086
M#13	-5X:23Z	g/lbf-sec	Residue Mode Shape	7.338E+04	26.76	0.009762	7.549E+04	18.89	0.004727
M#14	5Y:23Z	g/lbf-sec	Residue Mode Shape	5.23E+04	19.08	0.006958	7.034E+04	17.6	0.004405
M#15	-5Z:23Z	g/lbf-sec	Residue Mode Shape	3.93E+04	14.33	0.005228	1.78E+06	445.4	0.1115

Acceleration, Velocity or Displacement calculations is based on the **Units** of the **M#s.**

If the **Units** are ***acceleration*** units.

- **Velocity** shapes are calculated by ***dividing each shape component by the shape frequency***
- **Displacement** shapes are calculated by ***dividing each shape component by the shape frequency squared***

If the **Units** are ***velocity units***,

- **Acceleration** shapes are calculated by ***multiplying each shape component by the shape frequency***
- **Displacement** shapes are calculated by ***dividing each shape component by the shape frequency***

If the output **Units** are ***displacement***,

- **Velocity** shapes are calculated by ***multiplying each shape component by the shape frequency***
- **Acceleration** shapes are calculated by ***multiplying each shape component by the shape frequency squared***

Shape Table (SHP) Tools Menu

Tools | Integrate

Integrates **Residue mode shapes** from ***acceleration to velocity*** units or from ***velocity to displacement*** units.

- The mode shapes must be converted to **Residue mode shapes** before using this command
- Integration is performed by ***dividing each shape component*** by its ***complex pole*** (***frequency & damping***)

Tools | Differentiate

Differentiates **Residue mode shapes** from ***displacement to velocity*** units or from ***velocity to acceleration*** units

- The mode shapes must be converted to **Residue mode shapes** before using this command
- Differentiation is performed by ***multiplying each shape component*** by its ***complex pole*** (**frequency & damping**)

Tools | Shape Product

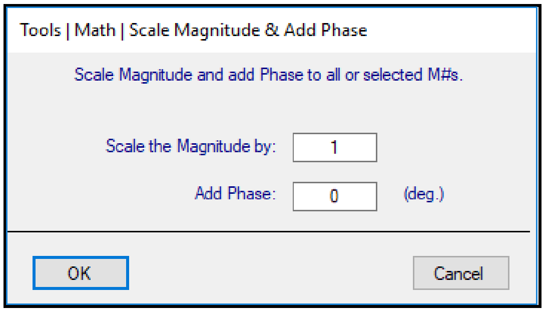
Multiplies ***all*** (or ***selected***) shapes together.

- A Shape Product shows ***where all shapes have node lines*** (zero values), and hence where ***inactive* DOFs** are located
- A Shape Product shows ***where all shapes have anti-nodes*** (large magnitudes**)**, and hence where ***active* DOFs** are located

When a Shape Product is displayed in animation on the structure model in a ***connected*** Structure (**STR**) window, ***node lines*** and ***anti-nodes are easily seen***

Tools | Math | Scale M#s

Scales the ***magnitude*** and ***adds phase*** to ***all*** (or ***selected***) Shapes and ***all*** (or ***selected***) **M#s**.


Tools | Math | Scale Magnitude & Add Phase

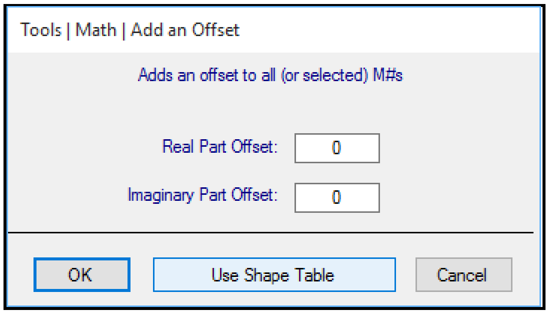
Scale Magnitude and add Phase to all or selected M#s.

Scale the Magnitude by: 1

Add Phase: 0 (deg.)

Tools | Math | Add an Offset

Adds a complex (real & imaginary) offset to ***all*** (or ***selected***) Shapes and ***all*** (or ***selected***) **M#s**.



Tools | Math | Add an Offset

Adds an offset to all (or selected) M#s

Real Part Offset: 0

Imaginary Part Offset: 0

Tools | Math | Invert M#s

Replaces each **M#** with its ***inverse*** for ***all*** (or ***selected***) Shapes and ***all*** (or ***selected***) **M#s**.

Tools | Math | Square M#s

Replaces each **M#** with its ***value squared*** for ***all*** (or ***selected***) Shapes and ***all*** (or ***selected***) **M#s**.

Tools | Math | Square Root of M#s

Replaces each **M#** with the ***square root*** of its value for ***all*** (or ***selected***) Shapes and ***all*** (or ***selected***) **M#s**.

Tools | Math | Add (Subtract, Multiply, Divide) two M#s

Performs the indicated operation between **M#s** in a Shape Table (**SHP**) and ***a selected*** **M#** in the same or a different Shape Table (**SHP**).

- If two Shape Tables (**SHP**s) have the ***same number of M#s*** in them, you can choose to perform the operation ***between M# pairs*** in the two Shape Tables (**SHP**s)