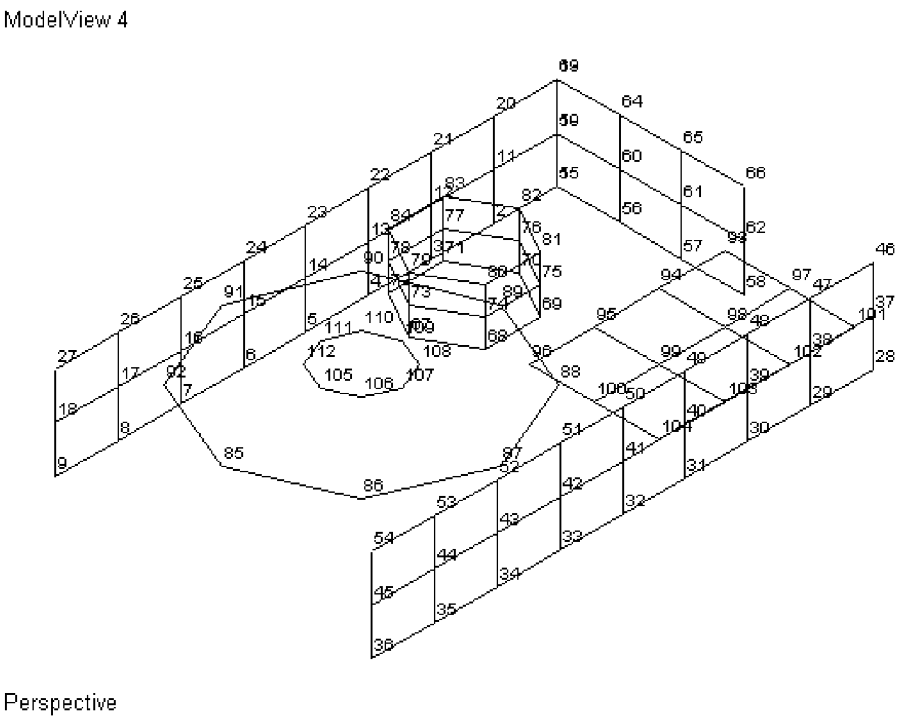
SPECTRAL DYNAMICS

STAR® 6

Features and Examples

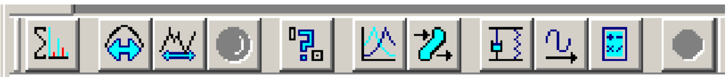
STAR 6 represents a major upgrade of the widely used, PC-based, STAR System Modal Analysis product. All of the popular features of STAR have been maintained and incredible new displays have been added to take advantage of today's enhanced graphical capabilities. A special version of STAR, CATS® Modal, has also been released to provide enhanced Data Acquisition and FRF measurement capability when using Spectral Dynamics Analyzers such as PUMA, COUGAR or PANTHER. STAR is equally at home using Single Reference or Multiple Reference (MIMO) data sets.

In terms of performing a complete Modal Analysis Project, STAR has acquired a well-deserved reputation as the most thorough and easy-to-use PC-based system available today. STAR 6 continues this tradition with enhanced visualization of the measurements and the structure at every step of the way. The example used in this presentation is a computer disk drive which has been modeled with 7 components, totaling 112 points. These components or elements include Side 1, Side 2, End 1, Motor Seat, Motor Seat 2, Disk Seat and Flat 1. These 7 components can be put together, in a Global Coordinate System to form a Model as shown below:



In the following presentation, many of the features and new displays of STAR 6 will be shown and described.

The main bar of STAR, shown above, gives an indication of the many areas covered by the STAR System. Particular functions or features which may be important to your particular project may be broken out as individual Icons to create a customized project bar for your own convenience and rapid access. An example of such a customization is shown below:



A full description of these Icons can be seen simply by pointing the mouse at a particular one. In this example the meaning of each of these Icons from left to right is:

- Modal Peaks
- Curve-fitting
- Advanced Curve-fit Wizard
- Live Time Domain Analysis
- Modal Assurance Criteria
- FRF Synthesis
- Forced Response Synthesis
- Structural Dynamics Modification
- Sinusoidal Response
- Mode Calculation
- Abort the current function

A set of measured Frequency Response Functions are typically brought into STAR by either writing them directly to STAR Binary files, as UFF files or by translating them from certain other file formats. However they are created, STAR 6 permits viewing of the FRF's in many different ways. Following are several examples of these versatile presentations.

Viewing the measured Response Functions:

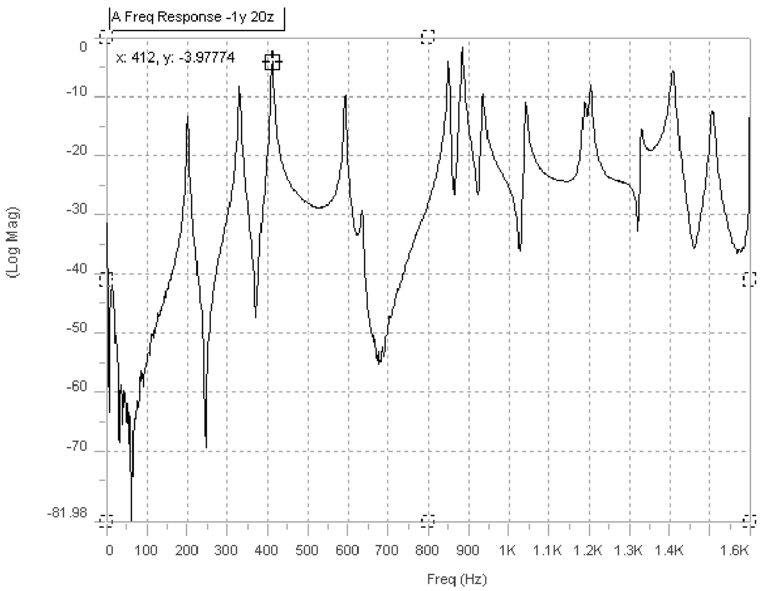


Fig. 1; Log Magnitude display of a cross Transfer Function

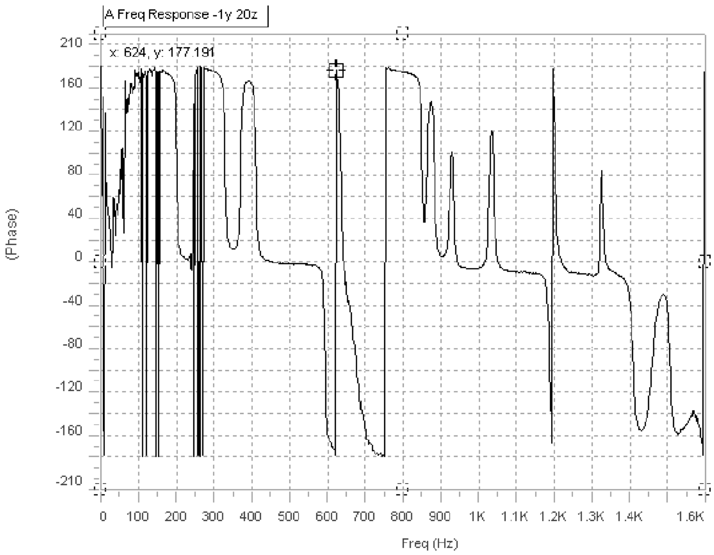


Fig. 2; Phase corresponding to FRF of Figure 1

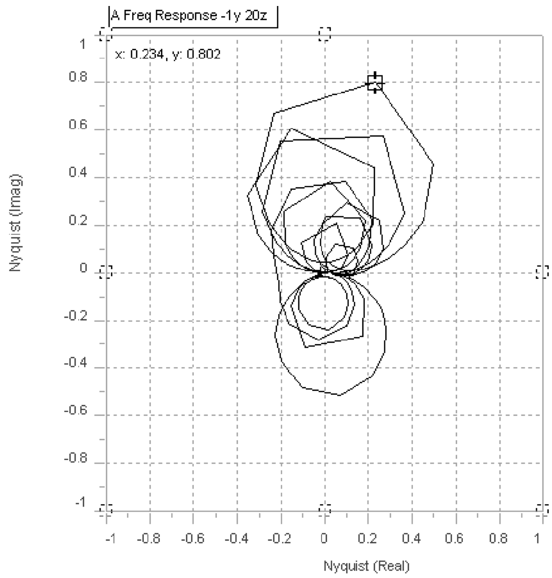


Fig. 3; Nyquist display of FRF from Figures 1 and 2

Note the Cursor which is shown in each of the first 3 FRF displays. For multiple, simultaneous displays, the cursors can be “locked”, permitting easy interpretation of both Magnitude and direction for any selected resonant peak. This also facilitates assigning a frequency to any point on a Nyquist display.

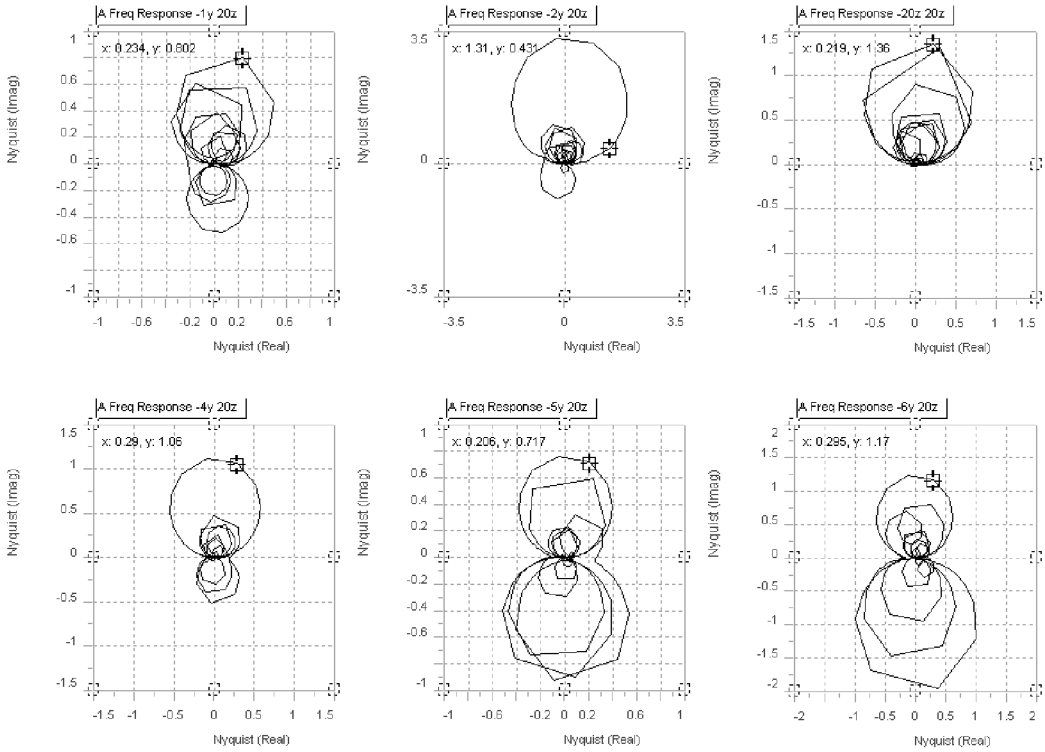


Fig. 4; Multiple Nyquist displays shown simultaneously

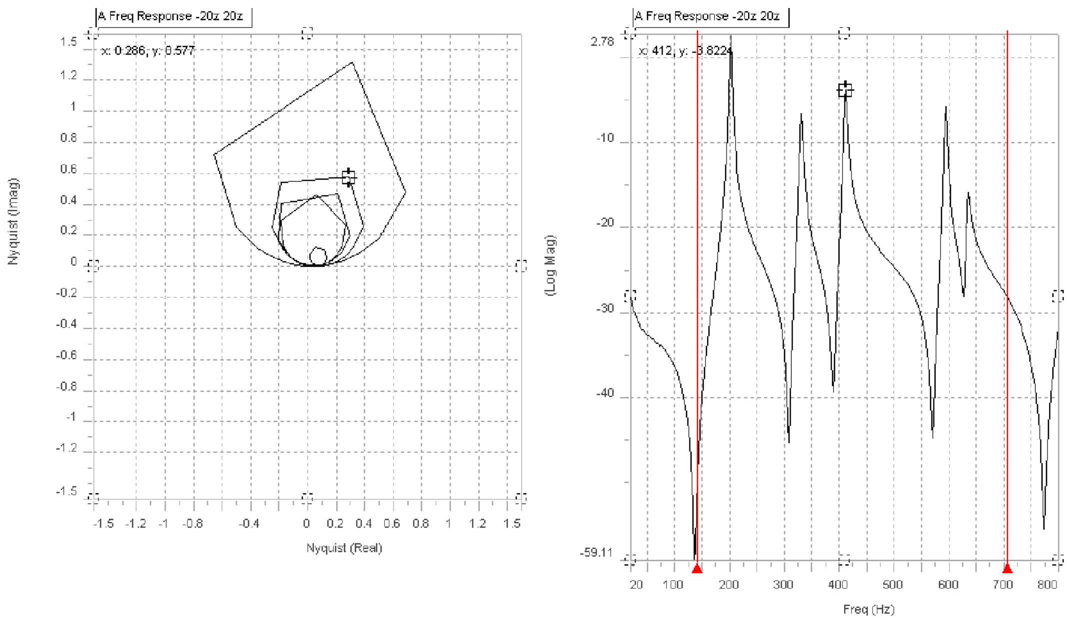


Fig. 5; Band limited display of Driving Point FRF

To more readily understand the content of certain measured Frequency Response Functions, a selected frequency band may be expanded whether the display is Magnitude, Phase or a Polar (Nyquist) diagram. An example of observing the first 5 resonances of the Driving Point FRF for the current data set is seen in Figure 5. Here it is clear that 5 distinct resonances are occurring between 20 Hz and 800 Hz.

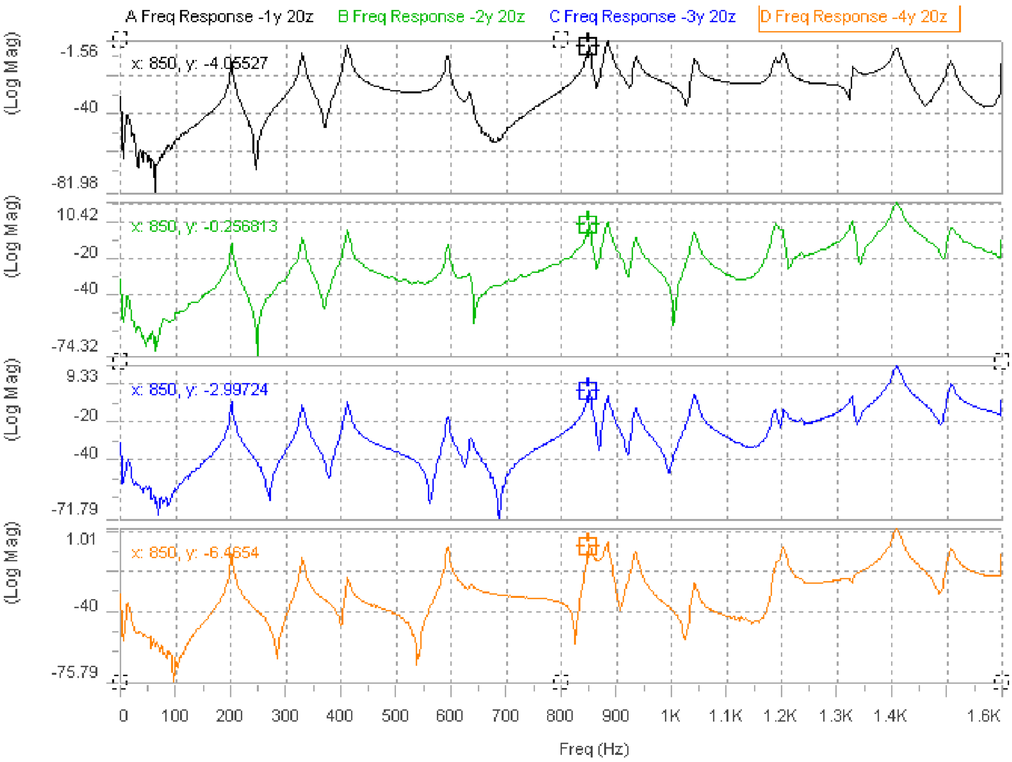


Fig. 6; First 4 FRF’s shown in Cascade format

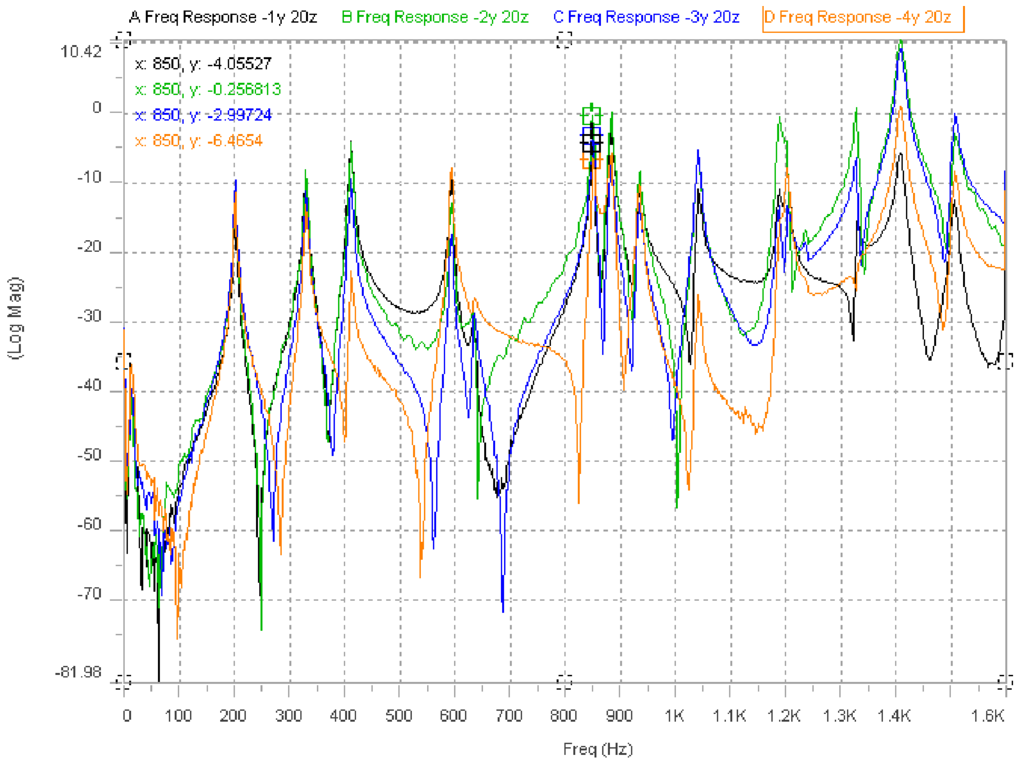


Fig. 7; First 4 FRF’s shown overlaid, one upon another

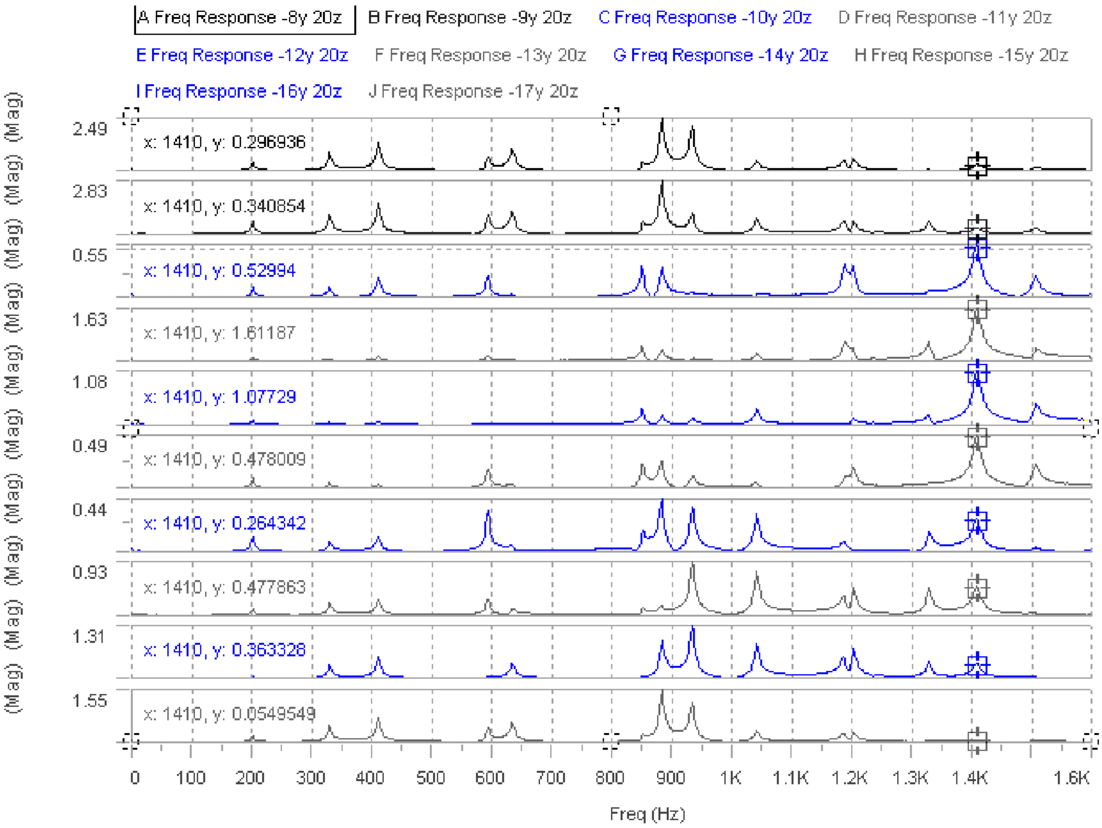


Fig. 8; Cascade of 10 FRF's shown in Linear Magnitude format

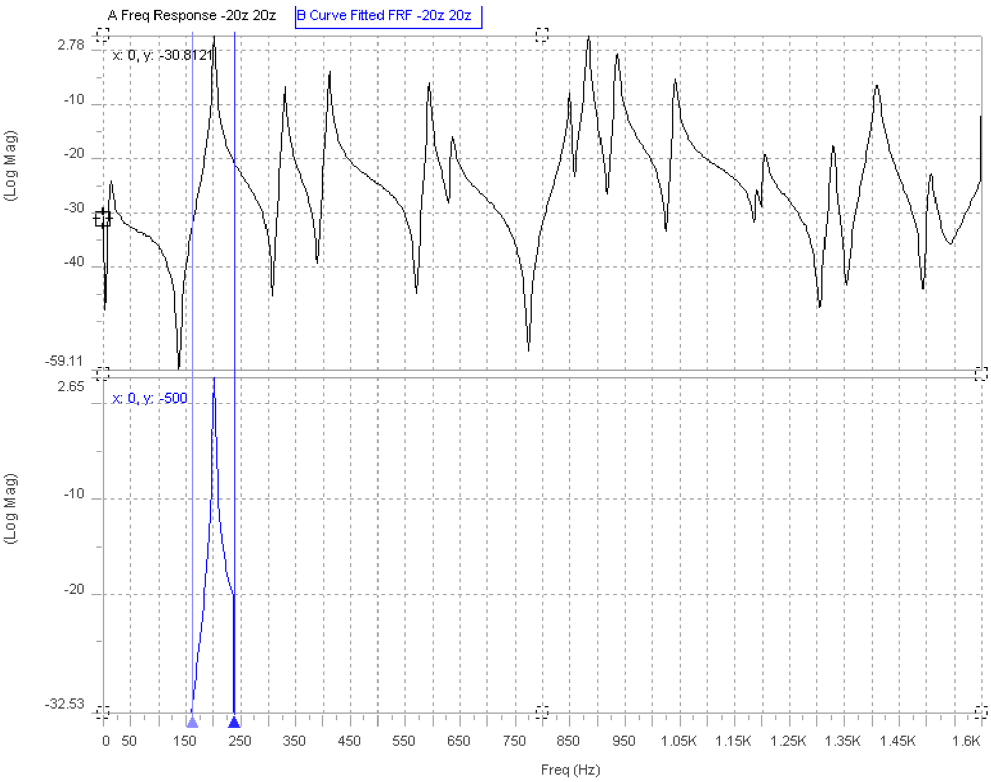


Fig. 9; Curve-fit of first resonance shown tiled with full Driving Point FRF

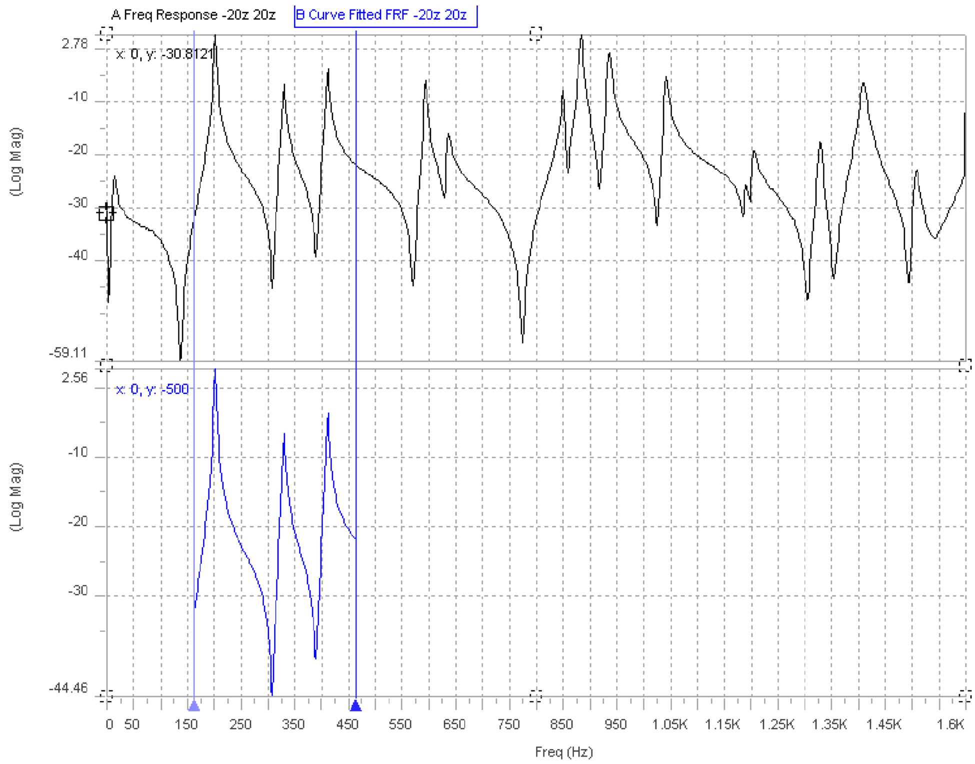


Fig. 10; Curve-fit of first 3 resonances shown tiled with full Driving Point FRF

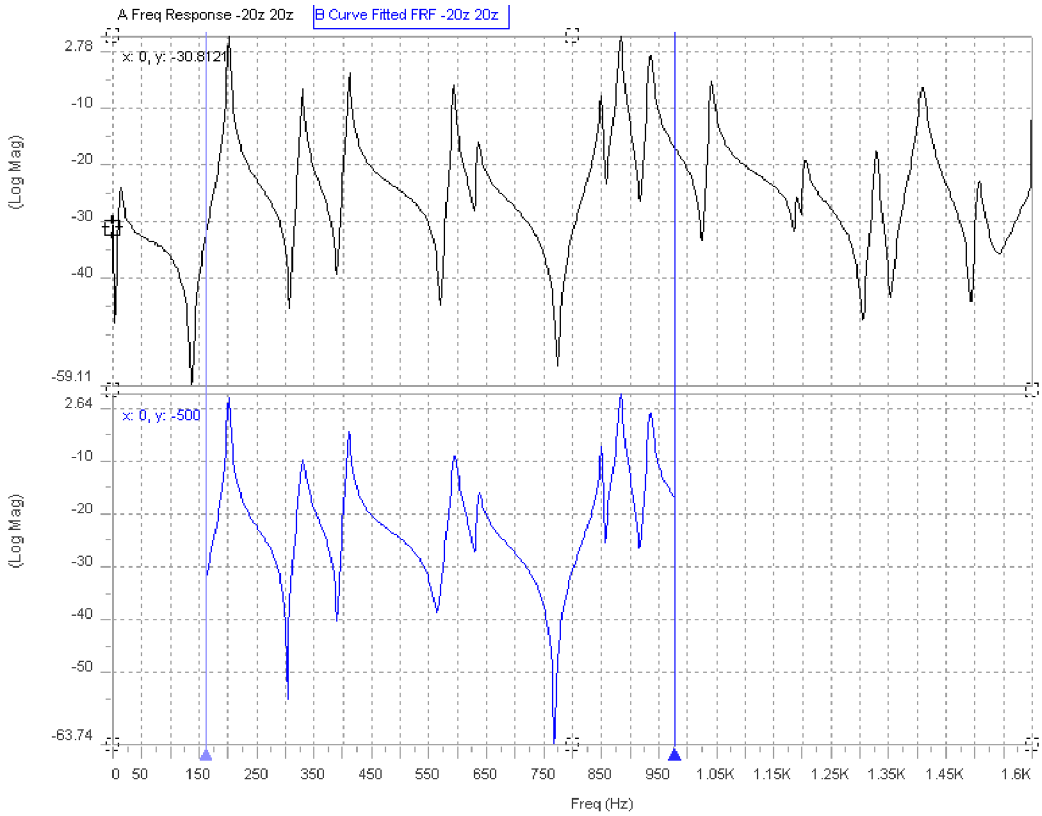


Fig. 11; Curve-fit of first 8 resonances shown tiled with full Driving Point FRF

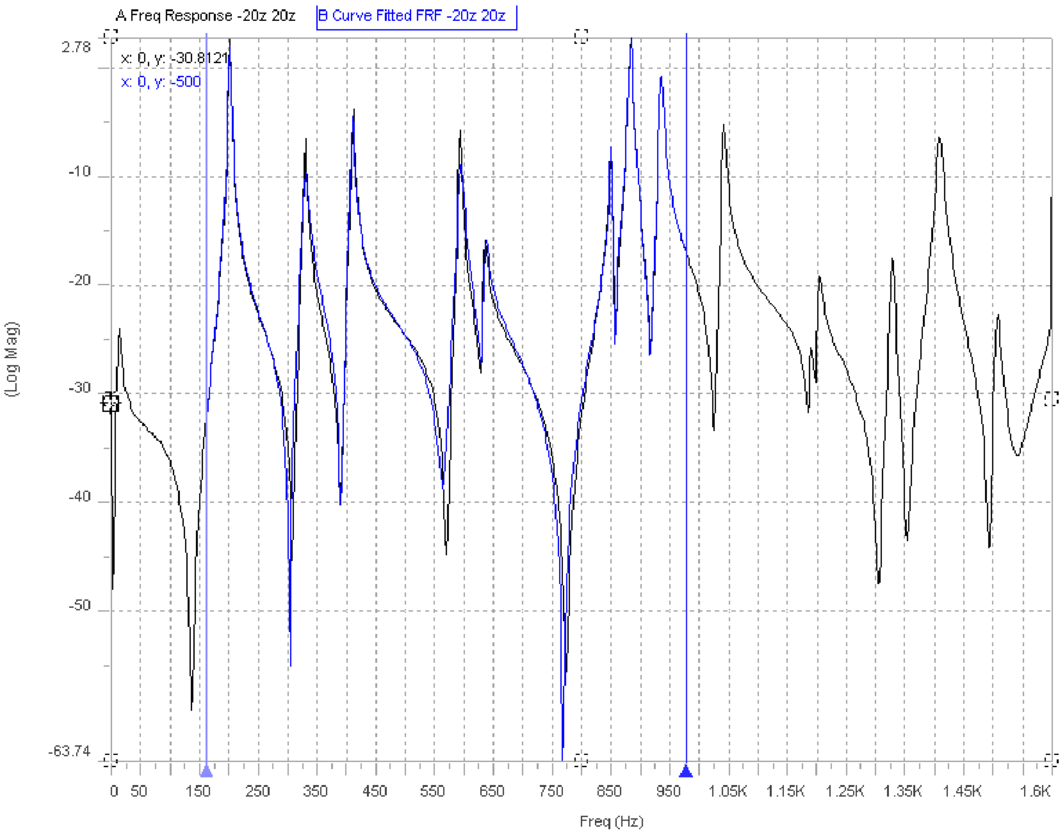


Fig. 12; Overlay of curve-fit of 8 resonances with test data

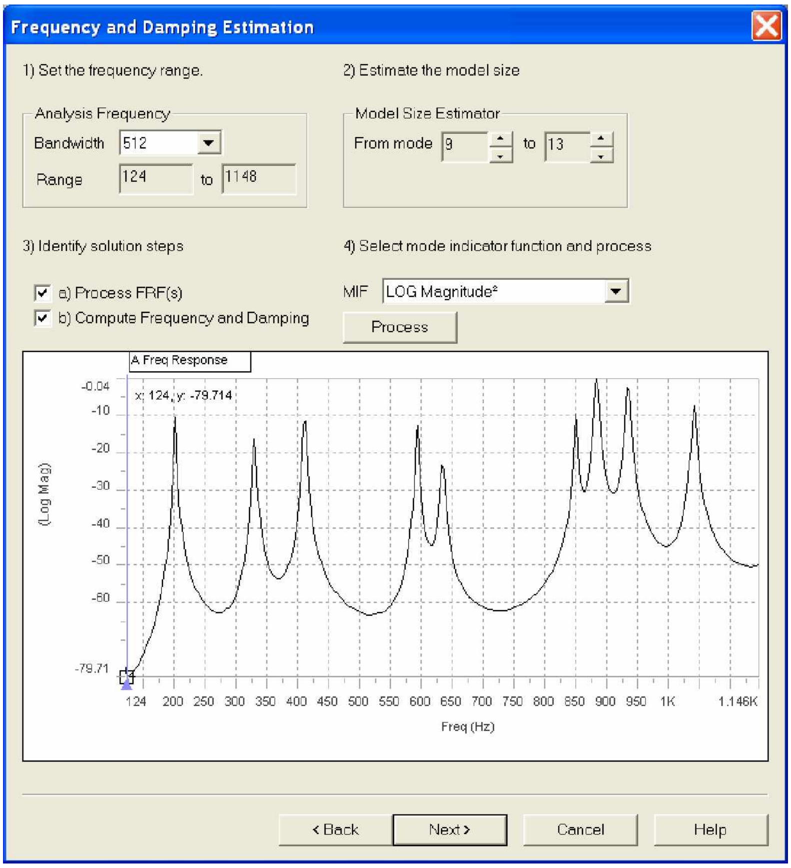


Fig. 13; Setting up FRF for curve-fit

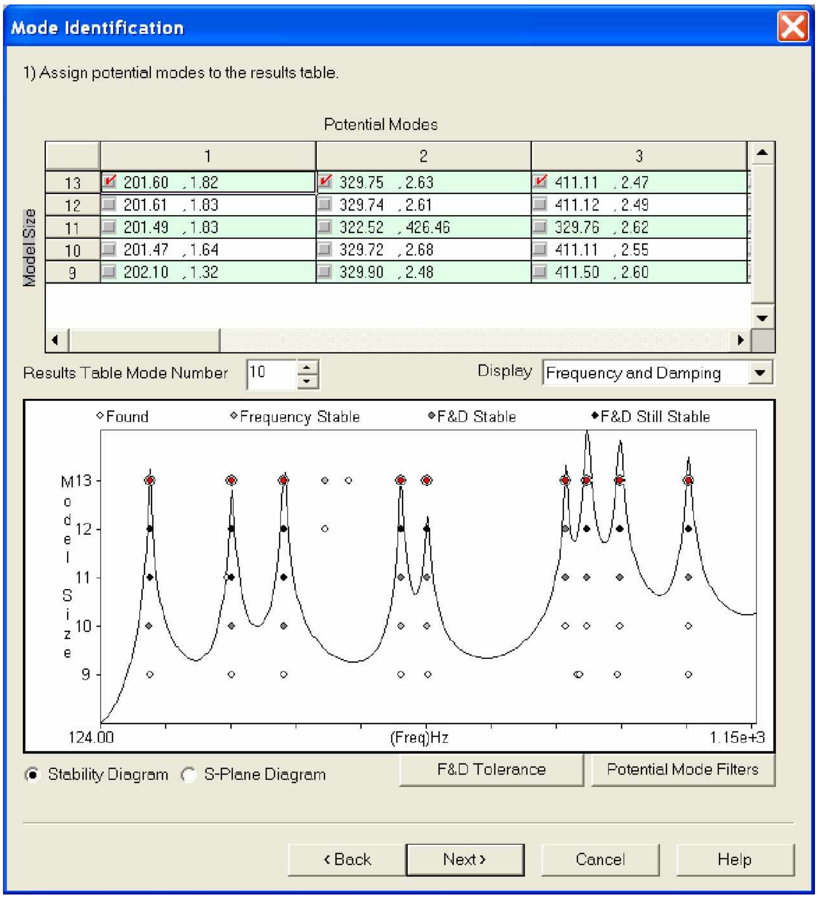


Fig. 14; Setting up Stability Diagram as part of Modal Identification Function

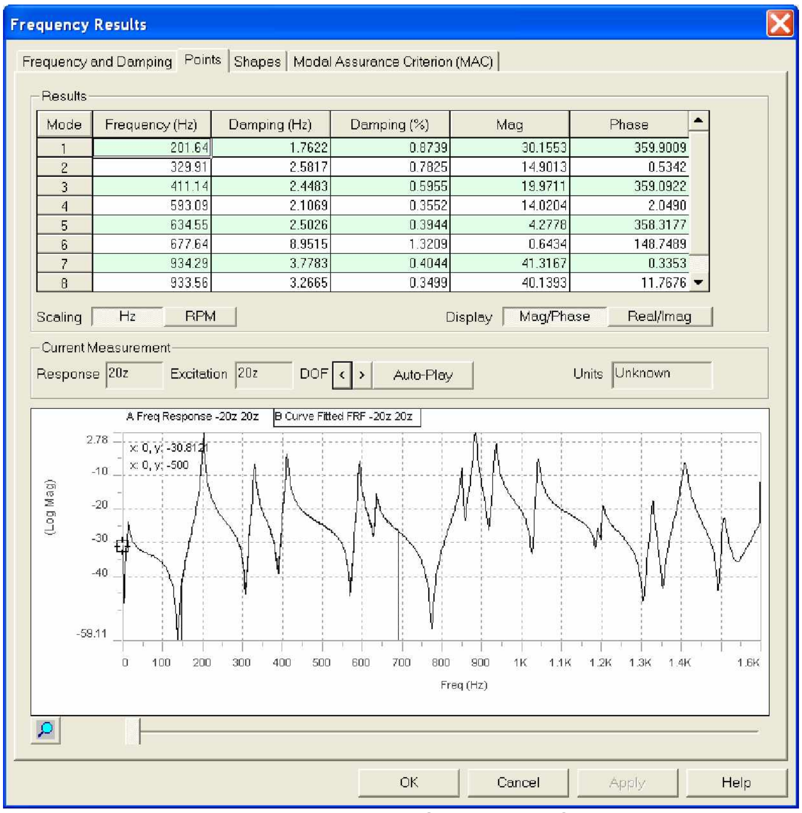
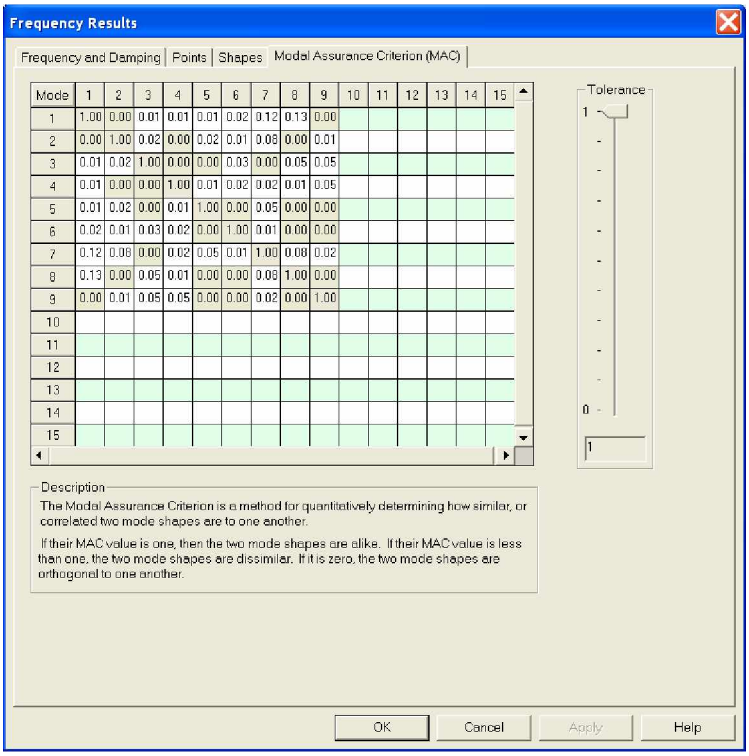


Fig. 15; Driving Point FRF with first 8 identified Resonances



Mode	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.00	0.00	0.01	0.01	0.01	0.02	0.12	0.13	0.00						
2	0.00	1.00	0.02	0.00	0.02	0.01	0.08	0.00	0.01						
3	0.01	0.02	1.00	0.00	0.00	0.03	0.00	0.05	0.05						
4	0.01	0.00	0.00	1.00	0.01	0.02	0.02	0.01	0.05						
5	0.01	0.02	0.00	0.01	1.00	0.00	0.05	0.00	0.00						
6	0.02	0.01	0.03	0.02	0.00	1.00	0.01	0.00	0.00						
7	0.12	0.08	0.00	0.02	0.05	0.01	1.00	0.08	0.02						
8	0.13	0.00	0.05	0.01	0.00	0.00	0.08	1.00	0.00						
9	0.00	0.01	0.05	0.05	0.00	0.00	0.02	0.00	1.00						
10															
11															
12															
13															
14															
15															

Fig. 16; Modal Assurance Criteria (MAC) for first 9 Modes

Displaying the Modal Model:

Once the Resonant Frequencies and Residues have been extracted through the selected curve-fitting technique and the Modal Assurance Criteria have been established, it is, typically, time to observe and animate the selected Mode Shapes. STAR 6 offers an incredible amount of flexibility in how these displays can be presented. The following pages give some examples of the latest Mode Shape displays.

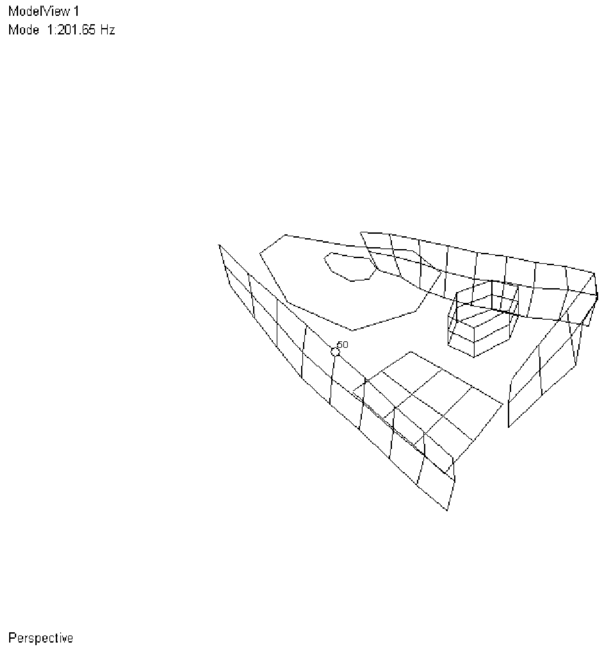


Fig. 17; First identified Mode at 201.65 Hz shown in perspective with location 50 highlighted

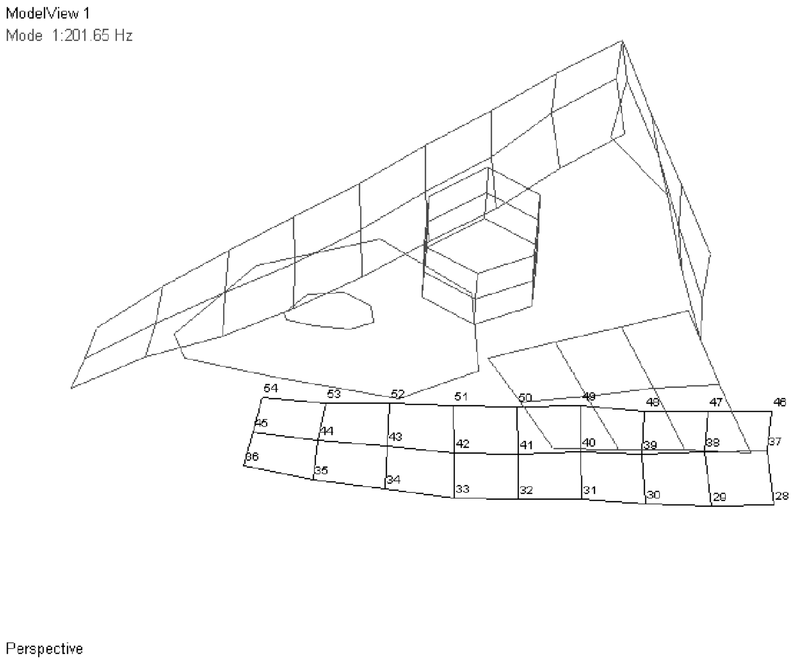


Fig. 18; First Mode shown in perspective with side panel locations highlighted

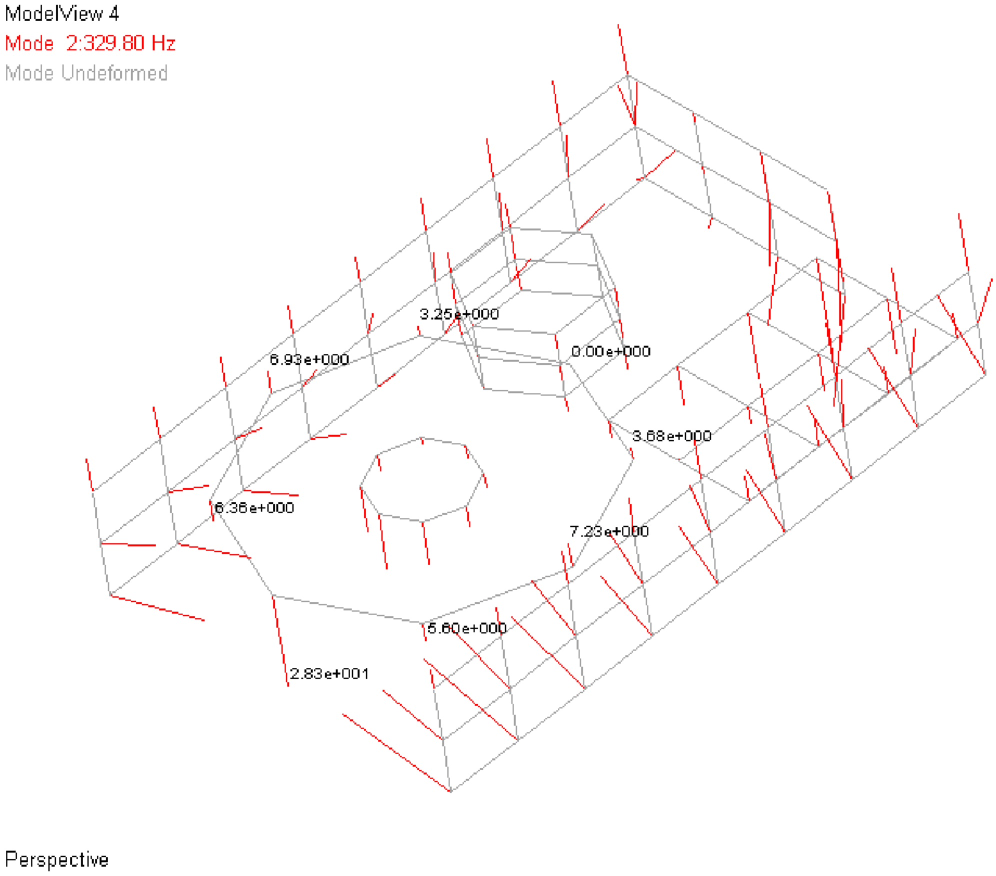


Fig. 19; 2nd Mode shown in perspective with Modal Vectors displayed and Motor Seat 2 identified

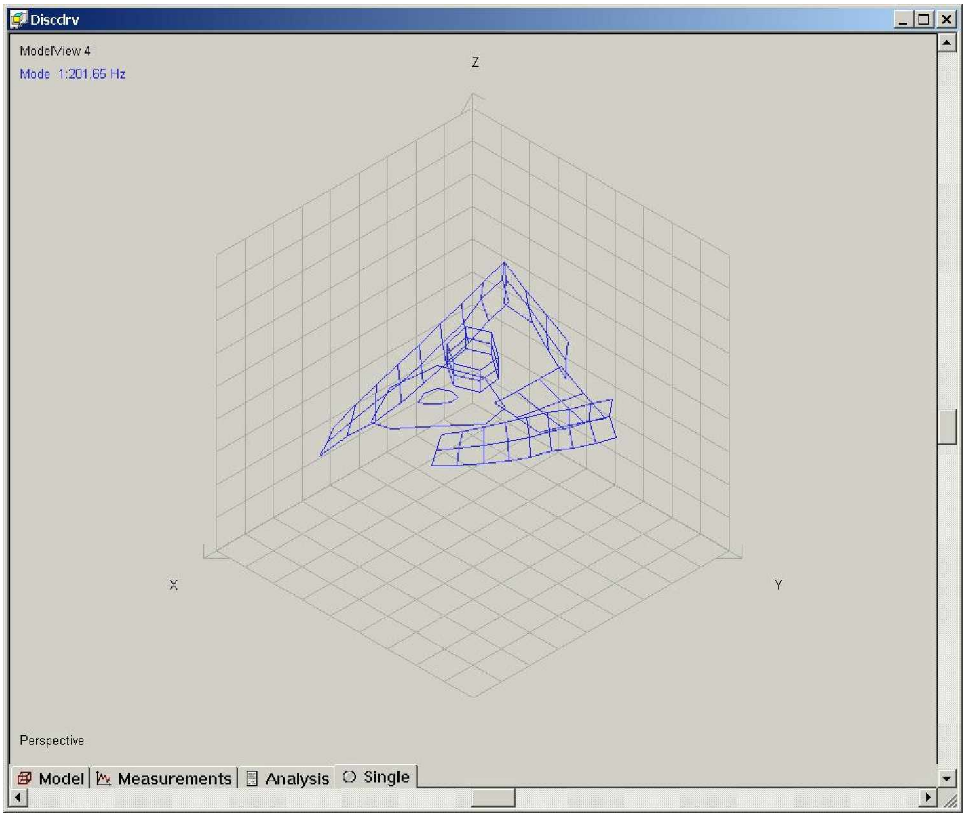


Fig. 20 Freeze frame animation of Mode 1 (201.65 Hz), with X, Y and Z axes superimposed

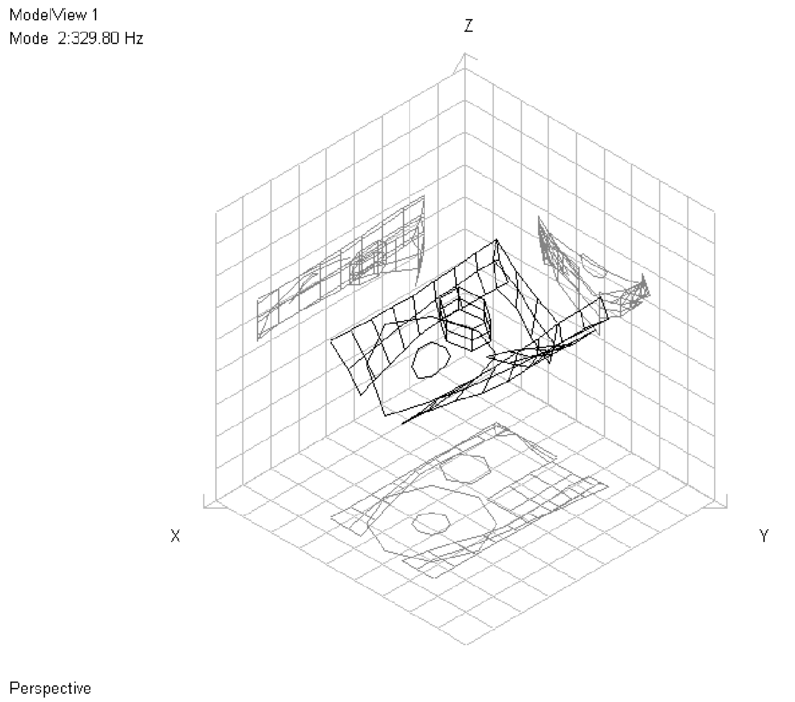


Fig. 21 Perspective animation of Mode 2 (329.80 Hz), with simultaneous projection of Mode onto X-Y, X-Z and Y-Z planes

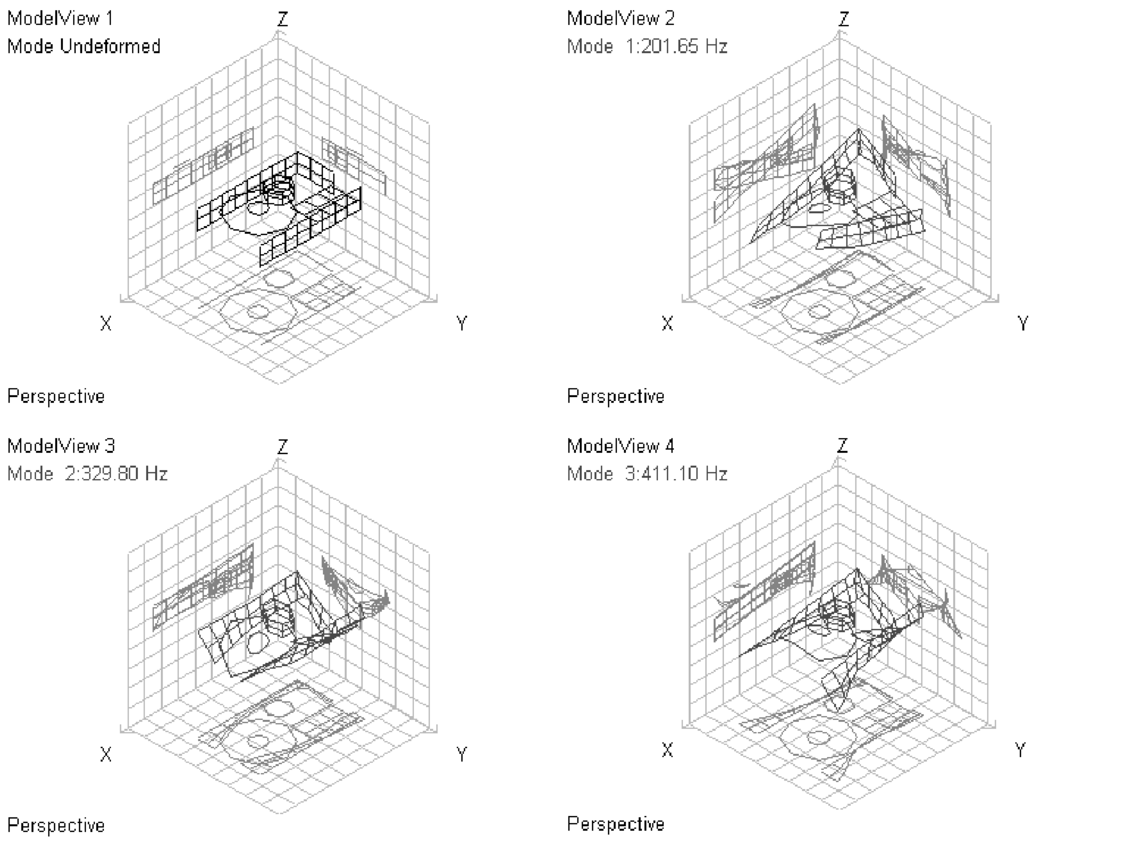


Fig. 22 Simultaneous projection and animation of undeformed test structure and first 3 modes onto coordinate axes.

STAR 6 offers a series of static and animated Mode Shape displays which present an unprecedented amount of information in one picture. For the first time, it is now possible to view the test structure from several angles simultaneously and see exactly how this modal motion projects onto each of the main design axes. No more guesswork about possible design change consequences. Here the measured or calculated motion can be easily seen from any angle and from several angles simultaneously. This unique display has quickly become the favorite of STAR 6 users the world over.

In addition to the display shown above, it is also possible to show multiple, simultaneous, projected displays for even more concentrated report information. Examples of these types of displays follow.

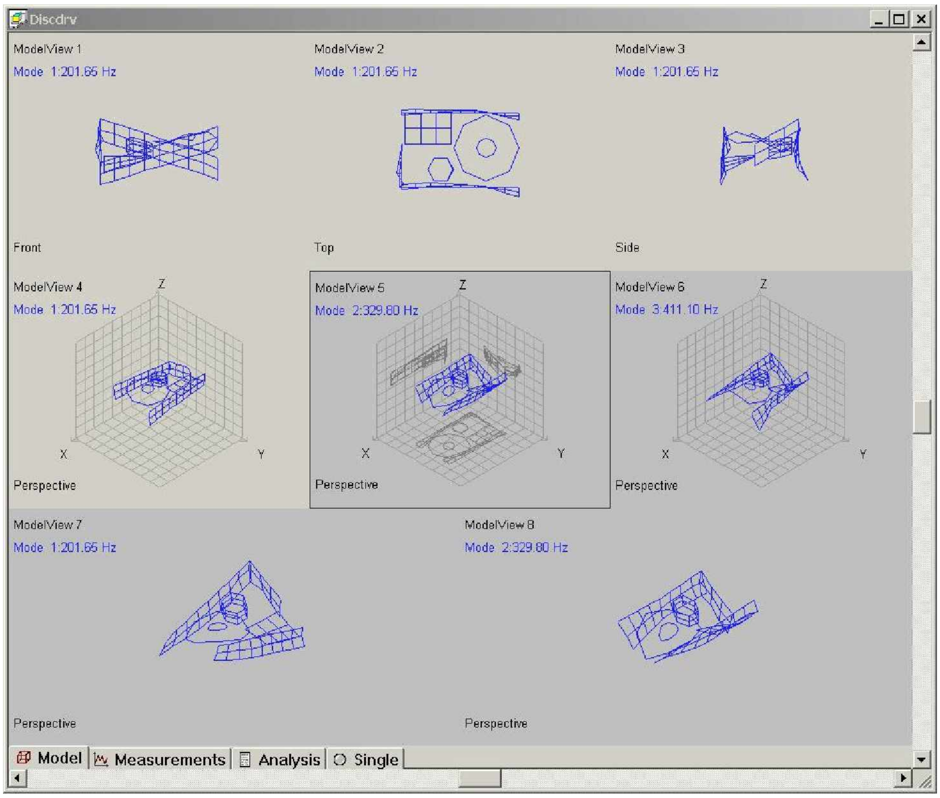


Fig. 23 Example of 8 different views and Modes displayed simultaneously, some animated.

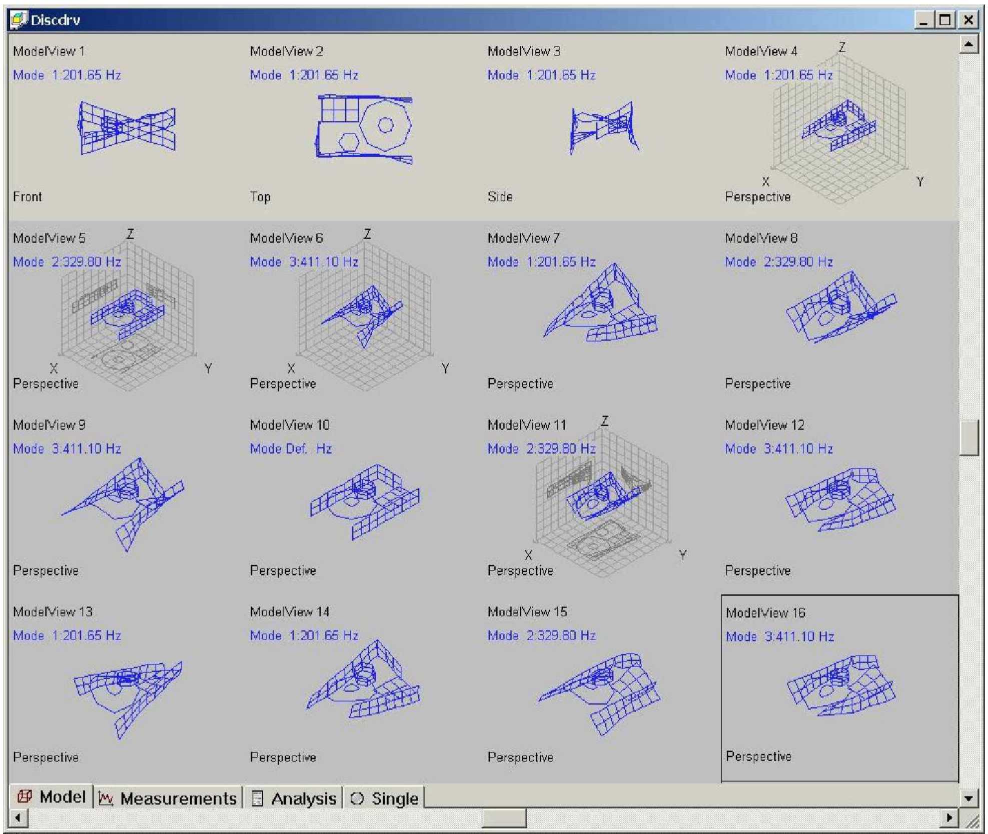


Fig. 24 Example of 16 different views and Modes displayed simultaneously, some or all animated.

Introducing shaded and colored surfaces:

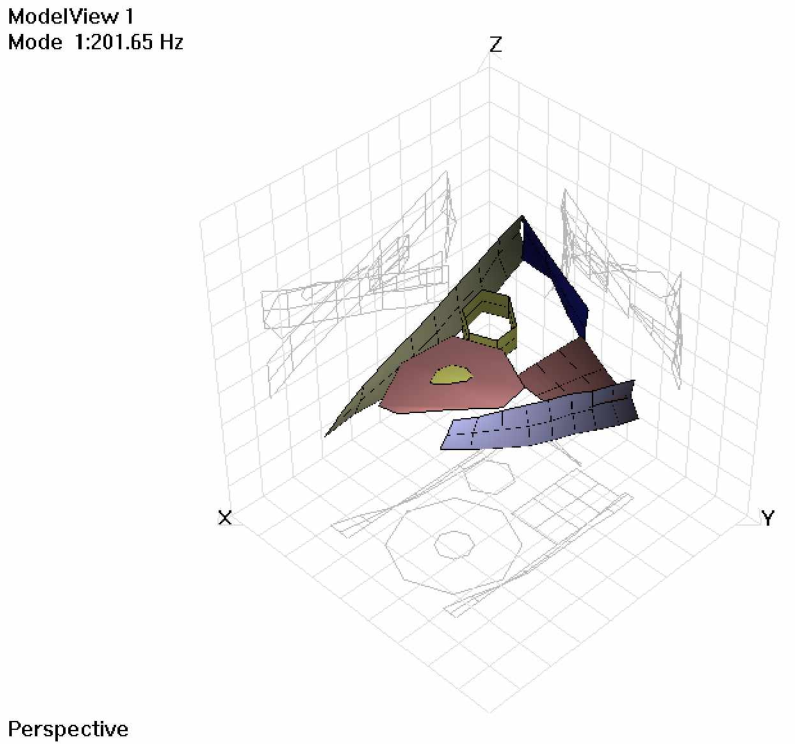


Fig. 25 First Mode shown with each component assigned its own color

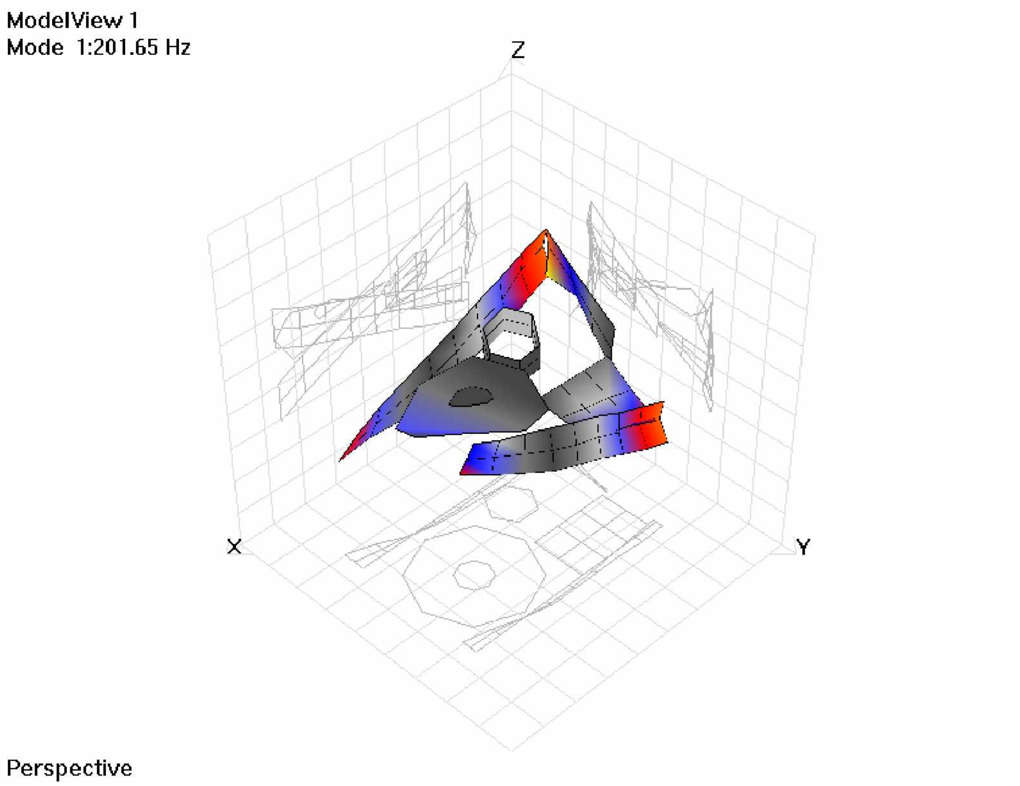


Fig. 26 Same Mode shown with color scale proportional to Displacement

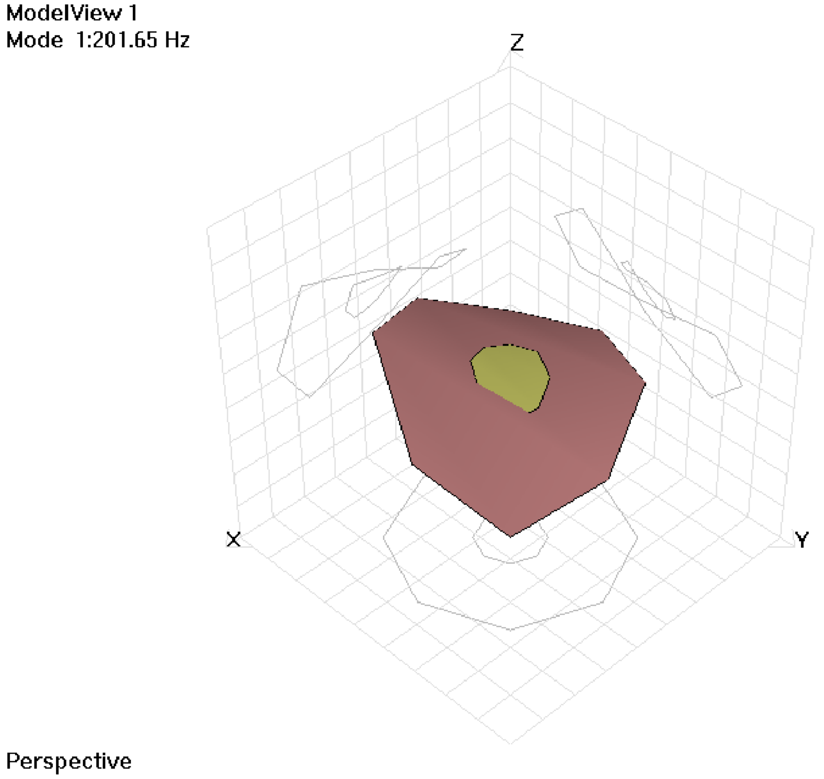


Fig. 27 Two components, Disk Seat & Motor Seat 2, isolated and shaded with same Mode shown

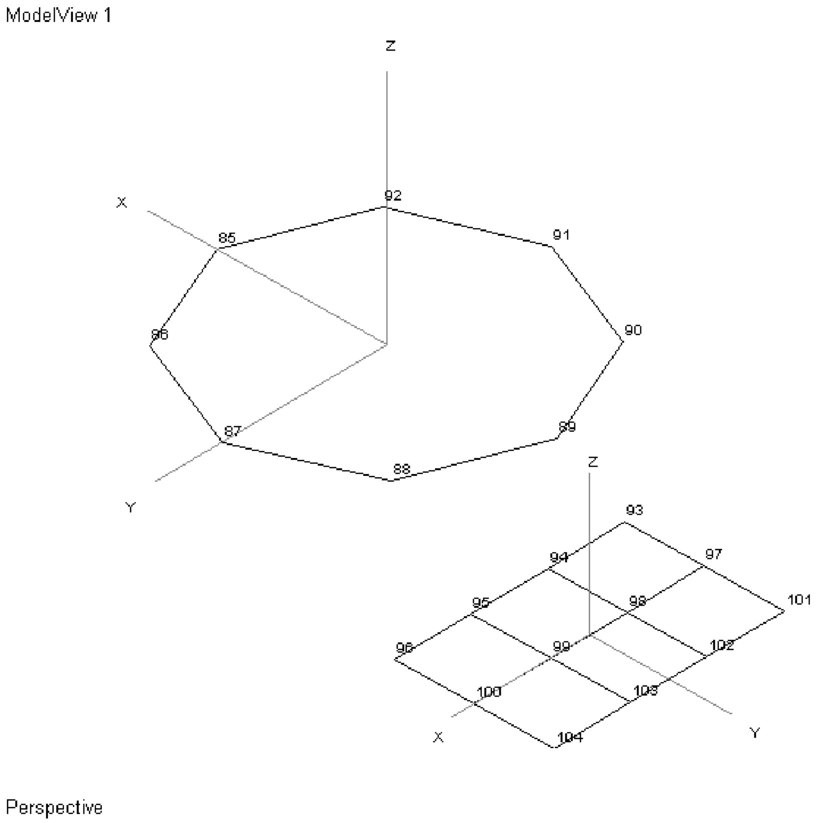


Fig. 28 Two components, Flat 1 and Disk Seat, isolated and separated for easier viewing.

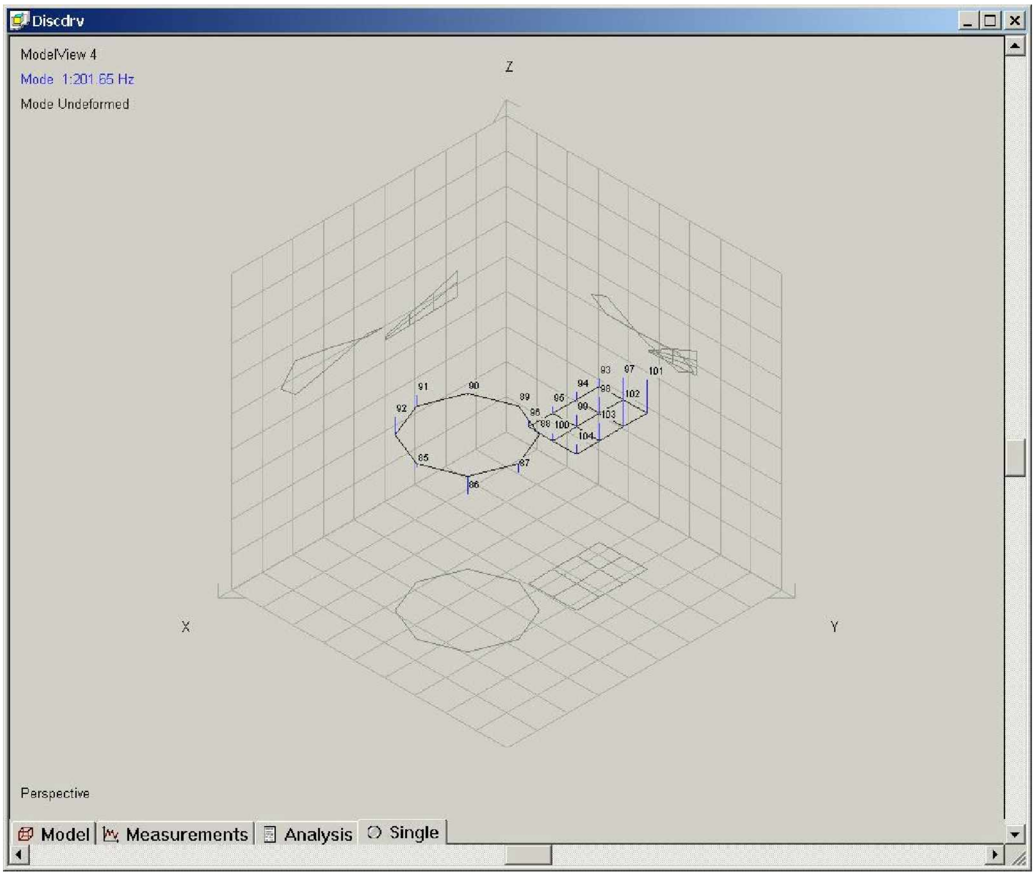


Fig. 29 Flat 1 and Disk Seat Mode 1 shown with Line Vectors, projection and point numbers

Frequency Response Function Synthesis

One of the great features of **STAR** 6 is it's ability to both create a Dynamic Model of the structure under evaluation, and to save you lots of time while doing it. In the current example, a total of 112 points were used to define the 7 components of the computer disk drive being modeled. Location 20Z+ was used as the reference point for each of the 112 measurements. In order to completely describe the example disk drive system, a matrix of 112 by 112 Frequency Response Functions (FRF's) is involved. This would look like:

$$
\begin{bmatrix}
H_{1,1}(j\omega) & H_{1,2}(j\omega) & \cdots\cdot & & & H_{1,112}(j\omega) \\
H_{2,1}(j\omega) & H_{2,2}(j\omega) & H_{2,3}(j\omega) & & & \\
\vdots & & & & & \\
H_{20,1}(j\omega) & \cdots & \mathbf{H_{20,20}(j\omega)} & \cdots & H_{20,47}(j\omega) & \\
\vdots & & & & & \\
H_{47,1}(j\omega) & \cdots & H_{47,20}(j\omega) & \cdots & \mathbf{H_{47,47}\,(j\omega)} & \\
\vdots & & & & & \\
H_{112,1}(j\omega) & & \cdots & & & H_{112,112}(j\omega)
\end{bmatrix}
$$

Fig. 30 Full Frequency Response Function Matrix example

In other words, a full description of the example system involves 112 X 112 possible Frequency Response Functions or 12,544 different FRF's. Obviously it is not practical to make this many measurements for several reasons. It would take far too much time, it would leave the Test Engineer open to measurement error for so many measurements, but best of all, it's not necessary!

It has been understood for over 30 years, that in order to create a computerized Dynamic Model of a structure, based on careful FRF measurements, it is only necessary to actually measure one row or one column of the Matrix FRF description shown above, plus a Driving Point (same location for excitation and response) FRF. With this combination of measurements, curve-fitting will typically create the desired modal parameters including damping and scaled Mode Shapes. But once these parameters have been calculated using the curve-fitter of choice, additional calculations of non-measured FRF's can also be quickly done. This is performed using the Synthesis mode of **STAR** 6.

In the current example location 20, on Side 1, was used as the reference location for all measurements and the Driving Point measurement for this location was shown in Figures 5, 9 to 12 and 15. With these measurements and the extracted Modal Parameters, it is now possible to

Synthesize any desired FRF from among the 12,544 elements in the FRF Matrix. As an example, the measured FRF -11Y,20Z was synthesized from the first 8 extracted modes. This is shown in Figure 31.

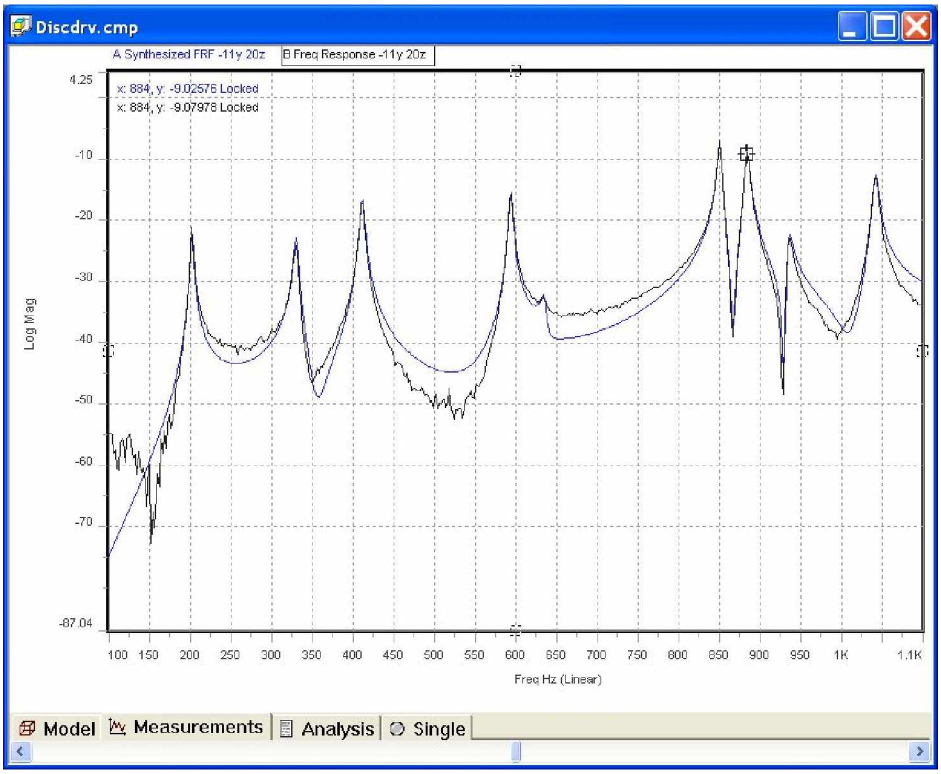


Fig. 31 Overlay of Measured and Synthesized FRF for -11Y, 20Z

As a practical matter, although it is possible to re-create or Synthesize measured FRF's, it is more exciting to be able to Synthesize FRF's which were not measured, for one reason or another. One reason for wanting to Synthesize unmeasured FRF's is to assist in design changes or modifications. And often, the most useful non-measured FRF will turn out to be a Driving Point measurement. This is shown in the following example:

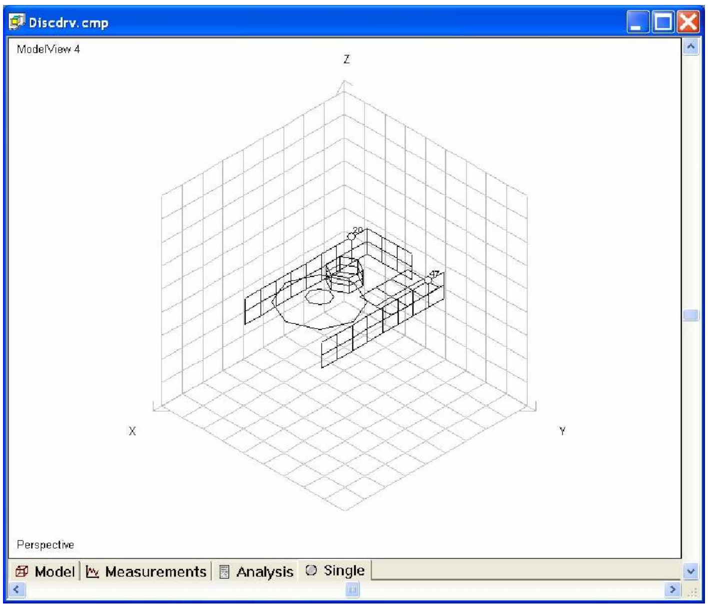


Fig. 32 Locations 20 and 47 identified on Disk Drive Model

In the current example the only measured Driving Point FRF was at location 20 and is identified as (-20Z, 20Z). This FRF is shown below in two formats. Note that each of the Imaginary peaks are in the same, positive, direction.

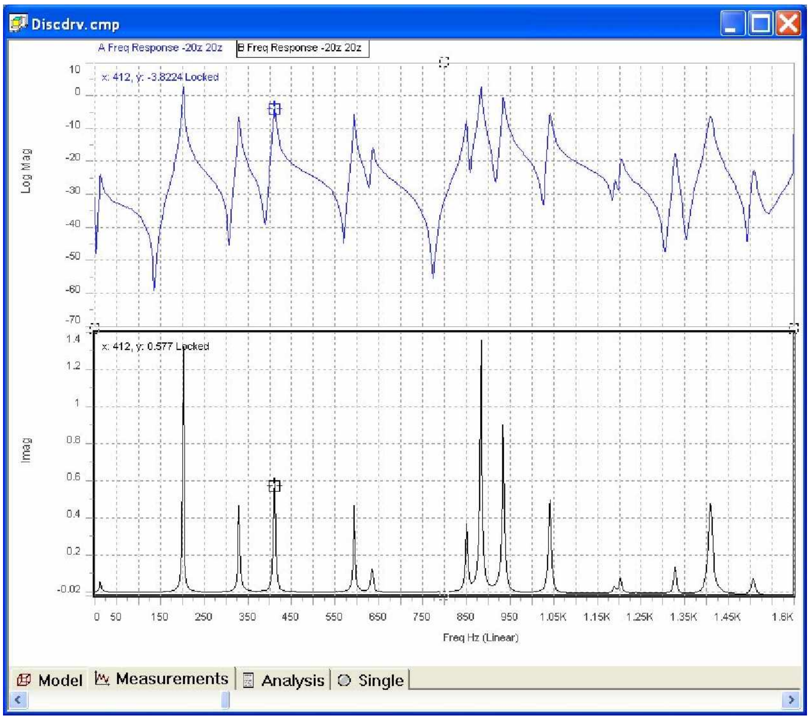


Fig. 33 Measured Driving Point FRF shown as Log Magnitude & Imaginary Part

In the current example, FRF -47Z 20Z, the Cross Frequency Response Function between locations 20 and 47 is used as a starting point and is shown below. However, the goal is to create an unmeasured Driving Point FRF at location 47 in the Z direction.

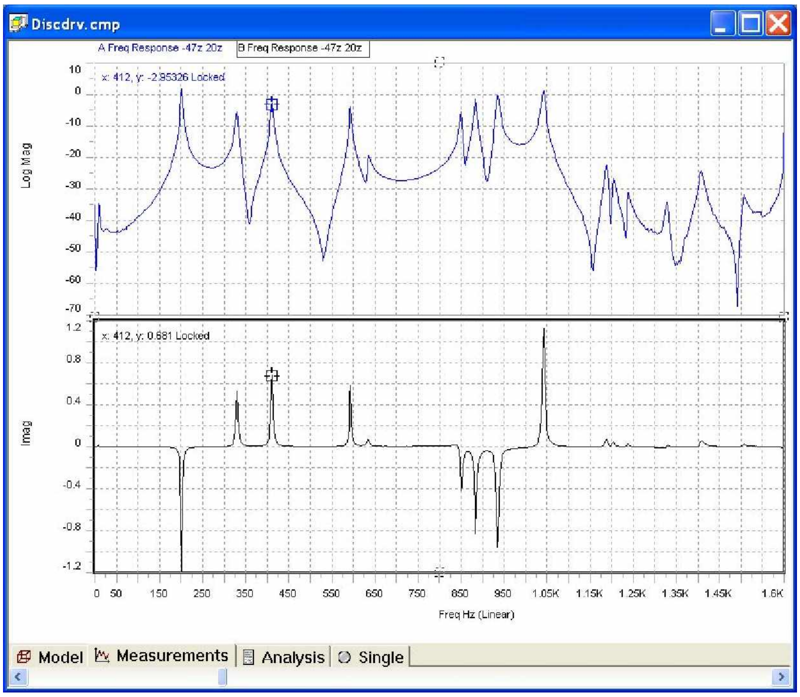


Fig. 34 Measured Cross FRF shown as Log Magnitude & Imaginary Part

Note that in this measurement the peaks in the Imaginary part are both positive and negative, indicating a complex Phase relationship between excited modes.

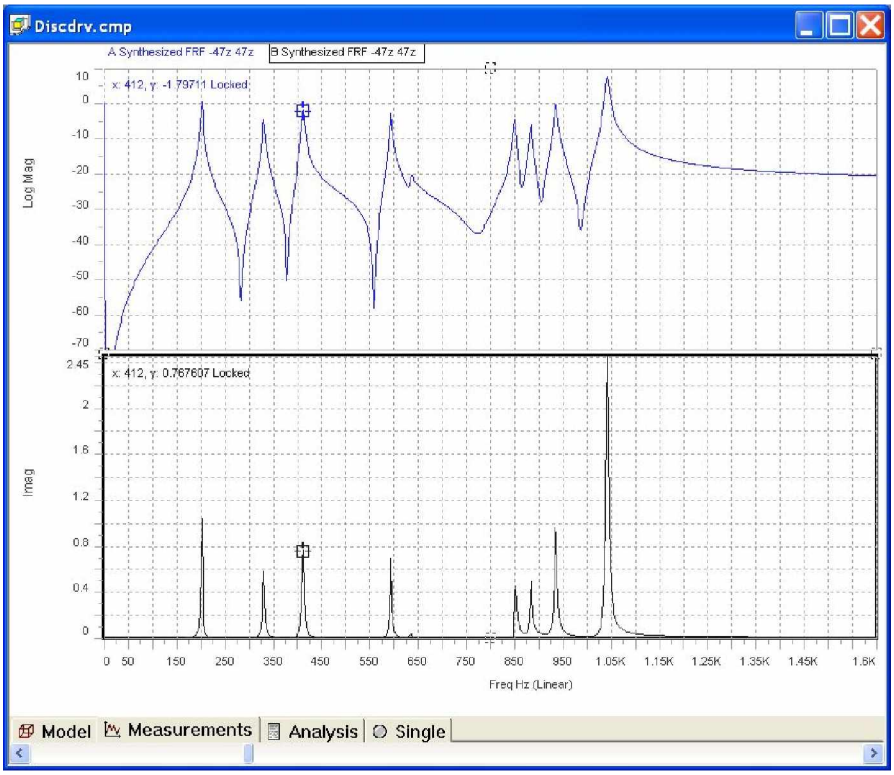


Fig. 35 Synthesized Driving Point FRF for location 47Z

Note in Figures 35 and 36 that each of the peaks in the Imaginary part is positive, indicating that as expected, all of the modes are in Phase at this location.

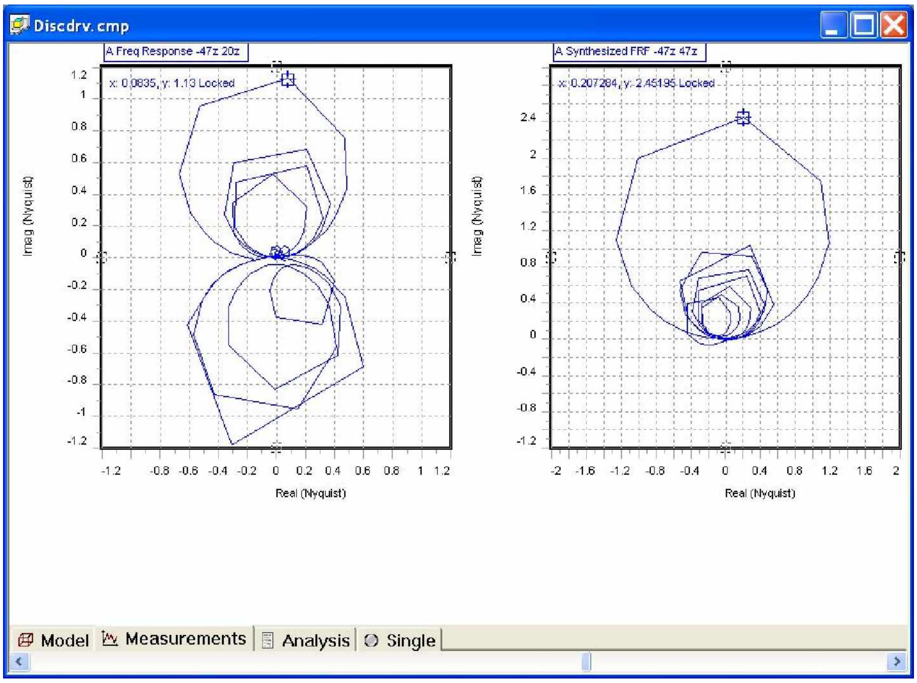


Fig. 36 Nyquist display for Cross and Driving Point FRF's at location 47

As expected, the Nyquist diagram for the Synthesized Driving Point FRF shows all positive Imaginary peaks. The designer would now have a very good indication of the type of dynamic response he would be looking into, if he was to attach something right at location 47.

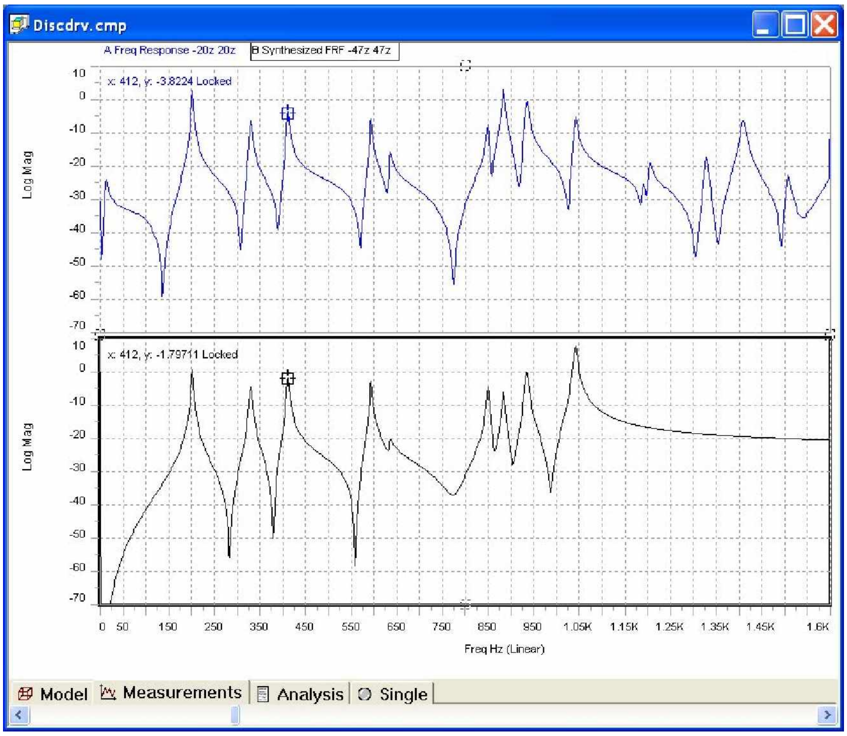


Fig. 35 Log Magnitude FRF for Measured (20) and Synthesized (47) Driving Points

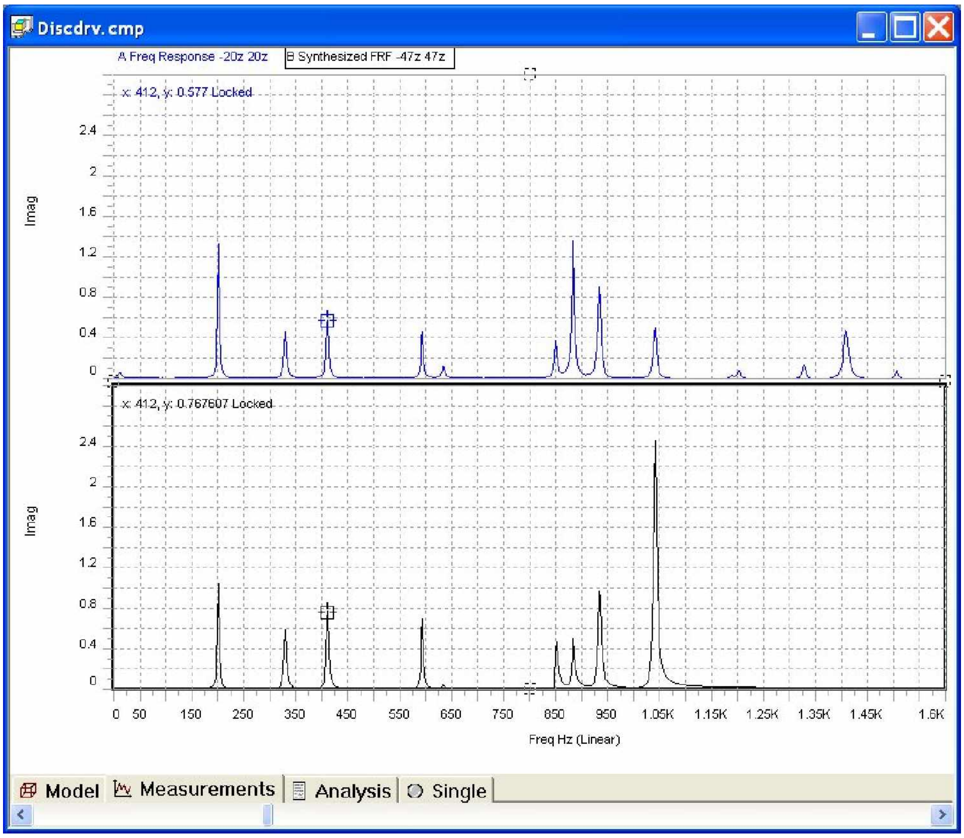


Fig. 36 Imaginary part of FRF for measured (20Z) and synthesized (47Z) Driving Point Frequency Response Functions

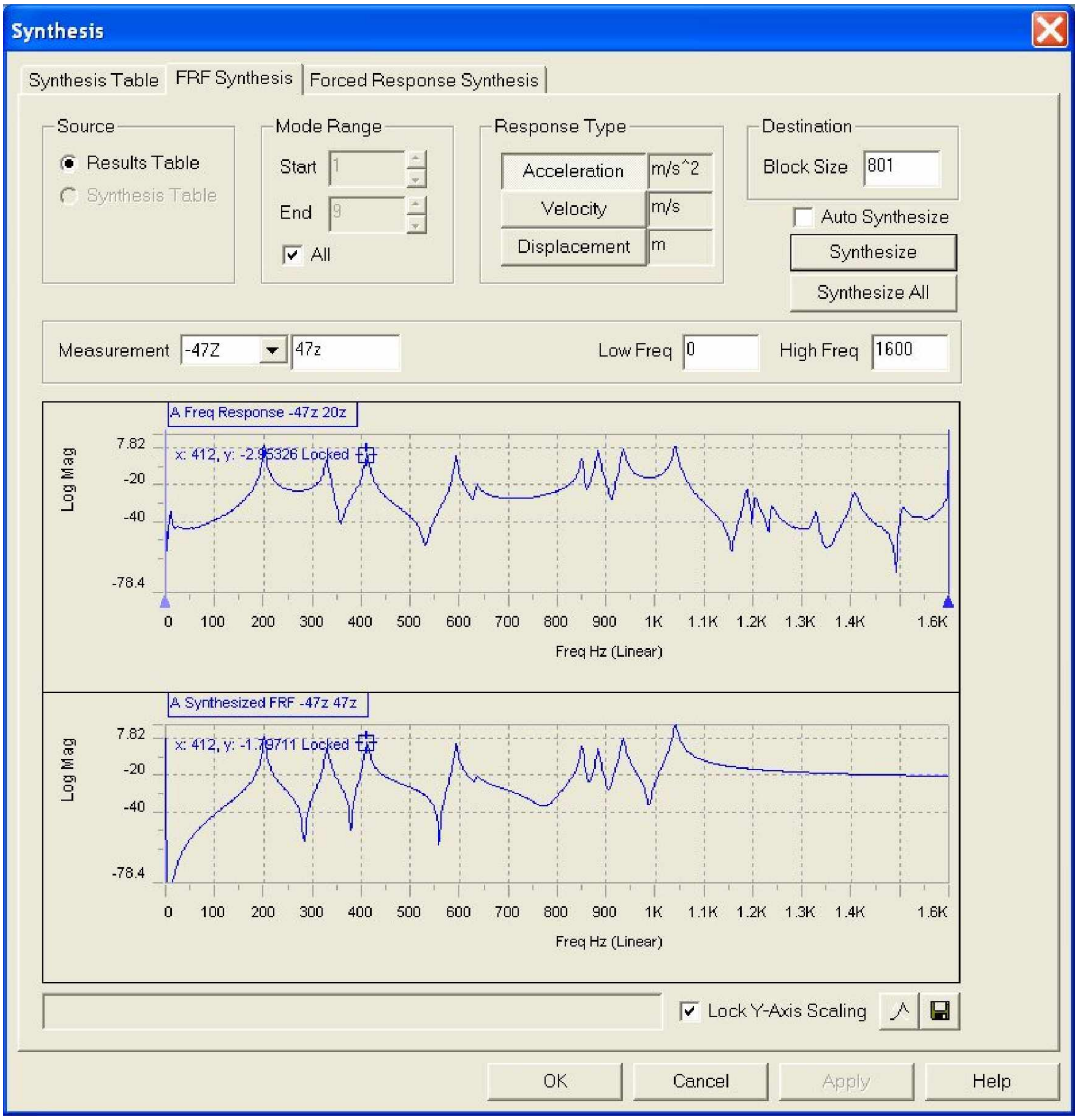
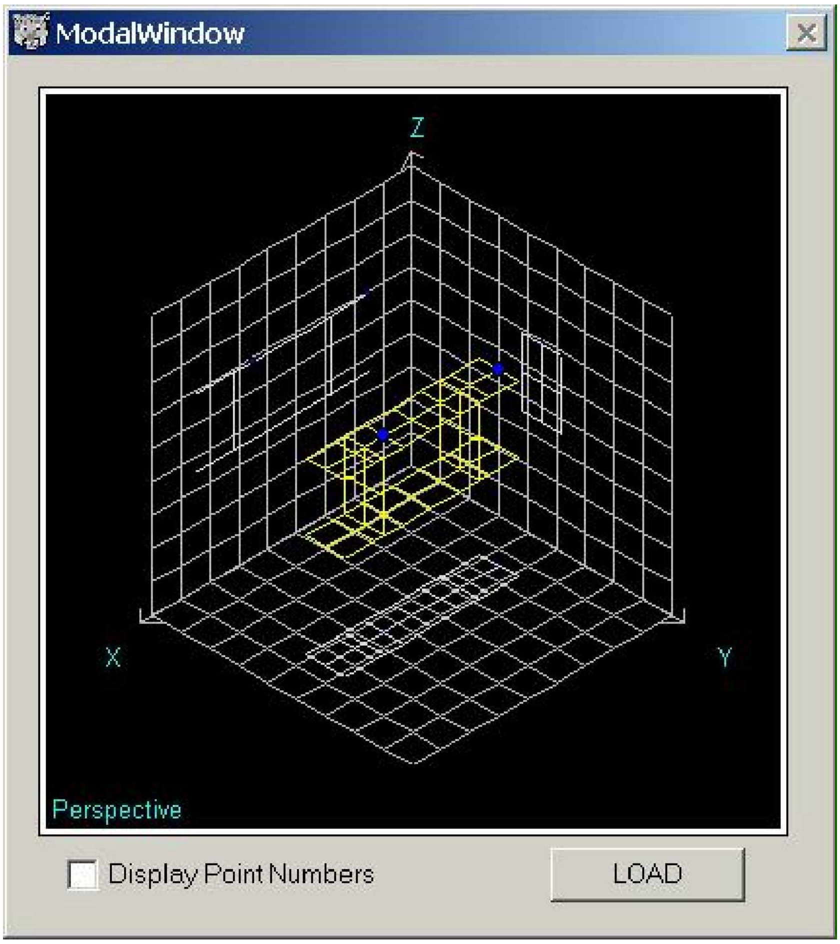
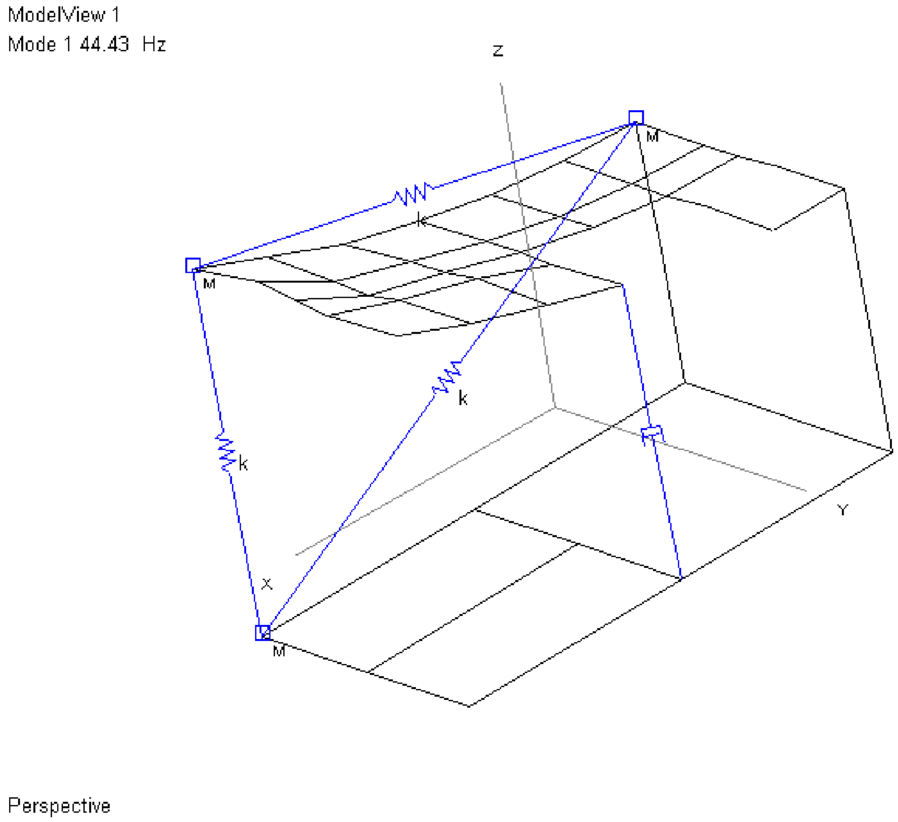


Fig. 37 Synthesis screen with parameters for current example

The display above shows a split screen presentation of the measured FRF at -47Z/20Z and the synthesized Driving Point FRF at -47Z/47Z together with the FRF Synthesis controls. In this case the table created from curve-fitting the first 9 Modes was used as the source for creating the desired, unmeasured, Driving Point FRF -47Z/47Z. In this way, any FRF from the 112 X 112 FRF Matrix can be synthesized.


ModalWindow
Z
X
Y
Perspective
Display Point Numbers
LOAD


ModelView 1
Mode 1 44.43 Hz
Z
M
k
M
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Y
X
M
Perspective