Multi-Resolution Spectrum Analysis in Modal Testing

Application Note 061

Aakash Umesh Mange - Senior Application Engineer

An efficient method to study structural dynamics is by carrying out a modal test. In order to analyze the mechanical properties of a structure, it is important to accurately measure the frequency and damping. With a regular FFT algorithm that is used to transform time domain signals to the frequency domain, a high block size would be required to obtain precise modal characteristics of the unit under test. However, this would increase the experimentation and computation time.

The latest 8.1 release of the Crystal Instrument's EDM Modal software features multi-Resolution spectrum technology implemented into the MIMO FRF testing suite. Multiple passes of FFT yield a much finer resolution in the lower frequency region. This provides the advantage of a better estimation of the quality factor (or damping) and the amplitude of the frequency response functions at the resonant frequencies.

To compare the effect of multi-resolution and single resolution spectrum, a modal test is executed. The structure under test is a plexiglass plate that is supported using bungee cords to produce a free-free boundary condition. Two modal shakers are used to provide a white noise excitation to excite the plexiglass plate. The response of the plate is captured using a few uni-axial accelerometers. (Figure 1.1)

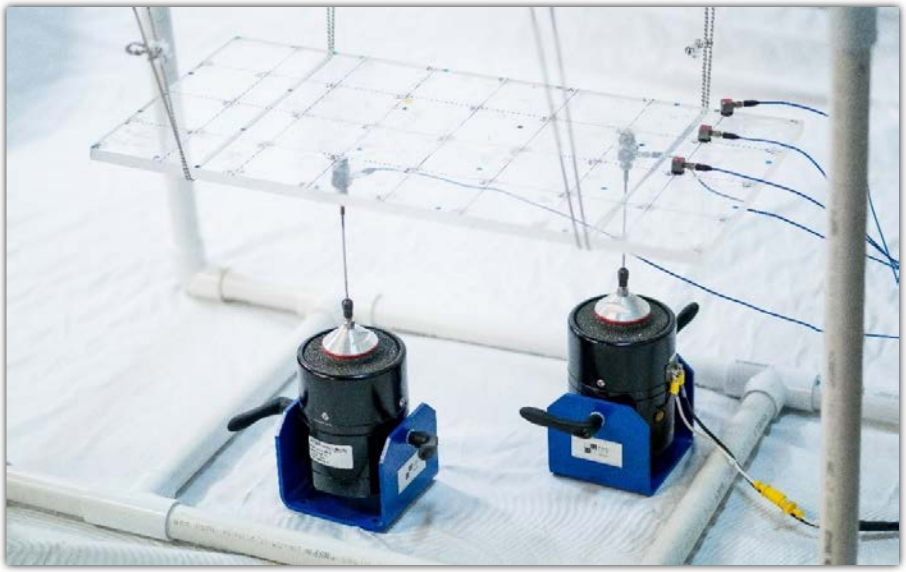

Figure 1.1 Modal Shaker Testing of the plexiglass plate

The test configuration details are described here. A sampling rate of 5.1 kHz is used for the interested analysis frequency range of 2.3 kHz. The block size of 2048 yields 900 spectral lines which yields a frequency resolution of 2.5 Hz. A Hann window is used to reduce the leakage from the white noise excitation and response. A linear averaging mode of 32 is used to compute the linear spectrum.

An 8 times finer resolution of 0.31 Hz is obtained in the low-frequency range using the multi-resolution spectrum. This is achieved by using a large block size which is not needed in the high frequency region because of the dynamics of the test structure. This implementation of different resolutions produces better results without any increase in the loop time. The cutoff frequency dividing the low and high frequency range is 281.25 Hz. In this low-frequency region, the results from the multi-resolution tests are better because of the finer frequency resolution. After this cut-off frequency, the multi-resolution and single-resolution spectrum would yield comparable results since they have the same frequency resolution. All other settings, configurations and setup are the same for both multi-resolution and single-resolution tests. (Figure 1.2)

The FRF measurements shows closely spaced modes in the 0-244 Hz region. The zoomed in comparison of the overlapped FRFs shows that with the multi-resolution spectrum the peaks are much sharper and better identified as compared to it being flat without the enabled multi-resolution spectrum. The richer information available because of the finer resolution captures more peaks that are not as clearly visible and spread out in the normal spectrum.

The advantage of multi-resolution spectrum is also seen in the curve-fitting process of the modal test as shown below. (Figure 1.3)

The stability diagrams above show that the poles (frequency and damping) recognized with Multi-Resolution spectrum are more accurate because of finer frequency resolution.

A similar MIMO FRF modal test was also carried out on steel plate of high-quality factor to investigate the advantages of multi-resolution spectrum in calculating the quality factor and peak amplitude of FRFs. The results are shown below. (Figure 1.4)

Zooming into the high-resolution region of the Multi resolution spectrum, and comparing to the single resolution, following spectrum graph is produced. (Figure 1.5)

The image shows that in the cut-off frequency region, where the frequency resolution is much finer with the multi-resolution spectrum (green), the peaks at several resonance frequencies are much clearly identified. This is due to the much higher block size, which ultimately produces higher spectral lines. Therefore, the Frequency Response Function curve is much smoother and neater.

This also facilitates a more accurate calculation of the quality factor and peak amplitude of the FRF as shown in the table below. The table shows that the first four resonance frequencies that are present within the low-frequency cut-off region have a much higher Q and peak amplitude with the implemented multi-resolution spectrum. Also, in the high-frequency region, the frequency resolution for the single and multi-resolution spectrums are the same and hence the Q and peak amplitude for these resonances are also very close.

The table above shows that the damping, amplitude and Q factor estimation using regular FFT methods are off from their true values by an order of magnitude of tens or hundreds. If people use these erroneous values to derive their conclusion about the structure and conduct further analysis, such as structure modification and optimization, the results would be inaccurate.

To learn more about EDM Modal software, visit: www.crystalinstruments.com/edm-modal-testing-and-analysis-software/

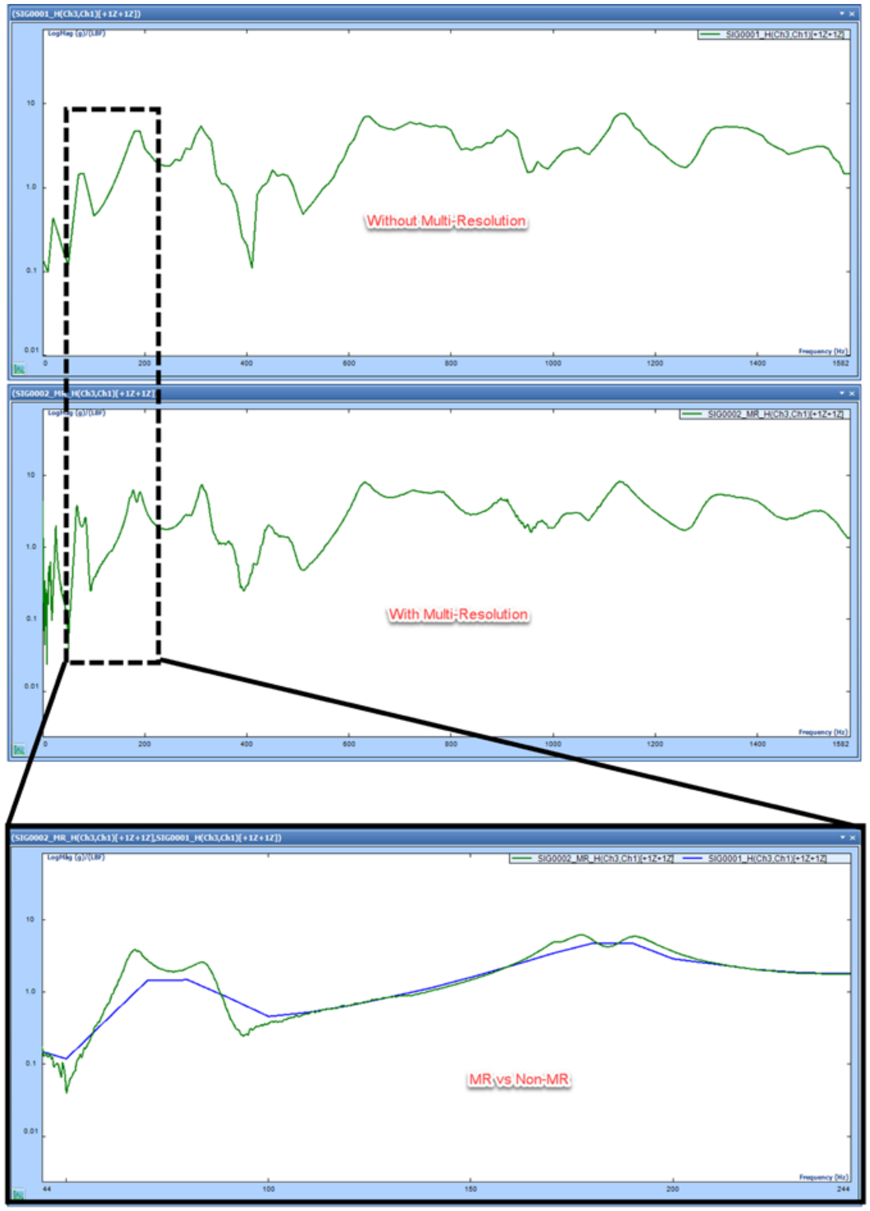

Figure 1.2 Comparison of FRFs measured using single resolution and multi-resolution spectrum for the plexiglass plate

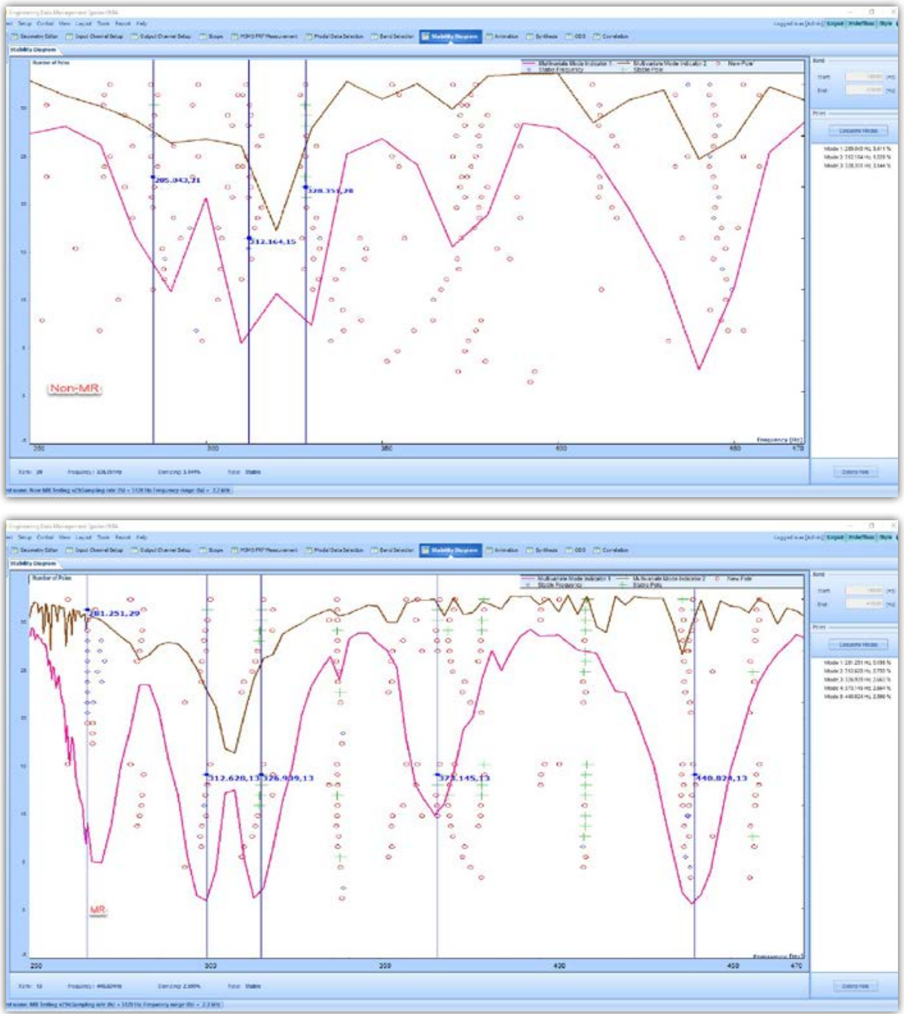

Figure 1.3 Comparison of Stability diagrams obtained using single resolution and multi-resolution spectrum for the plexiglass plate

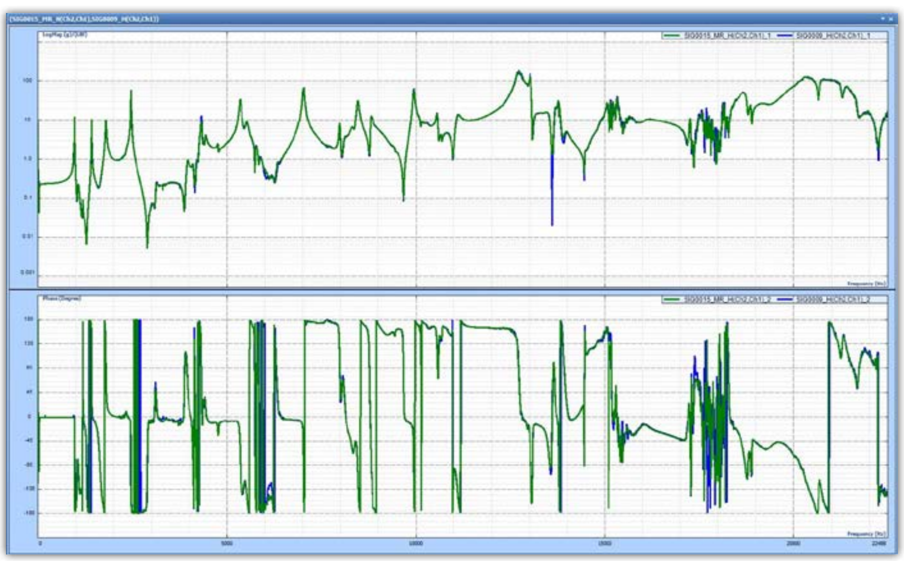

Figure 1.4 Comparison of overlapped FRFs measured using single resolution and multi-resolution spectrum for the Steel plate

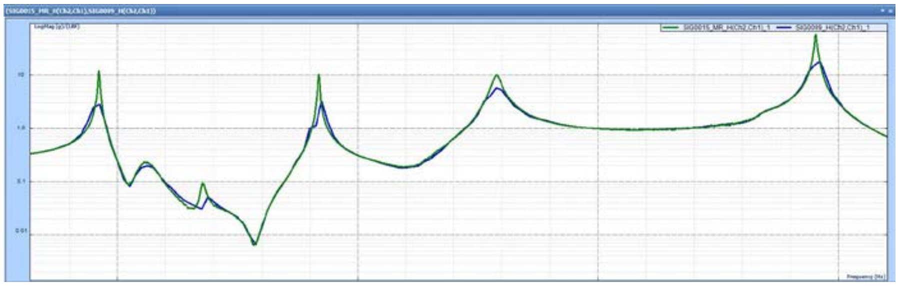

Figure 1.5 Comparison of overlapped FRFs measured within cut-off region using single resolution and multi-resolution spectrum for the steel plate

Resonant Frequency	Damping Estimation Using MR	Damping Estimation Using Regular FFT	Q Estimation Using MR	Q Estimation Using Regular FFT	FRF Amplitude Estimation Using MR (g/LBF)	FRF Amplitude Estimation Using Regular FFT (g/LBF)
960.94 Hz	0.0016074	0.01245702	311.069	40.138	12.269	2.832
1418.75 Hz	0.001596	0.00415103	313.292	120.452	10.687	3.274
1789.06 Hz	0.0051316	0.00955548	97.435	52.326	9.993	5.823
2453.13 Hz	0.0010845	0.0055879	461.059	89.479	60.277	18.42
5350 Hz	0.0039583	0.00396228	126.317	126.19	33.72	34.74
8462.5 Hz	0.002902	0.00269208	172.296	185.73	32.08	31.47
12725 Hz	0.0052911	0.00562019	94.498	88.965	186.23	187.72

Table 1 Comparison of Q and FRF amplitude calculated using single resolution and multi-resolution spectrum for the steel plate

Crystal Instruments Corporation
2090 Duane Avenue
Santa Clara, CA 95054

Crystal Instruments Testing Lab
15661 Producer Lane, STE H
Huntington Beach, CA 92649

Crystal Instruments Testing Lab
1548A Roger Dale Carter Boulevard
Kannapolis, NC 28081

Phone: +1 (408) 986-8880
Fax: +1 (408) 834-7818
www.crystalinstruments.com