CUED - EngineeringTriposPartIIA 2016-2017 **Module Experiment Report**

Tobecompletedbythestudent				*Note:Allworkmust beyourownunlessotherwiseacknowledged*			
Student name:	Aalok Patwardhan			CRSID:	Anp35	College:	EM
Module number:	3C6	Date experiment performed:	03/02/17	Date submitted for marking:	10/02/17	Totalhoursspent onreport:	<5>

			A*	A	B	C	D
CONTENT	**Completeness, quantity of content**	Has the report covered all aspects of the lab?					
		Has the analysis been carried out thoroughly?					
	Correctness, quality of content	Is the data correct?					
		Is the analysis of the data correct?					
	Depth of understanding, quality of discussion	Do the analysis and discussion show a good technical understanding?					
		Has it been written clearly?					
	Justification if not A grade:						
PRESENTATION	**Attention to detail, typesetting and typographical errors**	Has the report been typeset to a good technical standard?					
		Is the report free of typographical errors?					
		Are the figures/tables of good technical quality?					
	Justification if not A grade:						

☐**See also comments in the text**

The weighting of comments is not intended to be equal, and the relative importance of criteria may vary between reports. AgoodreportshouldreceiveanAgrade overall.

Overallassessment	**A***	**A**	**B**	**C**	**D**	**Overall Mark** Report mark capped to 4 + prep. mark – penalty
Module experiment report marks	4-5	**3.5**	3	2.5	0-2	
Preparation mark						
Penalty for lateness		***1 mark / week or part week***				

Marker: Date:

Engineering Tripos Part IIA: Module 3C6 Vibration

Short laboratory report for “Digital vibration analysis”

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1 Summary

Following the sequence outlined in the lab handout, a series of measurements were made on a system of two coupled cantilever beams. Excitation force was applied using a moving-coil shaker and an instrumented impulse hammer. Response was measured using an accelerometer, but the displayed signal represented vibration velocity because an integration stage was included in the amplifier.

The driving-point response was measured near the point at which the coupling link was inserted between the two beams. Three types of input force were employed: (1) sinusoidal excitation, in which the frequency was adjusted by hand and single-frequency measurements combined to give a response plot; (2) band-limited pseudo-random noise was applied using the shaker; (3) short impulses were applied using the hammer, fitted with a soft rubber tip.

Two additional exercise were also performed. First, calibration factors for the measurement set-up were determined by measuring the response of a freely-suspended known mass and using Newton’s law. Finally, the coupling link was removed and the responses of the two separate beams were measured using the hammer method. The two were combined using the theoretical formula for point coupling, and the result compared with the directly-measured response of the coupled system.

2 Results and discussion

2.1 Sinusoidal input

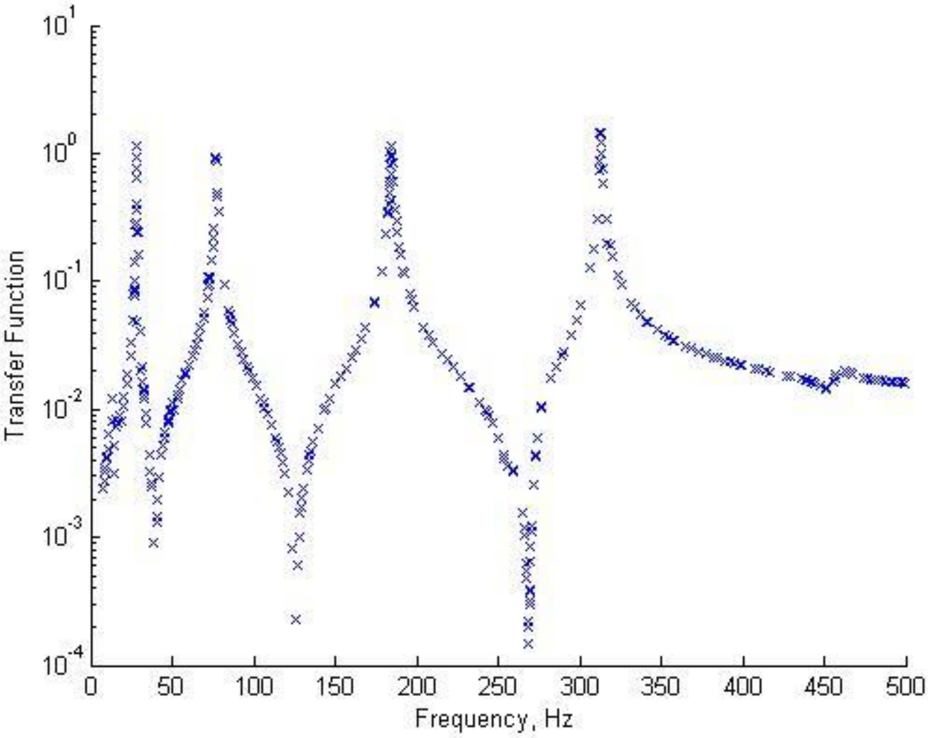

Figure 1 - Transfer function to sinusoidal input

Altering the frequency manually, the admittance (transfer function) was found at each frequency in the range 10-500Hz. This was laborious and time consuming, and although it gave the shape of the transfer function, only values at individual frequencies were plotted as opposed to a continuous sweep.

2.2 Random noise input

A random noise signal containing a large range of frequencies was inputted and by using its Fourier Analysis the frequency response was obtained. Figure 2 shows that there was a lot of variation around the general shape of the response. However the resonant peaks are clearly seen. The sample time for the test in figure 2 was two seconds.

To reduce the effect of stray noise in the response, the results from 5 tests were averaged. This resulted in the response seen in figure 3 which more accurately resembles the response to a sine sweep. The blue line shows the coherence between input and output. Although this improved the response around the resonant peaks, there was still lots of variation around the frequencies in the 'troughs' - away from the resonant peaks. This can be attributed to the fact that at these frequencies the magnitude of the response was less than -40dB which is low. The natural noise in the measurements would therefore account for a larger proportion of the measurements. To remove some discrepancies further around these regions, the sample time was increased to six seconds, resulting in the response shown in figure 4.

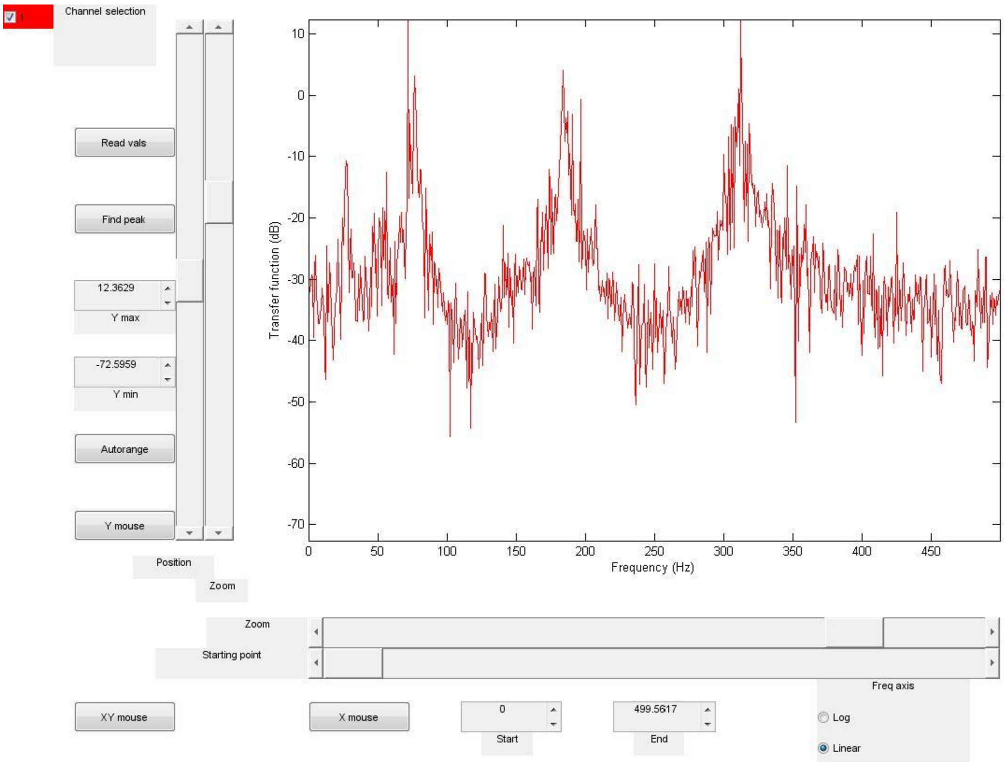

Figure 2 - Frequency response to noise, sample length 2 sec

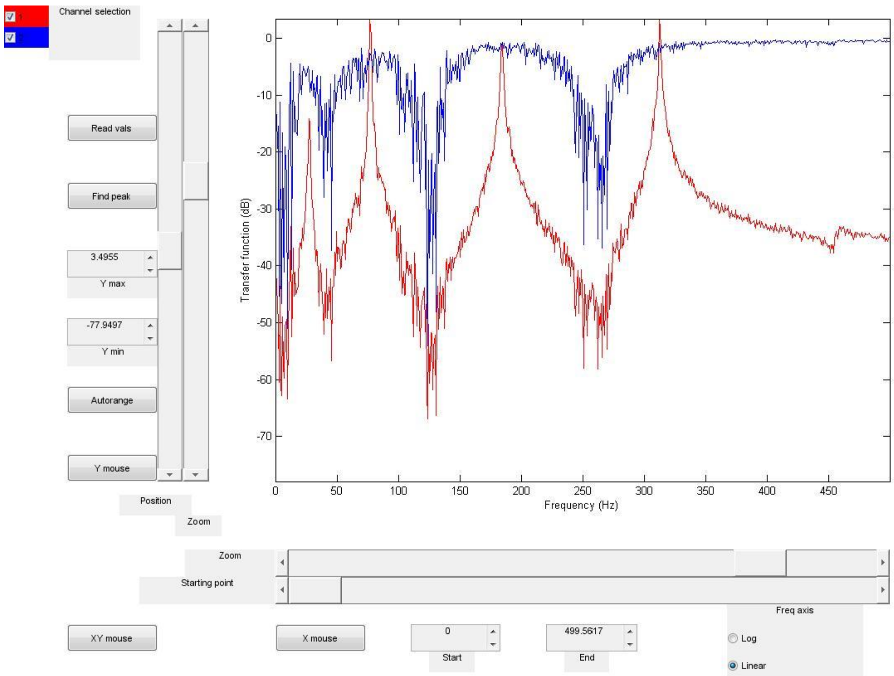

Figure 3 -Averaging over 5 tests, blue showing coherence between input and output.

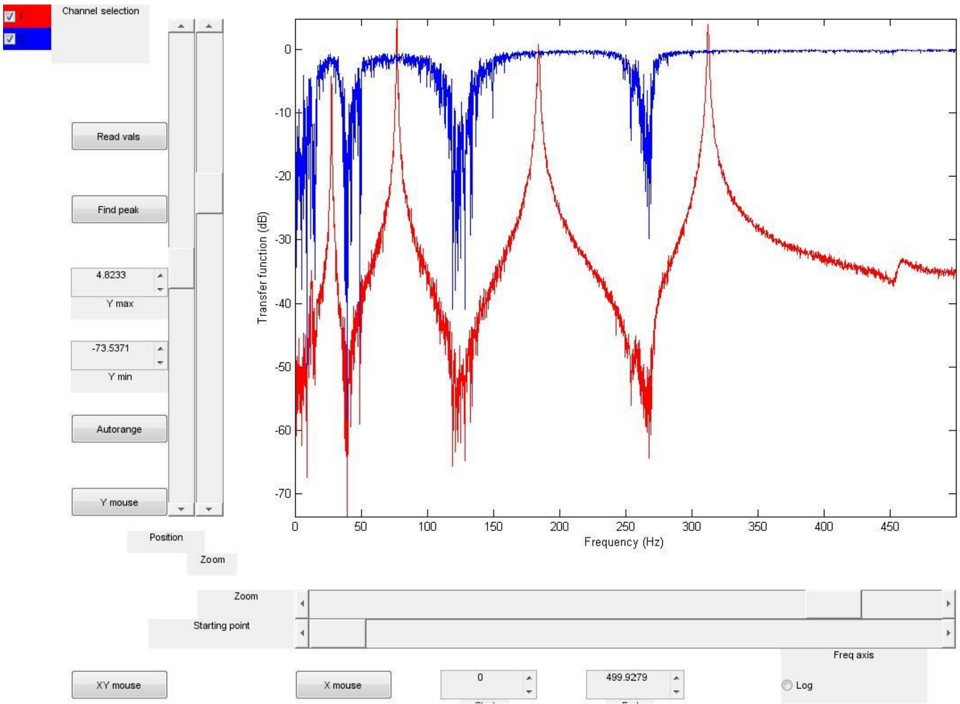

Figure 4 - Increasing sample time to 6 seconds

2.3 Hammer input

A hammer was used to excite the coupled cantilevers with an impulse measured to be 0.7V and its admittance is shown in figure 5. Some discrepancies due to noise are still observable, arising from vibrations from the table and ground. Theoretically an ideal impulse lasts for an infinitesimally small amount of time and contains all frequencies. An accurate transfer function can therefore be obtained from an ideal impulse. However the actual impulse used occurred for a duration of 3.33ms possibly due to the rubber tip deforming at contact. It can be seen that the transfer function drops off at high frequencies, this is due to the rounded edge of the hammer tip. A drop off at low frequencies was seen in the apparatus and results of other groups, perhaps as a result of removing the magnetic signal generator and thereby altering the mass of the structure. The drop off could also be due to performing a FFT on the computer, as the FFT is periodic and a high pass filter could have been applied in the software.

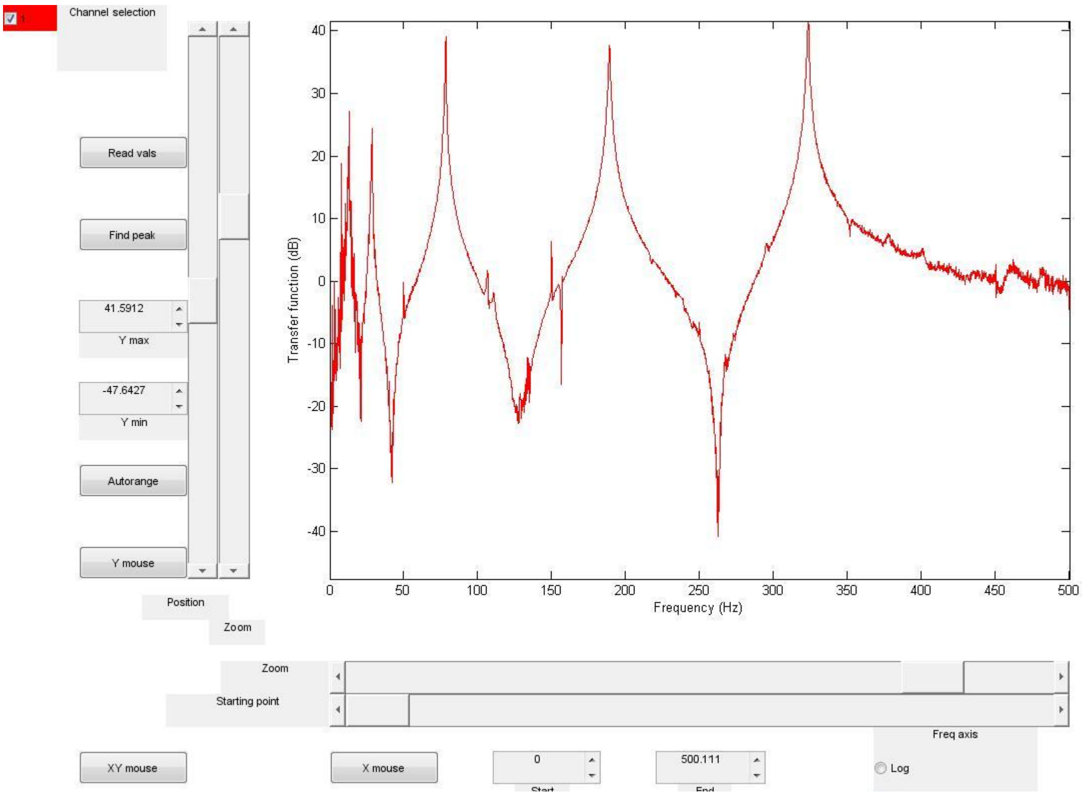

Figure 5 - Response to hammer impulse

2.4 Calibration

The relationship F = ma can be used to determine the transfer function between the force and acceleration. From the impulse method the transfer function could be scaled appropriately using the known quantity of mass which was roughly 0.3kg. The transfer function measured from the impulse on the calibrated mass related to velocity rather than acceleration so was multiplied by iω. The acceleration shown in figure 6 was found to be 5.304 x 10^3ms^{-1}. From the knowledge that the mass was roughly 0.3kg, a scale factor λ was found to be 5.66 x 10^{-5} following the relationship in equation 1. Figure 7 shows the scaled transfer function resulting the value of mass as expected.

$$\left(\frac{F}{a}\right) * \lambda = 0.3\text{kg} \tag{1}$$

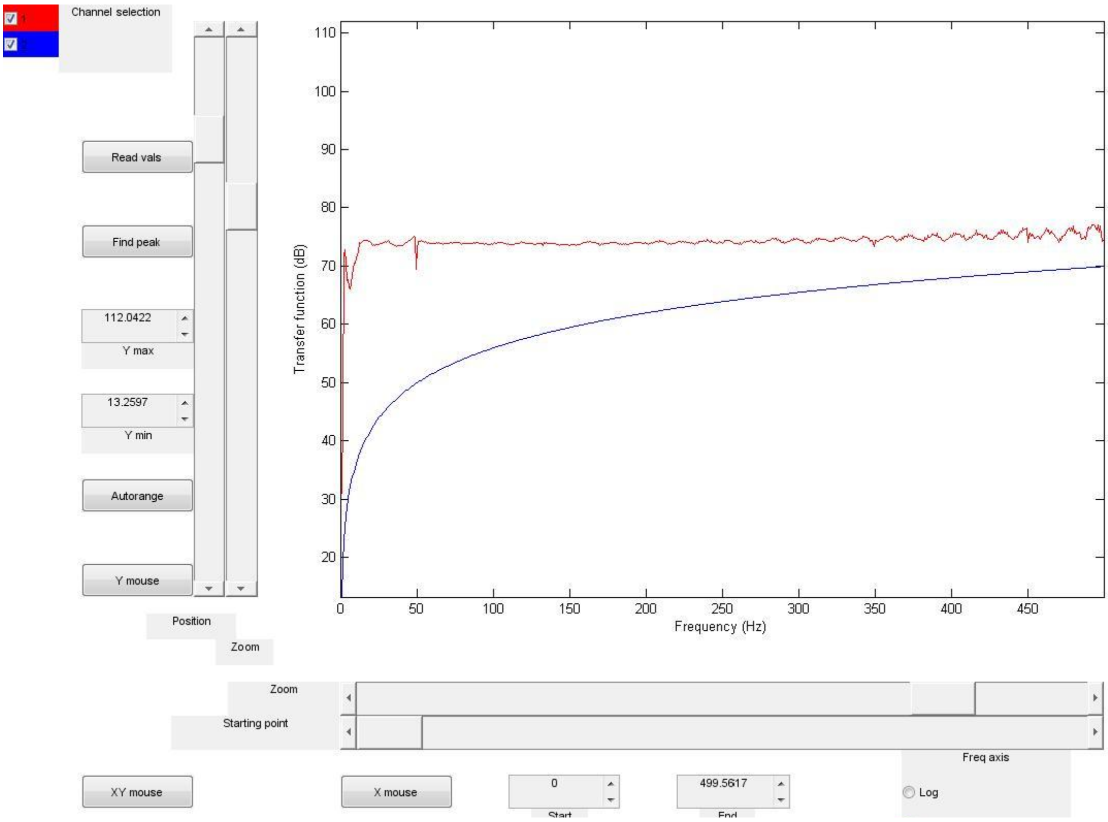

Figure 6 - Transfer function of calibrated mass

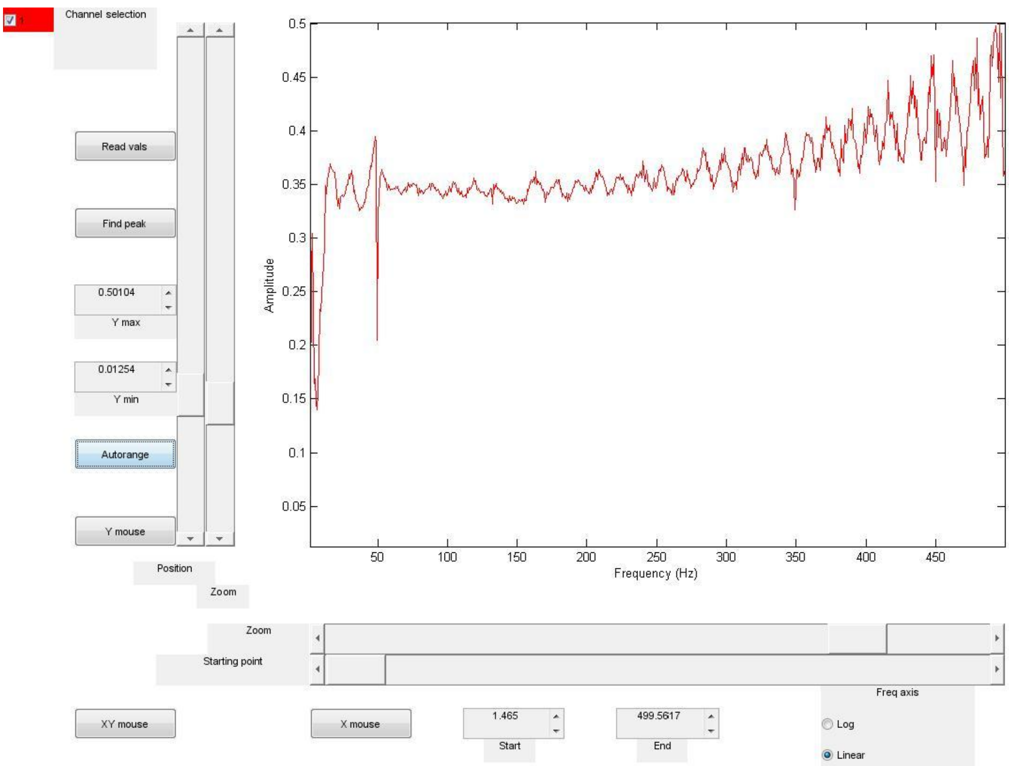

Figure 7 - Transfer function of calibrated mass using scale factor

2.5 Comparison of calibrated responses by the three methods

The above scaling factor was used to scale all of the transfer functions from the previous experiments.

Figure 8 shows all three methods of determining the frequency response superimposed onto one diagram. The red graph shows the impulse test.

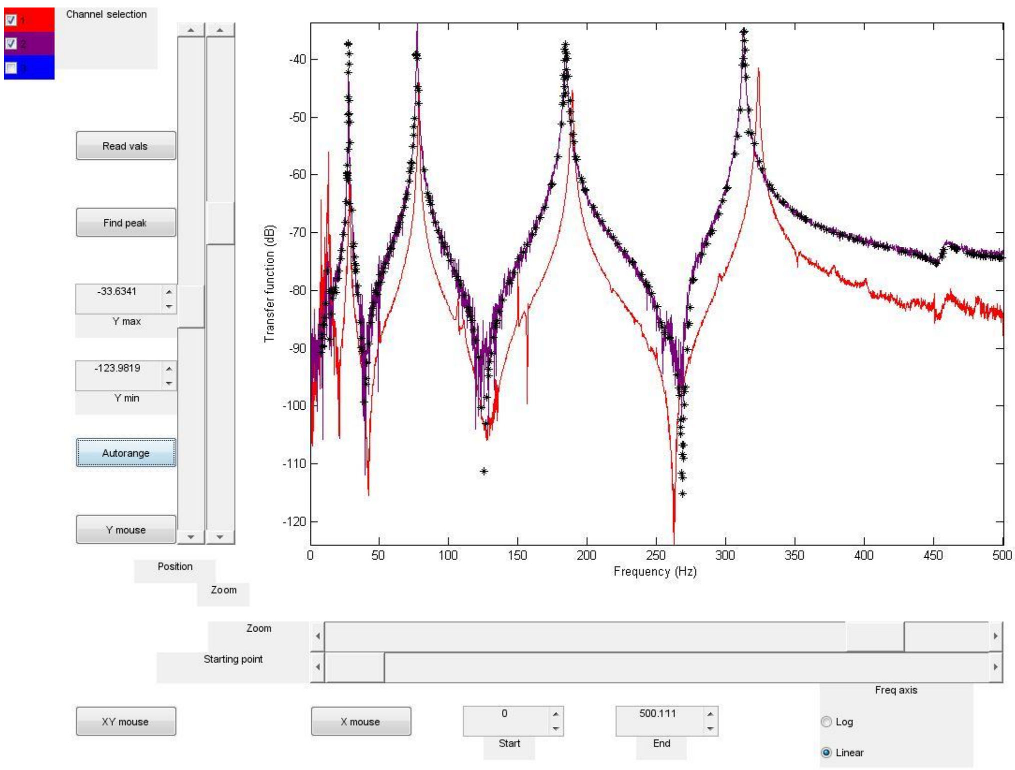

Figure 8 - Impulse test (red), Sine sweep (+), Noise test (purple)

2.6 Coupled system response and comparison

By removing the brass connector the transfer functions for each individual cantilever was found by the impulsive excitation test. Figure 9 shows these two functions, with the upper cantilever shown in red, and the lower in blue. The differences arise from the different lengths of the two cantilevers, resulting in different masses and therefore differences in the resonant peaks.

Applying the condition that the velocity at the point where force was applied must be the same in the case of both top and bottom cantilevers. The combined admittance was found from equation 2.

$$Y = (\frac{1}{Y_1} + \frac{1}{Y_2})^{-1} \tag{2}$$

Figure 10 shows the predicted response in purple, superimposed on top of the impulsively excited test in red which is shifted higher in frequency. The reason for this shift could be due to the fact that the magnetic signal generator was removed, altering the mass and therefore the resonant peaks slightly.

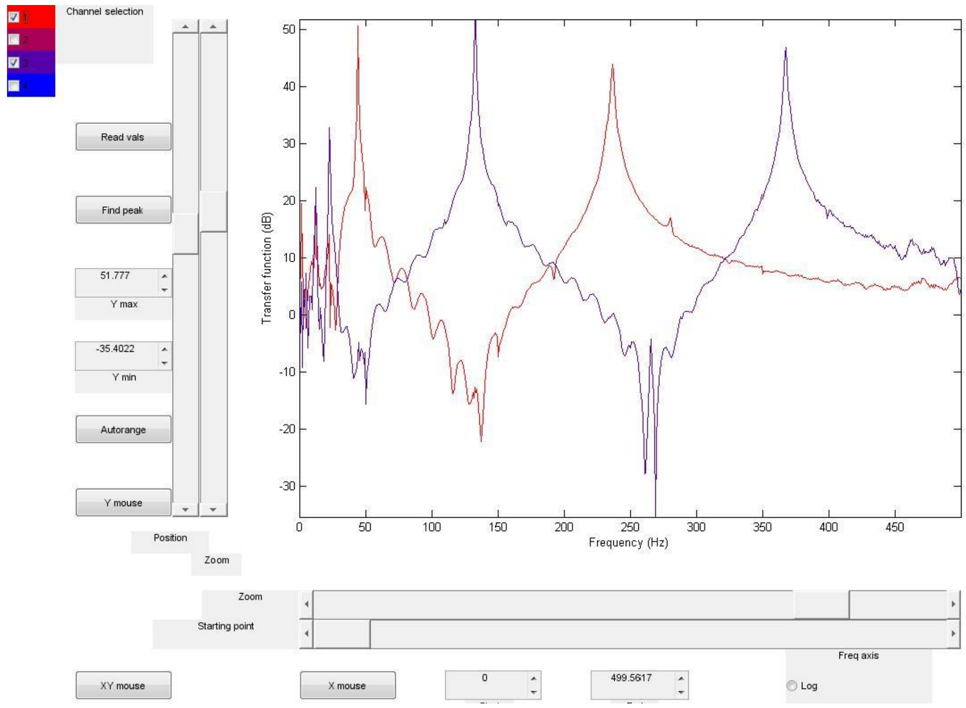

Figure 9 - Separate responses: Blue is lower cantilever, Red is upper

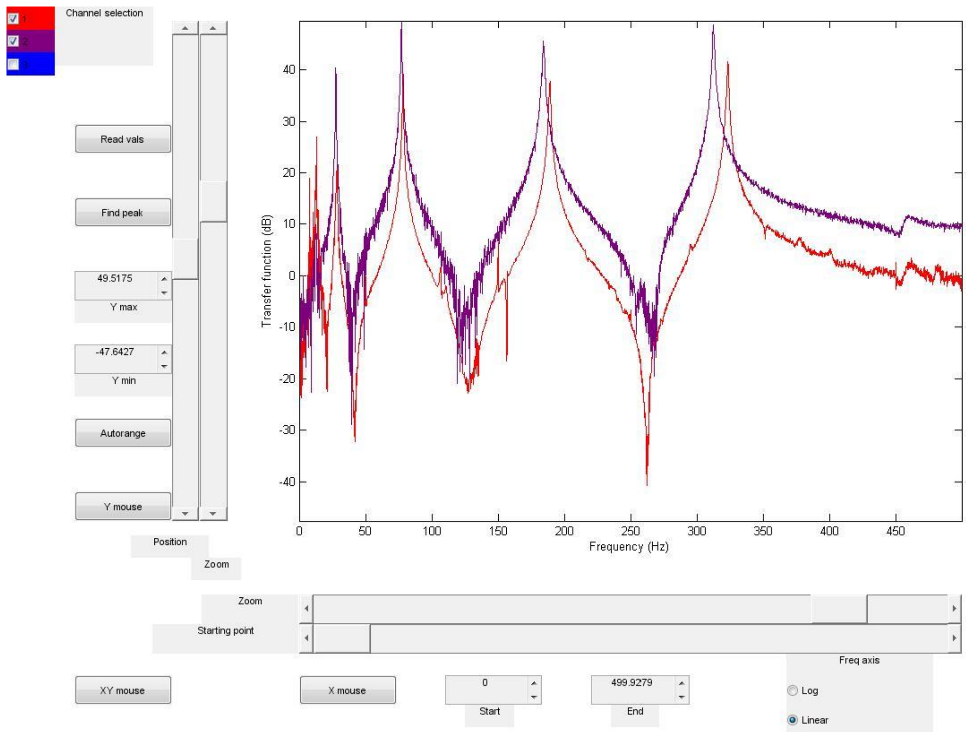

Figure 10 - Predicted coupled response (purple), Impulsively excited test (red)

2.7 Conclusions

Although performing a sine wave excitation throughout the frequency range is accurate for obtaining a transfer function, it gives discretised points, and not a continuous range of frequency response.

The transfer function can also be obtained by using random noise as an input if the sampling time is chosen such as to be long enough that transient effects die away and are not present in the measurements.

Using an impulse as an input gives a good idea of the transfer function across a large range of frequencies but fails to represent high frequencies due to the rounded shape of the hammer tip, and the finite nature of the input.

Decoupling the cantilevers or subsections of a large structure may be used to predict the transfer function of the coupled system.