MODAL SPACE - IN OUR OWN LITTLE WORLD

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Does the structure need to come to rest between impact measurements? Doesn't the damping window take care of that? This is important - Let's discuss this.

So now let's talk a little bit about what kind of problems can result from the measurement you described. The measurement you made was on a very lightly damped structure and in order to prevent leakage most likely an exponential window is needed. From what you described, the measurement is likely to look like what is shown in Figure 1.

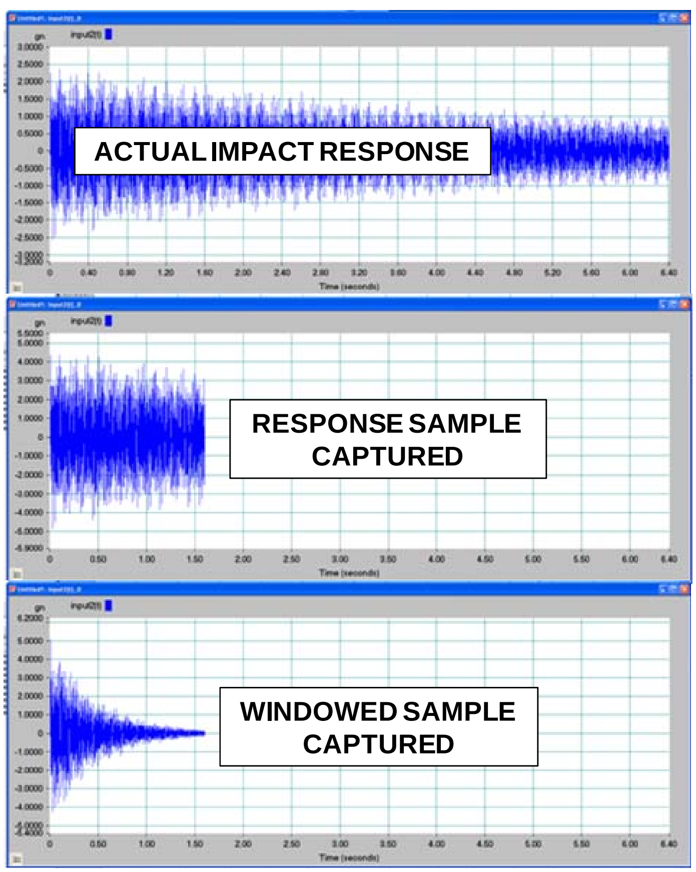

Figure 1 – Impact Response for One Sample

Now the upper trace shows the time response for a much longer sample than what you used for acquisition. The middle trace is what was actually captured from the FFT for the T seconds of data collected. And the lower trace is the time response with the window applied to the output response. So up until this point everything looks reasonably fine.

From what you described, the averaging was performed by impacting the structure and measuring the response for a series of many averages. A sample of these averages is shown in Figure 2. As far as you were concerned, the window was applied and the response was measured and averaging was performed to obtain the data described.

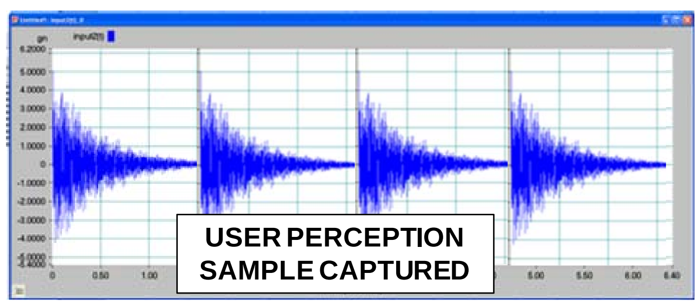

Figure 2 – User Perception of Impact Averaged Response

However, the frequency response function (FRF) that resulted (shown in Figure 3) did not look very good overall and the coherence was not very good either. In addition, this drive point FRF lacks the typical measurement characteristics that is expected with strong resonant and anti-resonant frequencies.

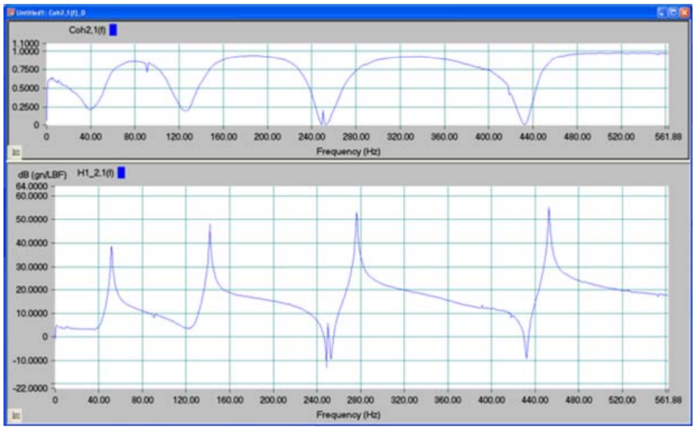

Figure 3 – FRF and Coherence from Initial Measurements

So what could possibly have gone wrong here. To understand what happened, we need to go back to the formulation of the system transfer function. When we write the equation of motion and perform the Laplace Transform we get

$$\left(ms^2 + cs + k\right)X(s) = f(s) + \left(ms + c\right)x_0 + m\dot{x}_0$$

and we get fairly comfortable writing the system transfer function as

$$H(s) = \frac{X(s)}{F(s)} = \frac{1}{ms^2 + cs + k}$$

but in order to do that we have to realize that the extra terms on the right hand side of the equation have been eliminated. It turns out that these are the initial conditions for the transformation.

So ignoring those terms assumes that the initial conditions are zero. But the problem is that the way that the original measurement was acquired, the structure's response in between each individual impact was assumed to be zero. While a damping window was applied to the data and it looks like the response has been decayed to zero, that is only with respect to the software used to acquire the data.

Actually what most likely happened is that the measurements were taken in close succession and the actual response of the structure never actually died out before the next sample was taken. This is schematically shown in Figure 4. So what happens is the response of the second average is contaminated by the remaining response of the first impact. And the third average is contaminated by the remaining response of the first and second average. And this continues for all the averages you took. So basically the measured response of each average (after the first average) is not the result of the impact excitation for that particular average and it is the response due to other than the measured force for that particular average. So that is why the coherence is so poor.

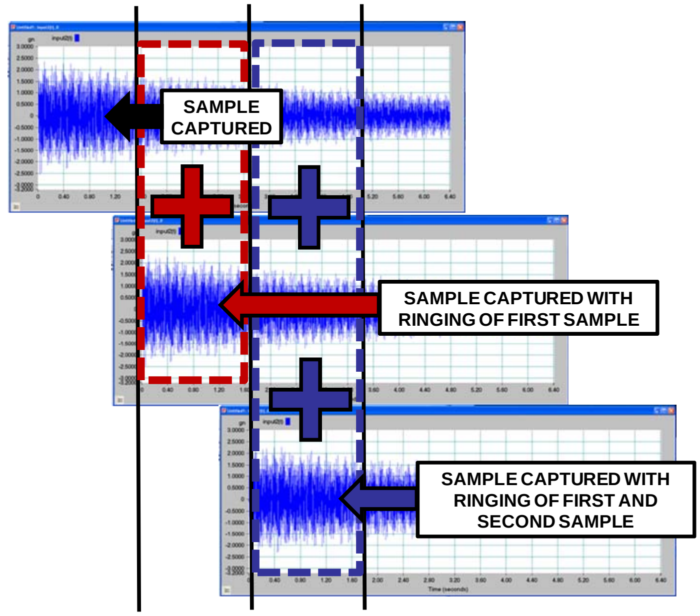

Figure 4 Impact Response from Structure Standpoint

To confirm that this is the case, another measurement was made where sufficient time was given to allow the structure to return to a steady state (no response) condition. The resulting FRF and coherence is shown in Figure 5 and it is very clear that this measurement is far superior to the one shown in Figure 3.

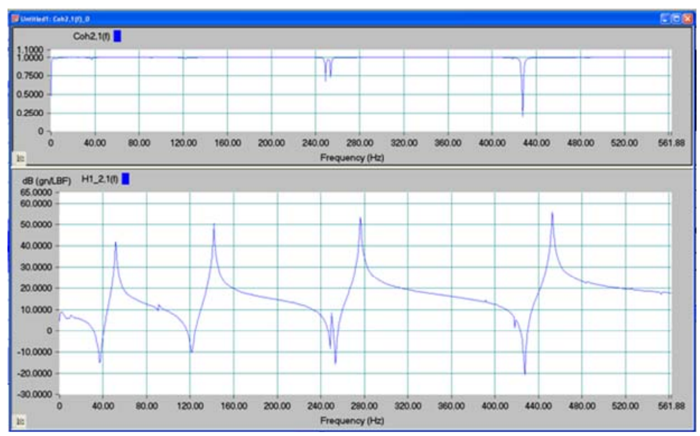

Figure 5 – Good FRF and Coherence from Proper Technique

I hope this explanation helps you to understand that the formation of the FRF is subject to some of the assumptions made in the formulation of the system transfer function, namely, that the initial conditions are assumed to be zero. Once these restrictions are observed, then proper measurements can be acquired. If you have any other questions about modal analysis, just ask me.