MODAL SPACE - IN OUR OWN LITTLE WORLD *by Pete Avitabile*

Illustration by Mike Avitabile

When impact testing, can the use of the exponential window cause any problems?
Let's discuss this

The exponential window can cause some problems if not used properly. If an excessive amount of damping is needed to minimize the effects of leakage, then you run the risk of missing closely spaced modes. There are a few examples to show the relative to the use of the window and what can happen if care is not exercised in using the exponential window.

First of all, let me clearly state that in many impact testing situations the use of an exponential window is necessary. However, before any window is applied, it is advisable to try alternate approaches to minimize the leakage in the measurement. Increasing the number of spectral lines or halving the bandwidth are two things that should always be investigated prior to using a damping window. Both of these items will essentially increase the total time for the collected data. This can often help by allowing the response of the system to naturally decay before the end of the sample period. If this can be accomplished, then the use of the exponential window may not be necessary.

However, if the response still does not decay by the end of the sample period, then an exponential window may be necessary. The use of the window should not be employed until these first two items (mentioned above) are checked as possible ways to minimize the leakage problem. The arbitrary use of the exponential window without first looking at the time response is not recommended as the first step in the measurement process. Let's look at this through the use of a simple example.

A very simple, lightly damped structure was subjected to an impact test. The signal processing parameters were selected for a 400 Hz bandwidth which resulted in a 1.0 second time window. Since the structure was expected to have a response that would not decay by the end of the sample interval, an exponential window was applied such that the windowed response would decay to a reasonably small value by the end of the sample interval thereby minimizing the effects of leakage. The impact excitation, windowed exponential response and the FRF are shown in Figure 1. On the surface, this measurement looks acceptable. [Note that the input spectrum (not shown) was reasonably flat over the entire frequency range thereby allowing sufficient excitation of the structure. Also note that the coherence (not shown) was also considered very acceptable.]

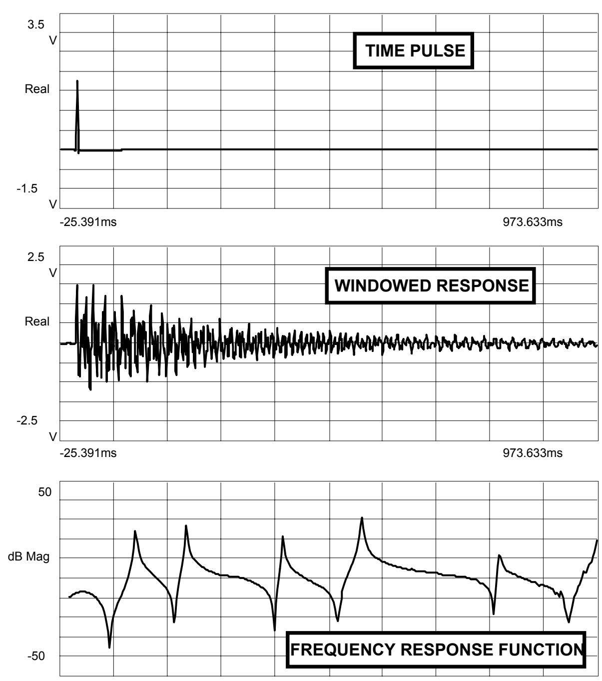

Figure 1 - FRF with slightly too much damping

From all aspects, this measurement appears very acceptable. But we need to look at this measurement in more depth. First, let's consider the same measurement but add significantly more damping to the response signal. Figure 2 shows the same data but with a significantly larger value of damping used for the exponential window. The FRF that results from the impact measurement of this signal clearly has significantly more damping than that shown in the FRF of Figure 1. The peaks of the FRF show this effect; notice that the peaks are much wider due to the excessive use of the damping window.

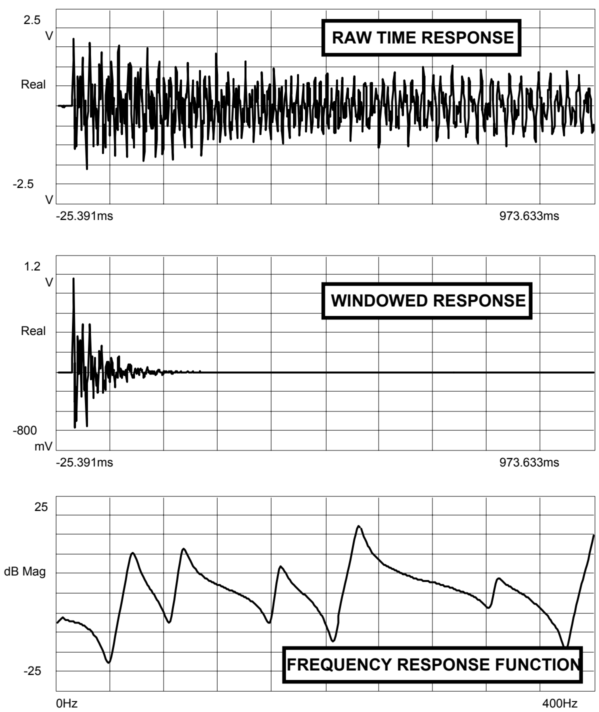

Figure 2 - FRF with too much damping

Now let's look yet a little deeper into this measurement and try some alternate signal processing parameters. In order to minimize the use of the damping window, either the bandwidth can be shortened or the number of spectral/time lines of resolution can be increased. Both of these changes result in an increase in the total time necessary to collect the sample of data. If the total time is increased, then there is less need for a significant amount of damping window to be applied to the collected time data.

Figure 3 shows a doubling of the number of spectral/time lines of resolution. The time sample was increased from 1.0 second to 2.0 seconds. While an exponential window was still necessary to minimize leakage, the overall damping effect that was added to the measurement is far less than that used for the measurements shown in Figure 1 and Figure 2 above.

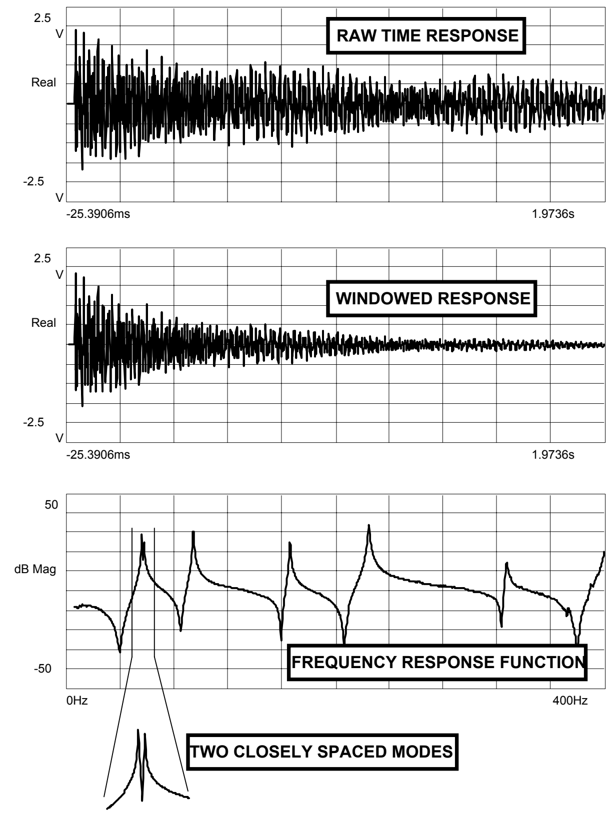

Figure 3 - FRF with increased time/spectral resolution

The most important item to notice in Figure 3 is that what appeared to be one mode at the first peak in the FRF actually turns out to be two very closely spaced modes of the structure. The use of the damping window in Figure 1 and 2 resulted in an FRF that appeared to have only one mode at the first peak in the FRF. The use of the damping window caused these two distinct modes to appear as only one peak in the FRF.

While the damping window was necessary to minimize the leakage, the window distorted the actual FRF in Figure 1 and 2 such that it was difficult to observe that two peaks existed at this frequency. The use of the exponential window, while necessary for digital signal processing considerations, can cause some significant difficulties when evaluating structures with light damping and closely spaced modes as seem in this example.

Now, I hope you can see some of the effects of the exponential window in this example. While an exponential window may be necessary to minimize the effects of leakage, the use of the window may also hide or distort the modes in the measurement. It is extremely important to be very careful when using the exponential window when performing an impact test. If you have any other questions about modal analysis, just ask me.