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

Illustration by Mike Avitabile

When I perform impact testing, the input spectrum looks distorted – do you think my FFT analyzer has a problem?
Let's take a measurement and see what's going on.

The only way to figure out what is going on is to do a little trouble shooting. But of course we have to have some idea of what the correct answer should be. Well … for an impact test, the force in the time domain should be just a simple pulse over a very short duration. And the resulting frequency spectrum should be a relatively flat input profile over some frequency range. The width of the input spectrum is directly related to the time of the pulse. Basically, the shorter the pulse in the time domain, the wider the frequency range that is excited. And conversely, the wider the pulse in the time domain, the narrower the frequency range that is excited. At least this is what we expect to get. So now let's go down to the lab and take a few measurements with your analyzer to see if this is what we get. (In this article, I will try to replicate what was actually observed during a test at a particular lab. But I cannot reproduce exactly what occurred due to FFT hardware differences.) For this test, a typical impact hammer is being used and the structure under test is just a typical structure with an accelerometer mounted on it.

The impact force is shown in Figure 1 with the time response (upper two traces in black). Now the time signal looks reasonable. The impact signal is a sharp pulse with relatively flat zero signal over the entire time. In terms of the response signal, the damped response of the system appears to be reasonable but a window may be necessary to minimize leakage.

The input spectrum (shown in blue in the lower trace and labeled as distorted force spectrum) is also fairly flat with little roll-off to the input spectrum as expected. But one thing to notice is that there is a significant spike in the spectrum at very low frequency which does not look correct. This is definitely not expected and is probably the reason you have asked a question regarding this measurement. This needs to be investigated further.

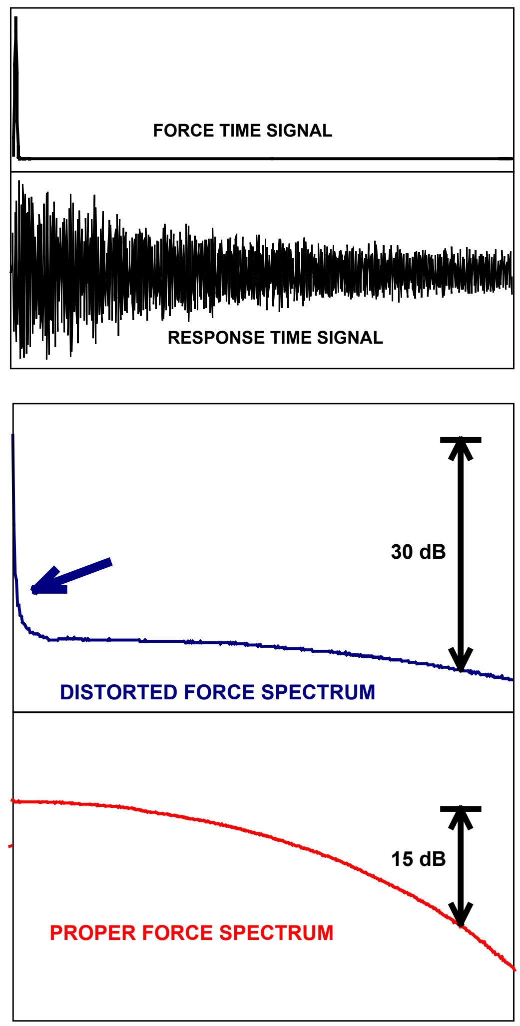

Figure 1 – Impact Time Force, Exponential Accelerometer Response and Force Spectrum (Proper and Distorted)

Now let's return to the time signals and do a little investigating on the measured signals. The first thing to check is if the input transducers have a suitable signal and whether the electronics may be a problem (ie, check for transducer saturation along with checking cables, batteries, etc). Usually the FFT analyzer can be setup into some type of time sampling mode to view the time signals as would be done on an oscilloscope. As long as there appears to be a suitable signal, then you can proceed to the FFT representation of the signal.

The time signal looked adequate … but a question needs to be asked if any windows have been applied to the measured data. Based on the analyzer window settings for this particular analyzer, there *does not appear* to be any windows applied to the force input signal. But the response signal may need a window. However, many times the labels for the force and response windows are confusing on many FFT analyzers. Most times the labels make sense but many times the analyzer software uses labels that may not clearly identify the window being used.

In this particular case, the input signal was labeled as not needing any window – the label on the force channel indicated something similar to "**response only window**". Now that label is confusing to me. The label might mean that "only a window is applied to the response channel" – or does it mean something else? Of course, we should open up the user's manual and read the paragraphs related to this particular window configuration. But many times, a typical user may think he knows what all the buttons/labels mean since he is familiar with other FFT analyzer equipment used in the past and not think that reading the user manual is really necessary. On the other hand, sometimes the user manuals are just as confusing. Often times I am more confused by the user manual information than when I started.

So, typically, I resort to a very simple "hunt and peck" approach. That is, select one parameter to be changed while others remain constant. In the case of the impact hammer, the first check is to make sure that the force gage is not damaged – swapping another force hammer is the simplest thing to check along with cabling and signal conditioners.

The next check is the FFT acquisition system setup. The analyzer window for the force channel was set to "**response only window".** The response window can also be changed – but our first impression is that this has nothing to do with the input force spectrum. Originally, the response window had been setup as a Hanning window which is obviously incorrect – this may have been set as a default setting for some other tests such as processing random type signals. The window should either be no window or the exponential window. As a first check, the rectangular window was selected (and should be done first even if an exponential window is ultimately required). Now the response signal appears to be the same as previously observed.

Now this is not possible since the Hanning window had been applied previously. Well, it turns out that the original signals were observed as the "un-windowed" signals which is the default setting for many analyzers – specific setting have to be selected in order to view the windowed signal on certain analyzers. While the response signal is obviously affected by the application of the window, the interesting observation is that the ***force spectrum on the input channel also appears to be affected by the window on the response channel!*** The force spectrum is shown in Figure 1 in the lower trace (shown in red and labeled as proper force spectrum). How could the force spectrum on the input channel change when the response window is changed?

Is the analyzer broken? Should you report this flaw to the manufacturer? Well – actually no! On many FFT analyzers, the response window is actually applied to the response signal as well as the force signal in order to properly compute the ratio of the output to input (this is commonly done to avoid the distortion that results from applying the window to just the output response – there are theoretical issues that justify this but we don't need to discuss those here). The important item here is that the response window is applied to both the input and output channels on many (but not all) FFT analyzers. So now we can see why that original force spectrum was distorted – now it is clear what "**response only window**" meant. The original FFT analyzer was setup with a default setting using the Hanning window – on the response channel. Even though the only channel being evaluated was the force channel, the window effect on the response channel was equally important.

You need to be extremely careful when performing any testing using FFT analyzers. You need to be very sure you understand how the analyzer operates – many analyzers have many different features and not all of them are the same. To be sure, make some simple checks like were done here to assure yourself that the measurements are acquired in a proper sense.

I hope that I have answered your question regarding this impact measurement problem. If you have any more questions on modal analysis, just ask me.

(Author Note: The events described in this paper have been replicated using different analyzer hardware to show what was essentially observed during this interesting measurement. It is not a statement concerning the hardware used – but rather a caution that test engineers need to carefully understand the functionality of their particular FFT analyzer hardware.)