MODAL SPACE - IN OUR OWN LITTLE WORLD

by Pete Avitabile

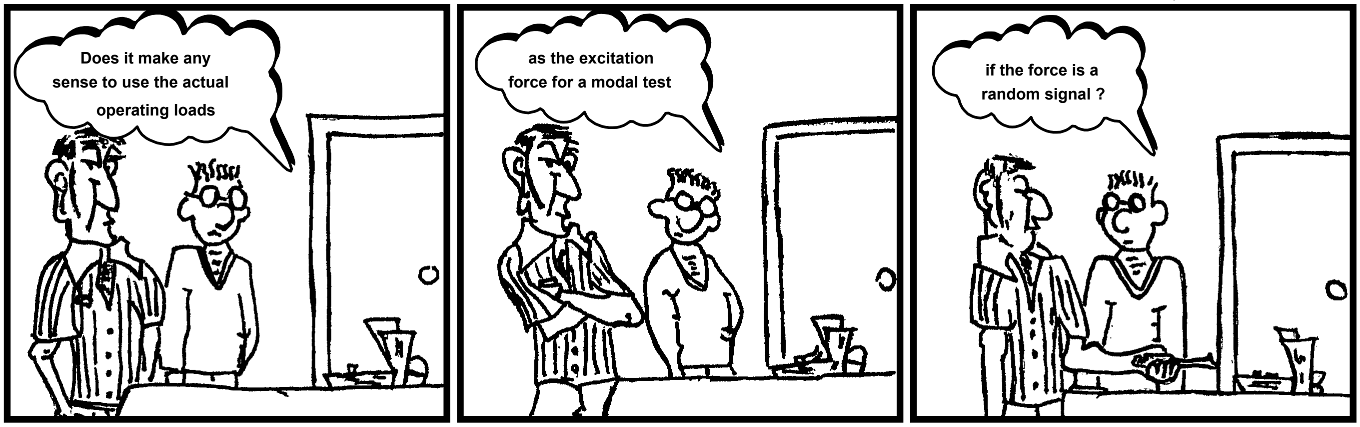

Illustration by Mike Avitabile

Does it make any sense to use the actual operating loads
as the excitation force for a modal test
if the force is a random signal ?

The answer to this question is not an easy one. There are many aspects related to this question that we need to discuss in order to fully understand the answer.

The use of a random operating excitation may seem to be an excellent idea, but the bottom line is that the modal parameters that are extracted are not likely to be nearly as good as those obtained from a modal test where the excitation is one of the more traditional excitation techniques. Let's discuss this to see where some of the pitfalls exist. In order to understand all of the implications, there have been some other modal questions that have been asked and answered that will help shed light on this question (SEM ET V23 No1, V23 No4, V23 No6).

Let's recall that an experimental modal test is typically performed to extract the underlying modal parameters of the structure - that is, the frequency, damping and mode shapes. Accurate measured frequency response functions are needed in order to extract these parameters. Typically, we go to extreme lengths to excite the structure with very specialized excitations to minimize, and ultimately eliminate, leakage and other signal processing errors that can possibly result. Remember that any signal processing errors that do result, distort the measured frequency response and manifest themselves as less accurate modal parameters.

As a general rule, random signals do not provide the best excitation for the development of accurate frequency response functions. Random excitation techniques are notorious for causing leakage in the measured spectra. Even with the use of windows, the measured frequency response functions are distorted when compared to other leakage-free measurement techniques (ie, burst random, sine chirp, digital stepped sine).

A comparison of a frequency response function from a random excitation and a burst random excitation is shown in Figure 1. It is very clear in the measurement that the burst random, leakage free measurement is far superior to the random measurement. (While not shown, the coherence is also far superior.)

To go one step further, the extracted modal parameters from the random excitation will also be distorted, and in many cases, there actually appears to be two peaks as seen in the measurement. This is a typical effect seen in frequency response functions measured using random excitation. Leakage is a serious concern and windows are necessary to minimize leakage. The whole purpose for the development of specialized functions for modal testing is to provide highly accurate frequency response functions which do not require the use of any windows and provide leakage free measurements for the accurate extraction of modal parameters.

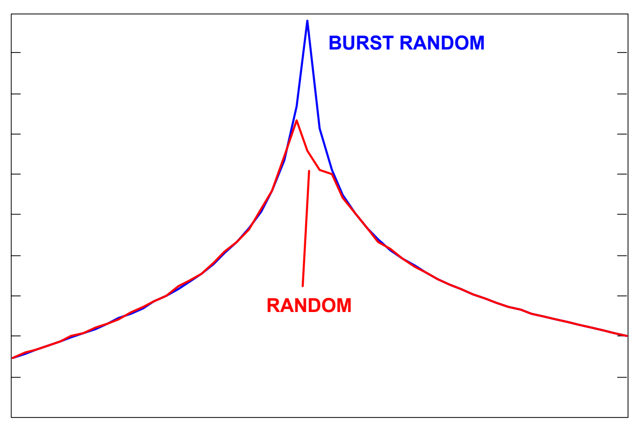

Figure 1 - FRF for Burst Random and Random

So what would ever posses anyone to perform a modal test using an operating random excitation. Well, if the actual force was used to excite the structure, then the response will be similar to the actual response in service. This response will be an accurate depiction of the actual in-service deformations that will be seen in the structure. But then the response that is measured is more appropriate for use in an operating deflection analysis - but not an experimental modal survey!

Figure 2 shows a schematic of the response of a structure due to an arbitrary input excitation. There are several aspects of this figure that will give greater insight into the question at hand. The forcing function is broadband, but has a very distinct profile which is not flat, thereby exciting all of the modes with different excitation levels.

First, and foremost, notice that the frequency response function is nothing more than an bandpass filter which amplifies and attenuates the input force excitation as a function of frequency. What would happen if the estimation of this frequency response was tainted or distorted by the digital signal processing procedure (ie, digitization, quantization, leakage, windows, FRF method, etc.) ??? Well, of course, there would be an effect on the computed response! The goal of a modal test is to extract the accurate dynamic system characteristics.

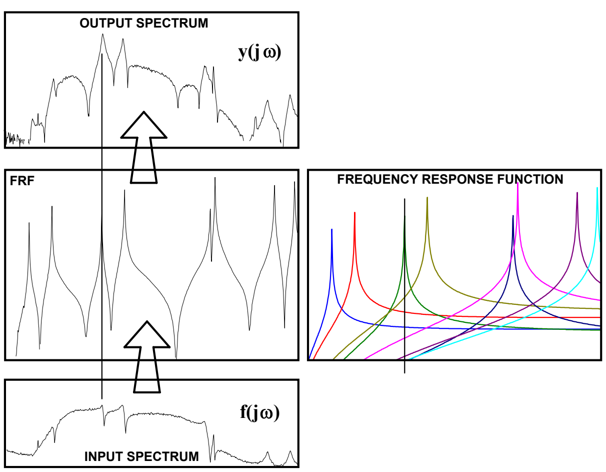

Figure 2 - Typical Input-Output Situation

Second, the level of the force spectrum over the frequency band has a direct effect on the response of the system. Figure 3 very clearly shows that the response has significant variation over the frequency band. Since the ADC maximum setting is determined by the total spectrum, there will be a wide variation in the accuracy of the measured function. In fact, the lower response spectral components will have a much larger effect due to quantization errors associated with the analog to digital conversion process. This is particularly true when looking at the response of mode 1 and mode 3. Notice that mode 1 shows very little response due to the extremely low input excitation; mode 1 response will be very small and may be affected by noise.

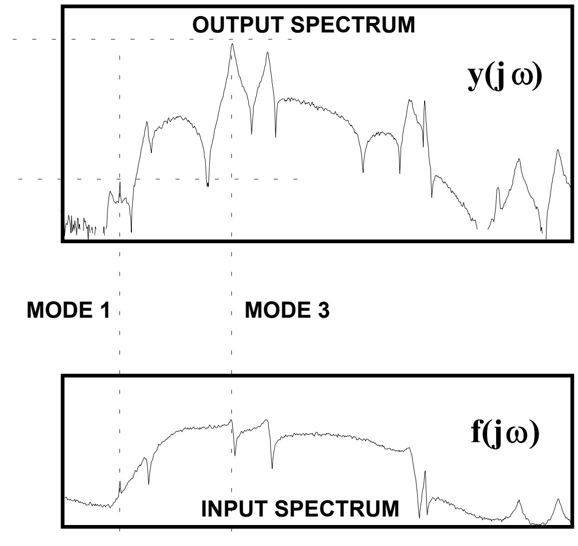

Figure 3 - Signal Level Differences

Third, remember that if a random signal is used, then a Hanning window must be applied otherwise the measured signals will contain significant leakage. In any event, the measured frequency response function will be affected by the window and leakage that does result. The measured function will not be of the best quality and the extracted modal parameters will suffer from these signal processing effects.

Fourth, the measured frequency response function will have errors associated with poor excitation signal strength over some frequency regions, leakage and window errors due to the random nature of the signal type, frequency response function errors as seen in the coherence associated with leakage especially at the resonant peaks, and modal parameter estimation errors due to poor estimated frequency response functions used for the modal parameter estimation process.

So in the big picture of the development of a modal model from measured functions, the best excitation techniques will provide the best representation of the modal parameters of the structure. This will not necessarily occur using an operating random spectrum. Once a modal model is developed, then the actual response of the structure can be determined, if necessary, using the measured frequency response function as pictorially shown in Figure 2. But in order for accurate response to be computed, an accurate modal model from accurate frequency response functions is of paramount importance.

Now, there is tremendous merit in performing an operating test using operating excitations. However, this is not necessarily the best way to estimate frequency response functions for use in the development of a modal model. Now I hope you understand the problems associated with running an experimental modal test with an operating excitation. If you have any other questions about modal analysis, just ask me.