MODAL SPACE - IN OUR OWN LITTLE WORLD

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Which shaker excitation is best? Is there any difference?
Well ... that's a good question
Let's talk about the different techniques.

Let's discuss the most commonly used excitation techniques for modal analysis today. These are random, burst random, sine chirp and digital stepped sine. But before we discuss the excitation techniques themselves, there are a few basics that we need to discuss first. Let's try to categorize the different techniques and explain when to use which technique. First of all, let's break up the excitations into deterministic and non-deterministic (or random) excitations.

Deterministic signals are those that can be described at any point in time by a mathematical function - they can be *determined*. Typical signals of this type are sinusoidal in nature, such as sine chirp and digital stepped sine. Random signals, on the other hand, can not be described by a mathematical function but are rather described by their statistical characteristics. Typical signals of this type are random and burst random.

In general, we use deterministic signals on linear systems. We also use deterministic signals to determine if a system is linear by performing a linearity check. We use random signals to average slight nonlinearities in a system due to things such as rattles. If we have a structure that has gross nonlinearities, then we need to stop and think just how useful the results of a *linear modal analysis* will be. But understanding the difference between these two categories helps in deciding which technique will provide the best measurement. Depending on the system being tested, you may want to *document the linearity* of the system under test, or you may want to *linearize* any slight nonlinearities that exist..

Now first, let's consider a random excitation. Random is used quite widely for general vibration testing today. But it is not considered one of the best techniques for acquiring FRF measurements for modal testing (although it is still often used). The random nature of the signal excites the structure with varying amplitude and phase as averages are collected. This tends to average any slight nonlinearities that may exist in the structure. While this is a benefit, the signal nevers satisfies the periodicity requirement of the FFT process. Therefore, leakage is a tremendous problem. Even with a Hanning window applied, the resulting FRFs will always suffer from leakage; the peak amplitude will be affected and there will be an appearance of more damping in the structure due to the leakage and windowing effects. A typical measurement sequence is shown in Figure 1. The resulting FRF and COH are shown in Figure 2. Notice how the coherence dips at the resonances of the system; this is a characteristic of random excitation.

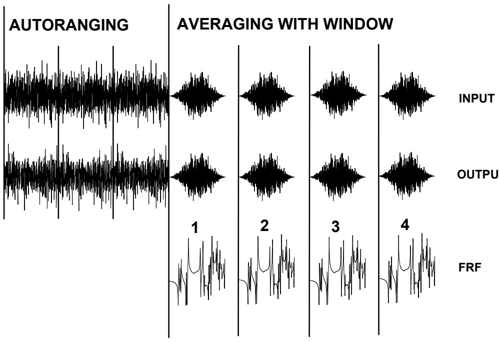

Figure 1 - Typical Random Measurement Sequence

Now, let's consider a burst random excitation. The only difference is that the random signal is only used during a portion of the data capture. If a pretrigger delay is also used, then the signal is totally observed within one sample interval.

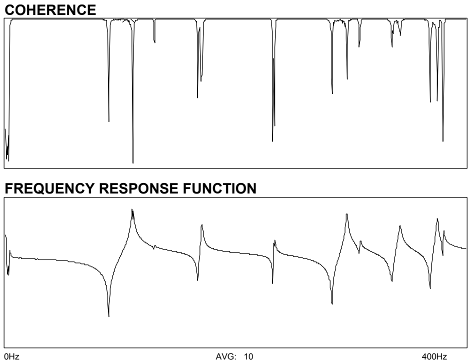

Figure 2 - Random Excitation w/Hanning

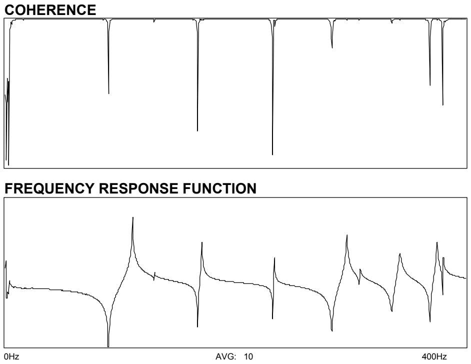

Figure 4 - Burst Random Excitation

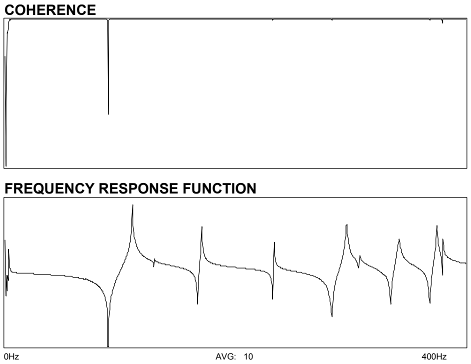

Figure 5 - Sine Chirp Excitation

Therefore, the signal satisfies the periodicity requirement of the FFT process. This means that no leakage will occur and no window is needed. Of course, both the input and responsesignals need to satisfy this requirement. This is easily done for most structures. This signal is well suited for averaging out slight nonlinearities that may be found in the measurement. A typical time measurement is shown in Figure 3. Notice that the excitation is terminated such that the response signal also decays to zero within the sample interval. The resulting FRF and COH are shown in Figure 4. Notice the improvement in the measurement and coherence when compared to Figure 2. The peaks are much sharper and better defined; the coherence is especially good at the resonances.

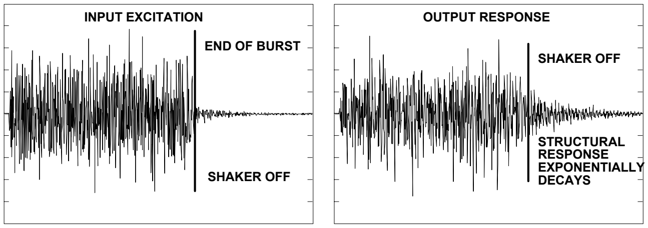

Figure 3 - Typical Random Measurement Sequence

Now, the sine chirp is a fast sweep from low to high frequency within one sample interval of the analyzer. The signal repeats and therefore satisfies the periodicity requirement of the FFT process. This means that no leakage will occur and no window is needed. Of course, the signal must be played continuously so that the structure steady state response is achieved. The resulting FRF and COH are shown in Figure 5. The measurement is very similar to the results from the burst random test. By changing the input force level applied to the system, linearity checks can be easily made using this excitation technique.

Finally, the digital stepped sine technique requires that a single frequency, coincident with an analyzer spectral line, is used to excite the system. Since the signal is guaranteed to be periodic with regards to the FFT process, no leakage occurs and no windows are necessary. Since it is not broadband in nature, this technique is the slowest of all techniques because each spectral line is evaluated individually. However, it is excellent for documenting nonlinearities and is likely to produce the best measurement of all the excitation techniques above.

When comparing the techniques, the burst random and sine chirp will produce similar results if the system is linear. In general, the random measurement will always suffer from leakage and the quality of the measurement will suffer when using this technique. To illustrate the degradation of the measurement when using random excitation, Figure 6 compares random and burst random with an expanded look around the first resonant peak of the system. The random signal contains alot of variance and the peak is distorted at resonance (where the coherence is known to dip). In fact, there almost appears to be two modes at that frequency; this is due to the distortion of leakage. The burst random measurement is clean and sharp. Clearly, the burst random measurement is the better of the two measurements.

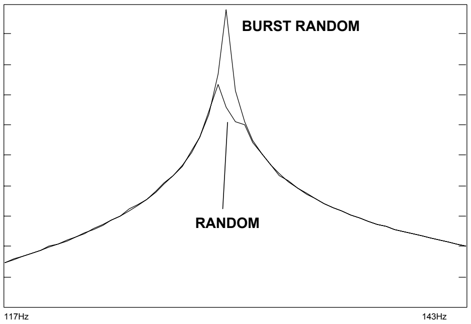

Figure 6 - FRF for Burst Random and Random

We could spend alot more time discussing all the details of each of the techniques (as well as others not mentioned) but there isn't enough time right now to cover everything. Maybe another time we can discuss each of the techniques in more detail. But this quick overview should give you what you need to know. If you have any more questions on modal analysis, just ask me.