MODAL SPACE - IN OUR OWN LITTLE WORLD

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I know that certain shaker excitations have different characteristics – but which is the best to use?
Let's discuss this.

Let's discuss the most commonly used excitation techniques for modal analysis today. These are random, pseudo random, burst random, sine chirp and digital stepped sine. These will just be briefly reviewed (because they have been covered before), but the more important issue is do they all provide the same results all the time. There is not always a straightforward answer to this so we will discuss some issues to consider when performing shaker testing. The main excitation techniques utilized are shown in Figure 1 for reference.

Random is still used at times today, even though leakage and windows cause some distortion of the signals acquired. The time signal is shown in different colors. (This is mainly done to highlight the fact that each measured time signal is different from one record to the next.) Since each signal sample is different than every other signal, the system is excited with different spectral characteristic for each record of data collected. If the system has slight non-linearities, then the system will respond differently for each record of data – the averaged data will then reflect the best linear description of the system in the presence of these slight nonlinearities. This type of excitation is very useful to minimize or smooth data that is subjected to noise or rattles or other measurement contaminants. But leakage and windows tend to distort the measurement so this is not the optimal excitation technique.

Pseudo random is really nothing more than a set frequency spectral lines over a frequency band of interest that are inverse transformed to the time domain to create an excitation signal. Since the excitation is basically sinusoidal in nature, the effects of leakage are non-existent providing the system is excited sufficiently long enough that steady state response is achieved. This proves to be a very useful excitation. However, because the signal is repetitious (notice that the excitation color is identical from one record to the next), the system will respond in a deterministic fashion. This will not average any slight nonlinearities or rattles that may exist in the system. Pseudo random works very well with structures that are fairly linear in character.

Burst random excitation was developed as a very good excitation technique which combines the advantages of both random and pseudo-random excitation. The signal is random from one record to the next (notice the different colors from one record to the next) and nonlinearities are averaged in the process. Since the signal is completely observed in one sample interval, there is no leakage and windows are not needed. The only concern is to make sure that both the input AND output response are totally observed within the sample record of data.

Sine chirp excitation is a fast swept sine that is completely observed within the sample interval. The effects of leakage are non-existent providing that steady state response is achieved. This excitation is very similar in advantages/disadvantages to pseudo random. One additional advantage is that the level of force can be controlled and can be used to identify the nonlinear character of the system.

Digital stepped sine excitation is yet another very useful excitation technique. This is very similar to pseudo random except that only one frequency is excited at a time. But one significant difference lies in the improved description of the signal amplitude. Broadband techniques (those discussed above) require that the analog to digital converter (ADC) be set to capture all the energy over the entire spectrum. But the frequency character may have a wide variation in amplitude over the frequency spectrum. This is not an issue with digital stepped sine since all of the energy of the excitation/response is dedicated to one single spectral line in the frequency spectrum. Therefore, quantization error is not an issue for this excitation.

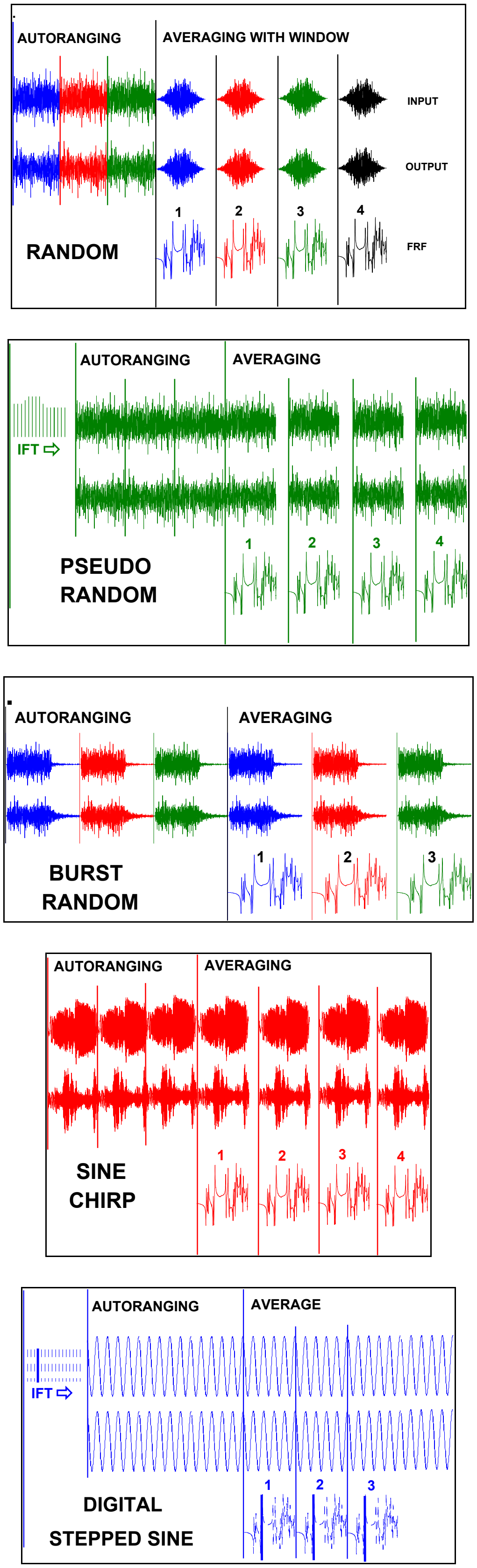

Figure 1 - Typical Shaker Excitations Employed

So it seems pretty straightforward what to do. Well, the reality is that things aren't always so simple. So now that we have categorized all the excitation techniques, let's talk about what some of the issues are that might arise. In general, over the past several decades I have generally found that burst random usually works best overall. But I have also used sine chirp on many occasions when the structures were fairly linear in nature. When I have needed extremely high resolution FRFs, then I have used digital stepped sine. Once or twice, I have used either pseudo-random and random. So let me explain some of the times I have used other signals and explain why.

One structure I tested many years ago was a very lightly damped system. It turned out that burst random was not very effective. The system was so lightly damped that the response could not be totally observed within one sample interval of the time record – even with the burst set to less than 5% of the time window. Fortunately, this system was fairly linear so that pseudo-random excitation was employed (but sine chirp could have also been effectively employed for this structure).

When a structure does have some nonlinear character, then it may be desirable to perform the test at a level that is comparable to the in-situ conditions. Sine chirp proves to be a very good excitation for this type of test. So why not use digital stepped sine – well for this particular test there were not a sufficient number of acquisition channels available to make the test feasible.

I guess the best thing to realize is that there is always going to be some situation which may make one of the available excitation techniques provide a better measurement than the other excitation techniques. Each of the techniques needs to be compared to determine which is the best. Don't just rely on one technique because it has proven to be acceptable in the past.

But today, with the large channel count systems that are more common for modal testing, my recommendation would be to utilize all of the excitation techniques. Today there is sufficient disk storage that this shouldn't be a concern. Since it takes a good deal of time to set up a large number of accelerometers on the structure, why not run all the different excitation techniques – even digital stepped sine which takes much more time than the broadband based techniques. If you have spent 3 or 4 days setting up a large test, do you think anyone will care if you take a few hours and collect all the data possible? I don't think there will be objections. At least then you have all the data.

I hope that I have answered your question regarding the different excitation techniques. If you have any more questions on modal analysis, just ask me.