MODAL SPACE - IN OUR OWN LITTLE WORLD by Pete Avitabile

Illustration by Mike Avitabile

Is there really a difference running a modal test with MIMO as opposed to SISO?
You bet there is - Let's discuss this.

Well I hear this question a lot. I guess mainly it is due to the fact that additional hardware and software needs to be purchased to do MIMO testing. And so it needs to be justified that MIMO is really much better than SISO.

So last time we discussed the fact that using a single shaker and "cranking up the signal" could likely excite nonlinearities in the structure and that the overall FRF would likely be affected by this. So from that data, it is very obvious that the single shaker test may not provide the best set of FRFs for modal parameter estimation.

Another approach that I often see people try is to use one shaker but then move the shaker to all the different locations for the desired number of references. On the surface this may seem to be a useable solution but there are limitations to this approach. The first problem is as we already discussed – the level of force with one shaker will need to be much higher in order to get adequate response at all the measurement locations in the structure.

Now a single shaker may work for structures that are not very complicated with many components and substructures that are attached in a manner to minimize the flow of energy through the subsystems. The situation is much different when the components are isolated from each other. In these situations it is very hard to get adequate response throughout the structure with just one excitation source. In these cases, multiple references are needed.

So let's discuss the difficulty with the data collected from a single shaker that is moved to the different reference locations to collect the multiple referenced FRF data. Unfortunately, many of the tests and data sets that I have seen are not available for public release. So instead, a simpler structure that contains all of the features typically seen in complicated structures with components and subsystems that are mounted to minimize the flow of energy in the structure (isolated) was assembled in the lab.

The laboratory structure is shown in Figure 1. This structure was assembled with 3 components mounted to a frame. Each of the components was mounted with a very soft mount, an intermediate mount and a very hard mount. Now the main frame and the attachments do have some of the typical "pesky" rattles and noise that plague the collection of FRF data; no attempt was made to minimize any of these noise sources and in fact they are welcome to illustrate a typical structure measurement.

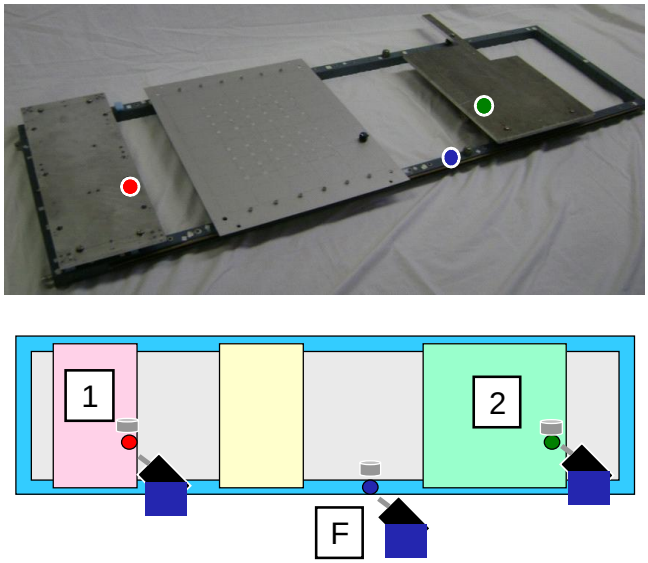

Figure 1 – Laboratory Structure with Isolated Components

The structure was tested in many different configurations and only a few of them are presented here to show the problem with the FRFs collected with single shaker set up and with a multiple

shaker set up.The three shaker reference locations are shown in Figure 1.

Now separate tests were run with each of the individual shakers used to collect FRF data from the structure as well as a multiple reference MIMO set of data. However, in order to make the best possible measurements, the individual SISO shaker tests needed more force excitation level to make suitable measurements; the MIMO configuration needed lower force levels in order to make accepatable FRF measurements.

In order to compare all the measurements, several FRFs were compared. In all FRFs the reference was made to the shaker mounted on the frame; the other references could be used and yielded essentially the same results as those presented next. In Figures 2, 3 and 4, the FRF in red was obtained from the SISO test and the FRF in black was obtained from the MIMO test. Two measurements are shown from the frame to the attached components and one of the measurements was a drive point on the frame itself.

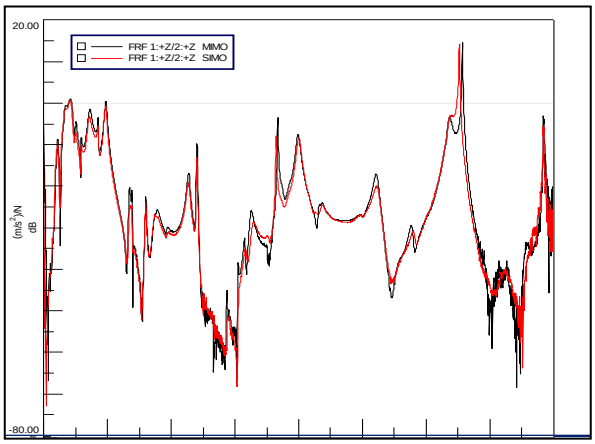

Figure 2 – FRF Component (1) to Frame (F) Reference

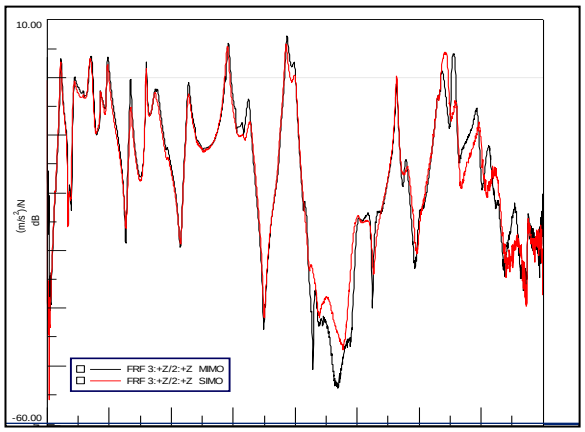

Figure 3 – FRF Component (2) to Frame (F) Reference

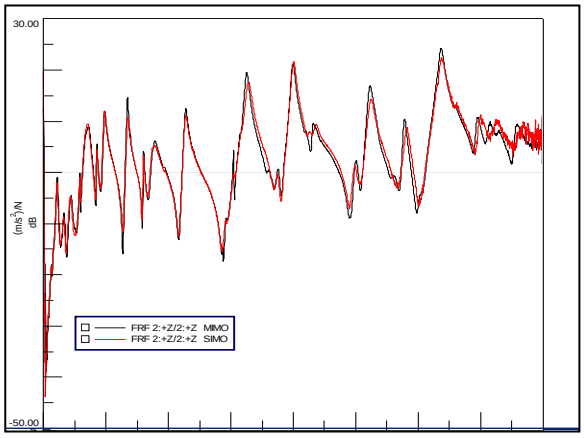

Figure 4 – FRF Frame (F) to Frame (F) Reference

So at first glance, the data in Figures 2, 3 and 4 don't look terribly different and I know that many people might actually say that data is just fine. But if you start poking around and looking more closely at some of the reciprocal FRFs, then it becomes very clear that the peaks of the FRFs from the SISO tests don't line up with each of the different SISO tests that were conducted. This then causes a discrepancy or inconsistency between the different data sets. A few of these are shown in Figure 5.

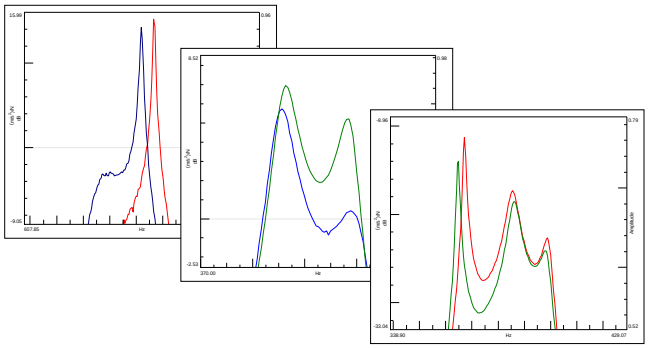

Figure 5 – Close Up of Several FRFs Showing Inconsistency

The bottom line of all of this is that the reciprocity between the different data sets is not satisfied! This will have a significant effect when modal parameters are extracted (and will be discussed in the next article).

I hope this explanation helps you to understand that using one shaker at different locations does not necessarily provide the best data. MIMO tests are needed in order to provide more consistently related FRF data from multiple references. If you have any other questions about modal analysis, just ask me.