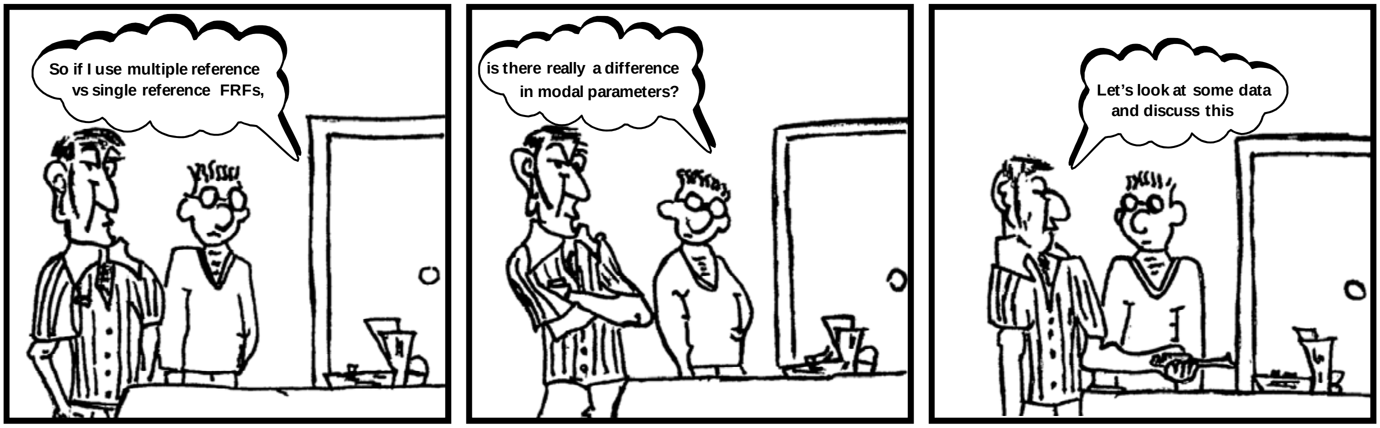

Illustration by Mike Avitabile

So if I use multiple reference vs single reference FRFs, is there really a difference in the modal parameters?
Let's look at some data and discuss this.

Well from a purely theoretical standpoint, you are able to extract modal parameters from any reference location as long as it is not at the node of a mode. But of course, the theory is perfect and we need to consider the practicality of the measurements we can make on any real structure.

In the last two articles, several aspects of the measurements were discussed. Overall, the FRF measurements are always much better overall when the data is collected simultaneously in a MIMO test. If a single shaker is used two issues arise that tend to provide FRFs that are not of the best quality for modal parameter estimation.

In one case, a single shaker needs to have a higher excitation level in order to make adequate measurements but this invariably cause nonlinearities to be excited and generally tends to increase the variance and the FRF measurements are not as good as one would like.

The second issue noted was that when multiple referenced data was formed from single reference tests, generally the FRFs are likely to not be related in a consistent fashion and the FRF peaks may show some slight variation in frequency. While the structure may be time invariant, the test set up can have an effect on the measured FRFs when the tests are obtained from separate tests. And then another variability can result in the fact that all the data is collected at different times and there may be slight environment changes that could compound this problem.

In order to have some continuity with the two previous articles, the test data for this discussion will be the same data previously used. Of course we noted that there were some shifting of the frequencies for some of the modes and that the reciprocity was not satisfied for all the SISO data that was collected and used to form the multiple reference data set.

The laboratory structure is schematically shown in Figure 1. Three reference sets of data were collected using SISO methodology in three separate tests; data was also collected for all three references simultaneously using a MIMO methodology.

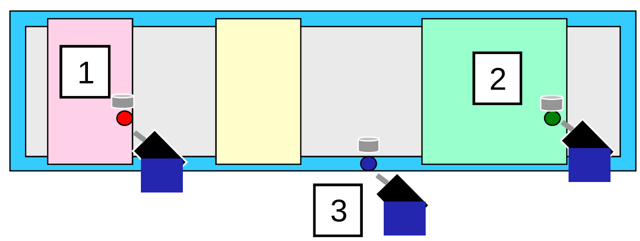

Figure 1 – Laboratory Structure with Isolated Components

So the previous articles discussed some of the measurement issues. Here what I want to do is to process some of this data to show some of the difficulties in identifying modal parameters. In all cases the stability diagram will be used to show how some of the variance on the data will present challenges for identification of the system poles.

So the first thing to try is to take all three separate SISO test FRFs and form one set of multiple reference data for processing. (And please note that I am not calling this MIMO data because it was actually all collected separately.) The first step in the modal parameter estimation process is to identify the system poles. This is usually done using the stability diagram with an overlay of one of the mode indicator function; for the plots here, the CMIF is used in all cases.

Figure 2 shows the stability diagram for this case. While this diagram may be acceptable to many, there is definitely some variation in the system poles and there is not a good strong stable pole identified for every one of the system poles. (As we reprocess this data, the improvement in the stability diagram will be seen.)

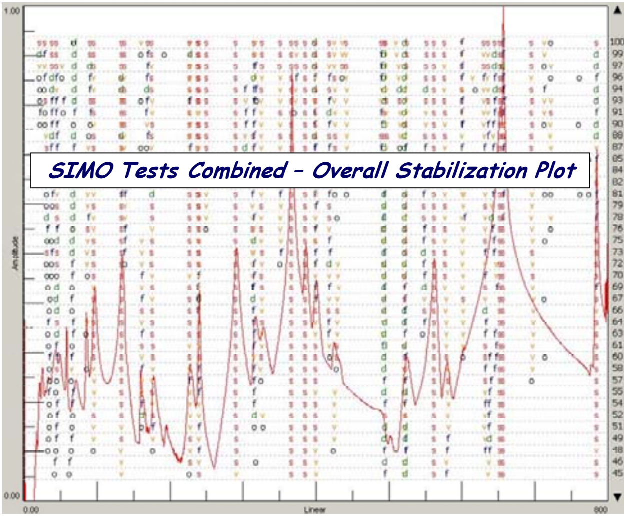

Figure 2 – Stability Diagram for Combined SISO FRFs

But before we look at the MIMO data set, let's look at the individual SISO data sets alone. Figure 3 shows the three separate SISO test data sets processed individually before being combined into one multiple referenced data set. The thing that is very obvious is that the stability diagram for each of the separate test cases produces very consistent stable system poles. There is no question what the system pole is when the data looks this good.

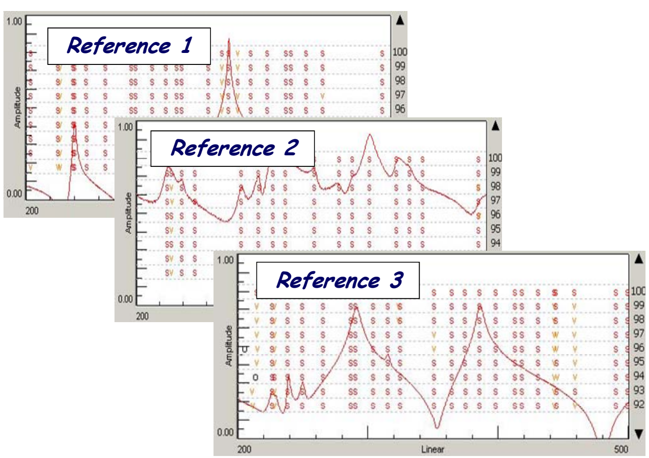

Figure 3 - Stability Diagram for Three Separate SISO Tests

So why are the individual data sets (Figure 3) so obvious as to what the system poles are and is not as clear cut (Figure 2) when all the data sets are combined? Well remember that each of the individual SISO data sets were collected consistently for each of the individual SISO tests. Even in light of some of the noise and nonlinearities that were discussed in the previous two articles, the identification of the system pole is not difficult at all. But when all the individual SISO data sets are combined, there is no guarantee that the data will be consistently related between the three different SISO tests that were performed. And in fact, the shifting of the peak of the FRF measurements was pointed out in the previous article. This shifting was noted in several measurements such as the reciprocal FRFs. So the main culprit here is the fact that the data was collected in three separate tests and the data was not necessarily guaranteed to be consistently related. This is why the stability diagram becomes a little more difficult to interpret and the system pole identification is not as straight-forward when this happens.

To confirm this, the MIMO data set (where all the data is collected simultaneously and in a consistent fashion) is used to generate a stability diagram. This is shown in Figure 4. This stability diagram is much better than the one shown in Figure 2. Of course there are some frequencies that are still not perfect – but this is much better than the previous scenario where the data was collected separately and the consistency of the data could not be guaranteed.

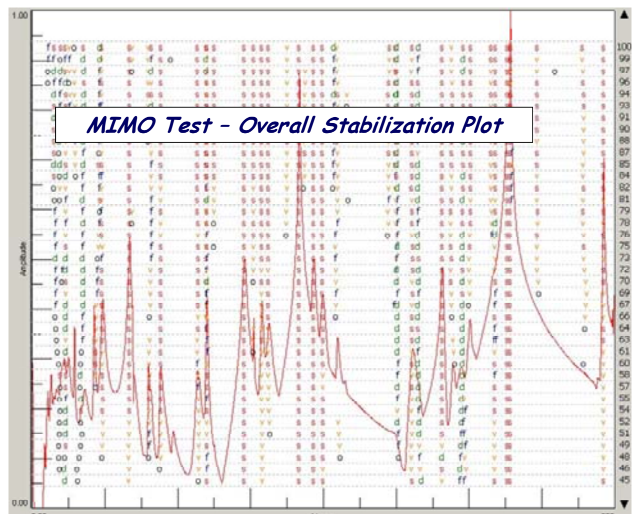

Figure 4 – Stability Diagram for MIMO FRFs

So the real problem here lies with the data. The FRFs must be collected in a consistent manner. The SISO test can not provide data with this consistency but the MIMO test generally does due to the nature by which data is collected.

I hope this helps to explain why collecting data in a consistent fashion is very important for any multiple reference test. Collecting data from separate single input reference tests may not provide the best data for modal parameter estimation. 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.