MODAL SPACE - IN OUR OWN LITTLE WORLD

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What is MRIT? I hear people talk about it for impact testing. Let's talk about this testing technique.

MRIT, or Multiple Reference Impact Technique, has been around for many years now. It became popular when multichannel FFT analyzers became more affordable and more commonly available in everyday experimental modal analysis testing. Let's first start with some simple concepts related to single input single output systems and then move on to a deeper understanding on the information in the FRF matrix. This will lead us to understand why we might be interested in MRIT as a testing technique for the development of multi-referenced data.

In the old days, most people only had a two channel FFT analyzer at best. (You know… we had to walk uphill to school, both ways, in the snow and rain, with no boots or rain coats!). We collected FRFs for one input output location at a time. Then another measurement was taken. Now depending on whether it was an impact test or shaker test would determine the reference location.

In a shaker test, the force measurement was the reference and the accelerometer was "roved" around the structure to different locations. (Obviously it was easier to move the accelerometer rather than the shaker.) Once all the measurements were acquired, a column of the FRF matrix was obtained. The particular column that was measured was determined by the location of the force measurement on the structure.

But in regards to impact testing, possibly the hammer could "rove" while the accelerometer was kept in the same location. In this case, the accelerometer was the reference and a row of the FRF matrix was obtained. Again the particular row is determined by the location of the accelerometer on the structure. (But there is also the possibility that the hammer could be held stationary and the accelerometer would "rove" around the structure).

In any event, the stationary measurement was called the "reference" because it was the same for every input output measurement acquired. Figure 1 shows a typical column from the FRF matrix for a shaker test (or stationary hammer test) in blue and a typical row of the FRF matrix for an impact test (where the hammer roves around the structure) in red.

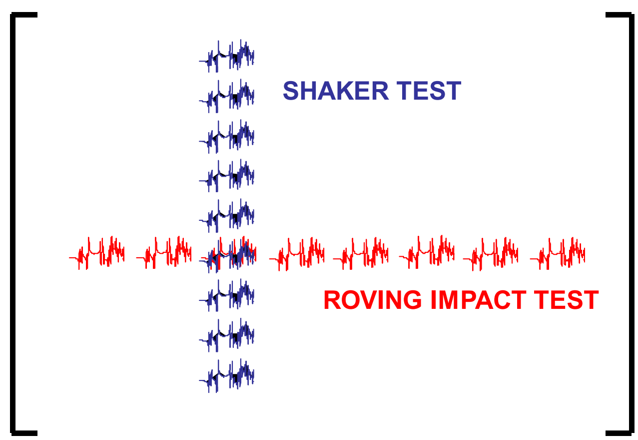

Figure 1 – Typical Row/Column Measured in FRF Matrix

OK – so now we know the old days. Because only one FRF was measured at a time, it was fairly simple to conduct a modal test. But the most critical aspect of the test was the appropriate selection of the reference location. This has been discussed several times before but it is clear that the reference location must be able to measure the mode shape for all the modes of interest from that reference location. The mode shape is related to the residues as

$$\begin{Bmatrix} a_{11k} \\ a_{21k} \\ a_{31k} \\ \vdots \end{Bmatrix} = q_k u_{1k} \begin{Bmatrix} u_{1k} \\ u_{2k} \\ u_{3k} \\ \vdots \end{Bmatrix}$$

for one particular reference location. This corresponds to one column of the residue matrix. (Remember that the residue matrix is symmetric so this can also be written to address a row of the residue matrix.) If the reference location is close to the node of a mode for one or more modes, then the measured FRFs will not provide the best information for extraction of the modal parameters. Therefore, this reference selection is critical. However, if more than one row or column of the FRF matrix is collected then redundant information is available. So as discussed several times before, the entire residue matrix is defined as

$$\begin{bmatrix} a_{11k} & a_{12k} & a_{13k} & \cdots \\ a_{21k} & a_{22k} & a_{23k} & \cdots \\ a_{31k} & a_{32k} & a_{33k} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix} = q_k \begin{bmatrix} u_{1k}u_{1k} & u_{1k}u_{2k} & u_{1k}u_{3k} & \cdots \\ u_{2k}u_{1k} & u_{2k}u_{2k} & u_{2k}u_{3k} & \cdots \\ u_{3k}u_{1k} & u_{3k}u_{2k} & u_{3k}u_{3k} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

The collection of multiple rows or columns of the FRF matrix is therefore very desirable. The multiple reference modal parameter estimation algorithms take advantage of this redundant information to get the best possible modal parameters from the redundant multiple references. Now I said "redundant" several times to emphasize this important fact. But sometimes these extra references may not be optimal for all the modes if that were the only reference. This is really the reason why multiple references are often used. Just in case one of the references is not located at an optimal location, there will be other references that will contain better information.

Now we understand that it is good to have more than one reference for the estimation of modal parameters. So as multiple channel FFT analyzers became more commonplace, the ability to collect simultaneous sets of references from multiple locations became very possible.

Thus the birth of ***Multiple Reference Impact Testing***. Generally, this can be done by placing multiple accelerometers at various locations on the structure that are expected to be reasonably good references for most of the modes of the structure. So, for example, if a four channel FFT was utilized, then one channel would be used for the force hammer and the remaining three channels would be used for a reference accelerometer. And contrary to popular belief, this does not have to be a triaxial accelerometer at one point on the structure – it is probably better to use three separate single axis accelerometers located at three different locations (and they don't have to be located one in x, one in the y and one in the z axis!).

Using this strategy, then each time a set of averages are acquired, there would be three different FRFs, in three different rows of the FRF matrix. As the hammer roves from one point to another, three additional FRFs would be acquired and as all impact locations were completed, then three separate rows of the FRF matrix would be acquired as seen in Figure 2. This data collection process is referred to as Multiple Reference Impact Testing.

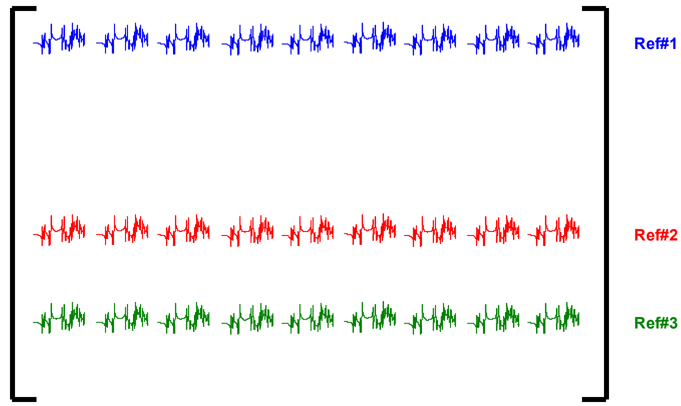

Figure 2 – Multiple Rows Measured in FRF Matrix

One variation of this MRIT occurs when a large multichannel system is used to measure all the accelerometer responses simultaneously. If only one location is impacted then one complete column of the FRF matrix is measured similar to the shaker test in Figure 1. Of course, if we would continue and impact a few different locations, then multiple columns of the FRF matrix would be obtained as seen in Figure 3.

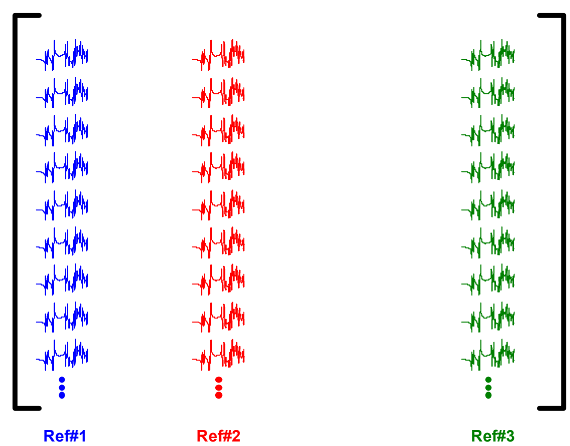

Figure 3 – Multiple Columns Measured in FRF Matrix

In both cases described, multiple reference data is obtained from the MRIT approach. This is a very good way to collect multiple referenced data. If a multiple channel FFT is available, I can't imagine not performing a MRIT test. It doesn't take any more time and multiple reference data results which is very useful.

If you have any more questions on modal analysis, just ask me.