MODAL SPACE - IN OUR OWN LITTLE WORLD

by Pete Avitabile

Illustration by Mike Avitabile

Why does my stability diagram of a component on a system show modes that the Sum or MIF don't show?
Let's look at some measurements and see what's going on.

There must be more to this problem than what was stated by your question. My guess is that you are performing a modal test on a structure but you are not measuring all the significant modally active portions of the system during the modal test.

Now what do I mean by that. Well, there are many times when a modal test is performed and there is only an interest in a portion of the structure and nobody wants you to spend any time testing more than what you actually need to do or are being funded to do. This happens all the time in real lab environments. Let's say for instance that you are trying to solve a vibration problem on the floor board of an automotive structure. Now your first thought might be that you don't want to make measurements on the exhaust system of the car – since you are only interested in the floor board.

Of course when you only make measurements on the floor board the rest of the automotive structure is not divorced from the measurements made on the floor board. That means that the measurements made see the response of the entire system. Now granted that most of the measurements on the floor board will be primarily due to the response of the floor board. But there will also be effects of other portions of the system that will be observed in the measurements. Their response may not be strong but it will be there. So a measurement on the floor board will also have the effects of other portions of the structure such as the exhaust system, seating system, etc. It is impossible to completely separate out the response of these other systems. Unless of course the floor board is cut out of the structure and tested separately. But then the floor board modes do not have the same boundary conditions as assembled in the system so the modes of this separate test may not provide the required insight into the response of the system.

This is a problem that can be seen in many experimental modal tests that are conducted on just about any type of structure. It could be floor boards in an automotive structure. Or maybe fuselage modes of a shell like structure when the only area of interest is the wing modes for flutter studies. Or it could be ….. well I just don't have enough room to list all the possible scenarios. But rest assured, it is a prevalent problem in just about every structure that could be subjected to modal testing.

So in order to illustrate what could happen, I went down to the lab and used one of my existing structures that has lots of local modes, a few global modes and some nonlinear behavior due to joint problems – just a typical structure that I often use to illustrate these types of problems you have described. The structure is shown in Figure 1 and is setup for some shaker testing. This structure consists of a very stiff outer frame and a very flexible panel structure that is held in with a clip arrangement. Notice that the shakers are set up for testing only the outer frame of the structure and in the initial test, accelerometers are only located on this outer structure; initially there are no measurements on the panel structure since it is not of immediate concern (or so it is assumed).

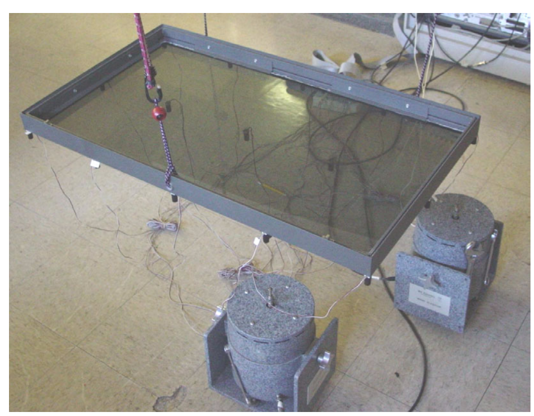

Figure 1 – Ribstiffened Panel Structure

Now Figure 2 contains a drive point measurement from one of the shaker reference locations. Notice that there are three well defined peaks and some other characteristics that are not well defined.

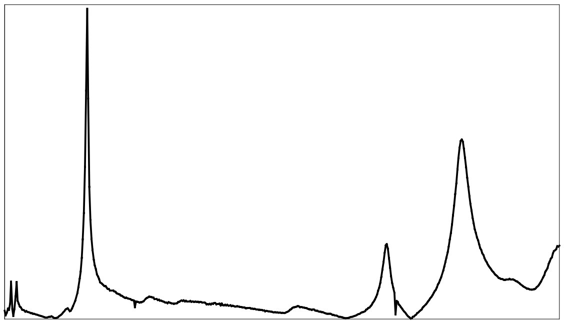

Figure 2 – Drive Point FRF on Frame Structure

Now using just the measurements on the frame structure, a stability diagram is developed as shown in Figure 3. Notice that there are many more than three fairly well stabilized poles in that plot. The SUM function and MIF function show the three peaks very well but the balance of the peaks are not shown very clearly at all. So this stabilization diagram appears to be identifying many more modes than what appear to be interpreted from the SUM and MIF functions.

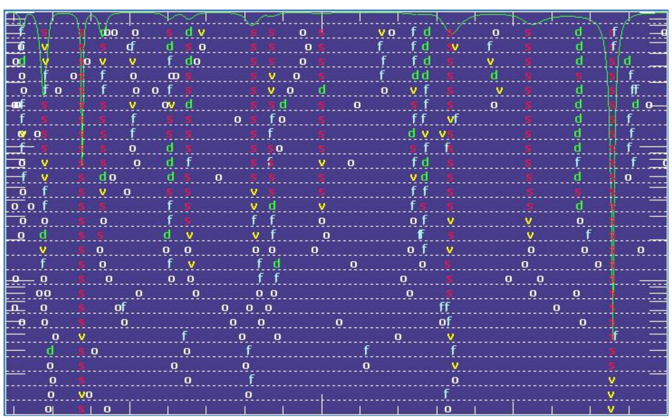

Figure 3 – Stability Diagram and MIF from Frame FRFs Alone

Now the problem is that the structure has many more modes that what can be easily seen on the frame portion of the structure. That panel has many modes that have very little contribution to the response of the frame portion of the structure but their effects can be seen in the measurements taken only on the frame. That is to say that the poles of the system can be seen in the stability diagram even though the SUM and MIF do not show those peaks very well at all.

Now let's take a set of measurements that includes the panel portion of the structure. A drive point FRF on the panel is shown in Figure 4. Notice that there are many more peaks in this measurement than seen in the previous drive point FRF in Figure 2. (Note: these measurements have significant effects of joint slop and have nonlinear characteristics but this structure is very good for illustrating the local modes effects of concern in this discussion).

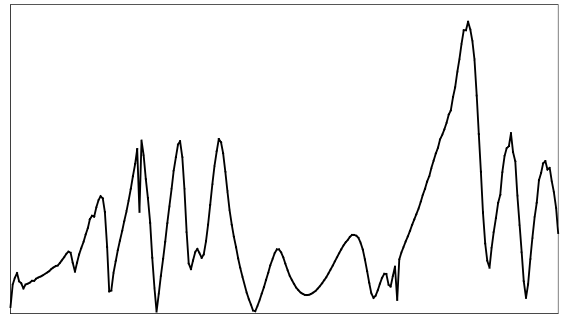

Figure 4 – Drive Point FRF on Panel Structure

Now using all the measurements on the outer fame as well as the panel, the stability diagram in conjunction with the SUM and MIF function shown in Figure 5 appear to present a much clearer picture of all the so called extra modes from the stability diagram of Figure 3 shown previously.

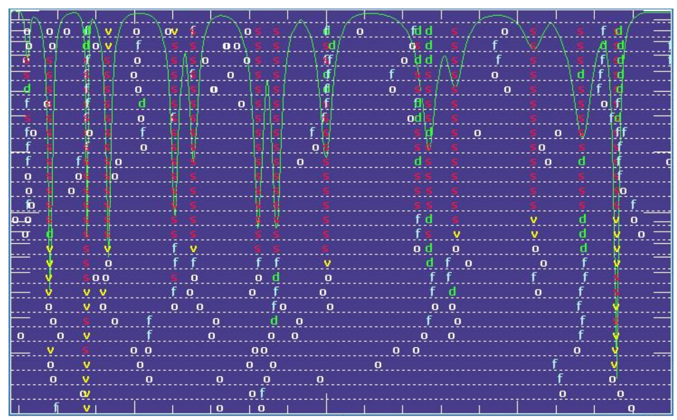

Figure 5 – Stability Diagram and MIF using all FRFs

So now it becomes much clearer as to how many modes are in the band and why the previous stability diagram did not provide useful information. In order to use the tools to interpret the measured data, it is imperative that a sufficient set of FRFs be acquired to adequately describe all the dynamics of the structure – not just the portion of the structure of immediate concern. I see this situation occur very often in industry. A problem arises regarding a portion of a system (or contractually you are only obligated to a portion of the system) and measurements are taken on just that portion of the system. The data obtained only contains a piece of the puzzle. The use of the mode identification tools can become confusing if only a subset of data is acquired. Many times more than just your "region of interest" may need to be measured in order to understand the complete dynamics of the system.

I hope that I have answered your question regarding this interpretation of the stability diagram. If you have any more questions on modal analysis, just ask me.