MODAL SPACE - IN OUR OWN LITTLE WORLD *by Pete Avitabile*

Illustration by Mike Avitabile

So what really is a drive point FRF? Do you have to impact exactly at the same point?
Let's take a look at this.

Drive point measurements have always raised questions in regards to experimental modal tests. There are several things that need to be considered when conducting a test especially for this measurement. So it is very important to discuss it.

The drive point measurement is a very important measurement to be made as part of an experimental modal test. The drive point frequency response function is a measurement where both the input force and response are measured on a structure at the same point and in the same direction. Now a few things need to be considered when we discuss this type of measurement.

For sure, it is very difficult to actually hit the structure at the same location where you are simultaneously measuring the response, so there are some practical implications that need to be considered. I have seen some cases where accelerometer casings appear to have been subjected to physical impacts in order to try to take this drive point frequency response function. Now this is definitely not recommended as the way to take this measurement. So we need to think about how to make the measurement and how to consider the implications of the practicality of actually taking this measurement.

So obviously we need to try to achieve the desired result as closely possible without actually impacting right on the accelerometer itself. So one way to achieve that would be to measure on the opposite side of the structure. If the cross section is very stiff or a solid cross section then this would appear to be a possible way to achieve that result. The only difference would be that the phase of the measurement would need to be considered so that if the positive sensing direction of the accelerometer was 180 degrees opposite to the desired measurement then the phase would need to be corrected. And in just about every modal software package available, the software allows for the phase to be included with the specification of the measurement being in either the "plus" direction or in the "minus" direction. So that is not really a problem (but we will discuss one difficulty in a few moments).

The other way to achieve the drive point measurement is to impact alongside the accelerometer when making the measurement. Now this is not truly a drive point measurement but if the structure is very large, then this is not a problem. So if I were to take a measurement on a big wind turbine blade, then the effects of this small difference in the location of the impact would be essentially insignificant. But if I were to take the same drive point measurement on a much smaller structure such as a disk drive or jet engine turbine blade then the size of the structure relative to the small difference in the actual geometric location of the accelerometer and the actual impact location may have a fairly significant change in the drive point measurement in that case.

The effect is going to be very dependent on the change in the value of the mode shape over that very small distance. If the mode shape doesn't change very much then the difference in the actual drive point measurement and the acquired drive point measurement may be essentially insignificant. But as the structure starts to get smaller or higher modes are considered, then the effects of the actual change in the mode shape can have a much bigger impact (no pun intended). This can really all be related back to the equation describing the frequency response function written in terms of mode shapes for a single mode approximation can be given as

$$h(j\omega) = h(s)\,\Big|_{s=j\omega} = \frac{(q\, u_i\, u_j)}{(j\omega - p_1)} + \frac{(q\, u_i\, u_j)^*}{(j\omega - p_1^*)}$$

Obviously if the value of the mode shape between point "i" and "j" is extremely small then the change in the actual measured frequency response function and the drive point measurement will be very small. So it is all dependent on size and the change in the mode shape over the very small distance of the accelerometer and impact location.

But let's consider one additional case that might be a more common problem that needs to be addressed. Many times a measurement will be made and the accelerometer is located on the opposite side of the structure for convenience. If the structure is a solid cross section or it is very stiff then it would seem reasonable to make that measurement in that manner. Or it might not be possible due to space constraints. In any event, a simple tubular beam cross section will be used to show some additional concerns that need to be considered. The beam cross section is shown in Figure 1 with two small teardrop accelerometers mounted on the structure along with a schematic to the right with a red accelerometer shown as the true drive point measurement and the blue accelerometer shown as the approximation of the drive point measurement that might typically be acquired. Obviously the measurement here can be made because the FRF drive point measurement is made at the end of the beam where access is available; but if this measurement was needed at an interior location then this measurement of the true drive point measurement could not be possible. (For reference, this an aluminum beam approximately 60 inches long with a 1 inch by 2 inch cross section with a 3/16 inch wall thickness.)

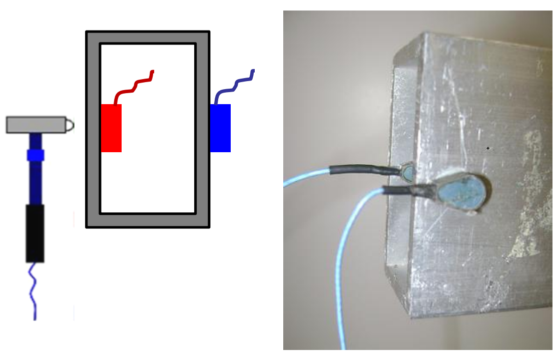

Figure 1 –Schematic of the Beam Measurement

Now an impact measurement was taken over a 4000 Hz range and also zoomed in over a 1100 Hz range to more clearly see the difference in the frequency response function. Figure 2 shows the imaginary part of the frequency response function and the two traces (red for the true drive point frequency response and the blue for the approximate frequency response function) are overlaid for comparison. Essentially there is no difference in the imaginary part of the function. Remember that the imaginary part of the frequency response will be a peak when the real part is a zero for a proportionately damped system with well spaced modes. Figure 2 seems to indicate that there is essentially no difference at all and would lead you to believe that there is no error in this measurement.

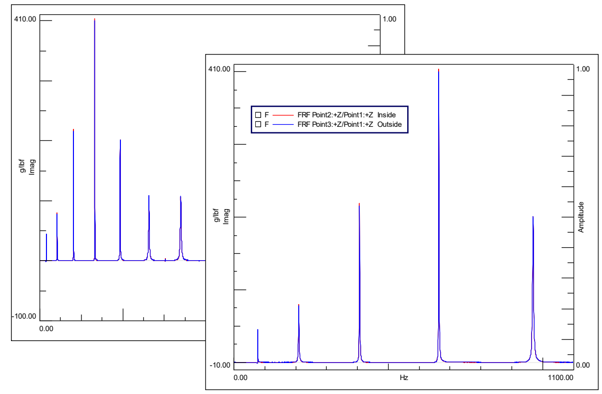

Figure 2 – Imaginary Part of the FRF

However, if we look at the magnitude of the frequency response function we see something that indicates a different story. Notice that the anti-resonances do not line up between the two measurements. This is directly related to a phase difference between the two measurements. So while the magnitudes line up properly, the phase between the two measurements shows a significant difference. Yet upon first looking at this simple beam section, the lower order modes would be expected to be relatively unaffected by the difference between measuring the exact drive point and the approximation of the drive point measurement, especially for the lower order modes. But it is clearly seen that there is a difference. (And just to be sure there was no instrumentation issues the measurement was repeated with both accelerometers mounted on top of each other and the measurement was essentially identical.)

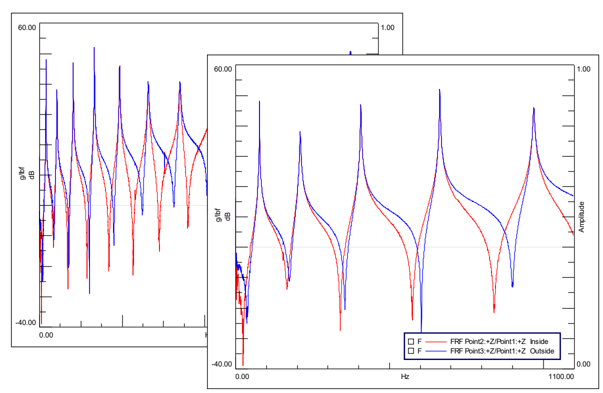

Figure 3 – Magnitude Part of the FRF

While the amplitudes would likely give a good representation of the mode shape, the more important item to observe is that if these FRFs were used for any frequency based substructuring type applications, then that phase/anti-resonance issue would cause difficulties in numerically processing any inconsistent data that might be collected at different measurement points. I hope you have a better appreciation of drive point measurements now. If you have any more questions on modal analysis, just ask me.