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

Illustration by Mike Avitabile

Should the measurement bandwidth match the frequency range of interest for impact testing?
Let's discuss this to see why they may not need to match.

Now here is a question that may appear simple on the surface. But as we discuss it, you may realize that there are some alternate issues that may make you think differently regarding this problem. On the surface, it would appear that the measurement to be made should be over the bandwidth of interest.

Obviously, if the bandwidth is narrower, then the higher modes of interest may not be observed. And, of course, if the bandwidth is too large then there will be response of higher modes that may not be of interest. But the real point is this – is the latter case undesirable or can a wider frequency range be selected and get an equivalent or better measurement? Hmmm…. maybe this needs to be discussed and evaluated some more before a final call is made here.

Let's consider a simple measurement on a typical structure where the first two or three modes are of interest. These first three modes are expected to exist over an 800 Hz bandwidth. A typical measurement over that 800 Hz bandwidth with 800 lines of resolution can be seen in Figure 1.

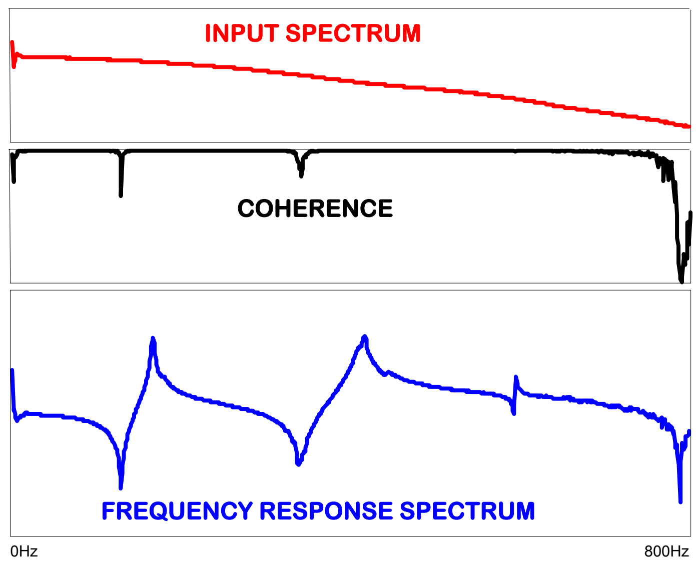

Figure 1 – Input Spectrum, Coherence and Frequency Response Function over an 800 Hz Bandwidth

In general, the measurement looks reasonably good. The frequency response shows the desired peaks well and the measurement appears acceptable. The input spectrum shows reasonably flat input over all frequencies with approximately 20 dB roll off over the frequency range. The coherence is reasonably good at most frequencies in the range of interest. (While difficult to see in the plot, there is some minor drop off of the coherence over the frequency range even at the resonances but likely to be acceptable for most engineers' use.)

So what could possibly be wrong with the measurement? Let's take a look at the time signal associated with the response of the system.

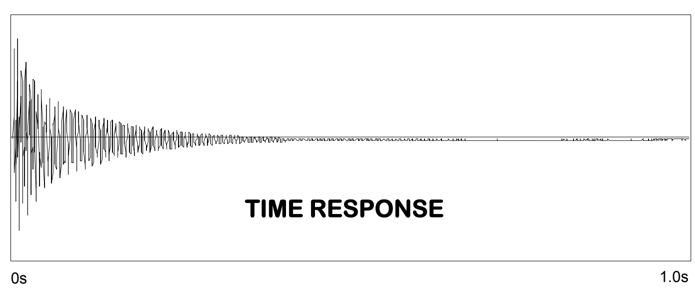

Figure 2 – Time Response Output for 800 Hz Bandwidth

Now the time response is noted to be fairly well diminished within one-quarter of the time record.

So is this a problem. On the surface – no. But the question I really want to ask is this. Could I make a better measurement? And how would I do that?

Look at the time response in Figure 2. There is a very strong possibility that any noise on the response channel might be significant in the measured frequency response function. (For the case shown in this example, there was not any appreciable amount of noise. But if there were, then the frequency response function would be degraded as well as the coherence.)

Let's consider a different frequency bandwidth for the measurement. For the next measurement, let's try to optimize the time response to be a significant signal for the majority of the time record or block of data collected. If the frequency range is quadrupled, then the time record length will be one fourth of the original time record. This signal is shown in Figure 3. Notice that the time response now fills the majority of the time record.

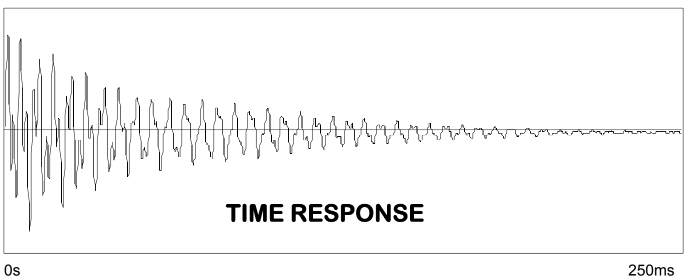

Figure 3 – Time Response Output for 3200 Hz Bandwidth

Now also take a look at the resulting input spectrum, coherence and frequency response function shown in Figure 4.

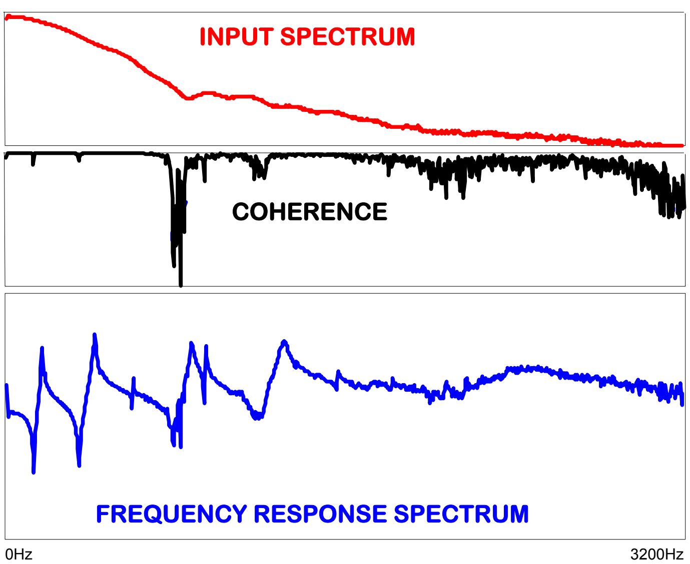

Figure 4 – Input Spectrum, Coherence and Frequency Response Function over a 3200 Hz Bandwidth

The measurement at first glance does not look very good over the entire frequency range. BUT over the range of interest for the first several modes, the measurement is actually very good. (Again, while difficult to see in the plot, the coherence is actually as good as Figure 2, if not better overall.)

So the bottom line here is that the second measurement may actually be the preferred measurement depending on the coherence of the measured response. The trick to this measurement is that the hammer tip should be selected to excite ***only the frequency range of interest*** – NOT the entire bandwidth of the FFT analyzer. In this way, a good measurement can be obtained for the modes of interest.

I have run across this issue several times in a variety of different measurement situations. Generally, people are bewildered why this measurement might be acceptable but as I discuss this measurement problem it becomes apparent that the overall measurement can actually be better than the narrow bandwidth.

A specific example relates to some measurements taken a few years ago on a surveillance pod for an aircraft structure. The initial measurements over the narrow specific frequency range were very noisy since the response died very quickly in the measurement time record. Selecting a wider frequency range, where the response signal was significant over the entire time record, actually produced a much better measurement for the modes of interest. And again, the force hammer tip was selected to excite only the modes of interest and not the entire frequency range of the FFT analysis process. A typical measurement from that structure is shown in Figure 5. (Unfortunately, the narrow band FRF measurement is not available for comparison but was a much poorer measurement overall.)

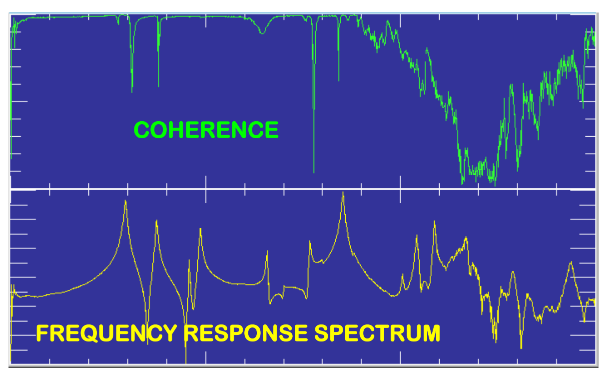

Figure 5 – FRF/Coherence for POD Measurement

I hope that this little discussion has shed some light on alternate ways to improve a measurement. In either case, judgment needs to be made to determine which measurement is the best overall before proceeding with a specific course of action. If you have any more questions on modal analysis, just ask me.