MODAL SPACE - IN OUR OWN LITTLE WORLD

by Pete Avitabile

Illustration by Mike Avitabile

I find overload and underload of the digitizer and range setting difficult to understand.
Let's discuss this.

This is a very good item to discuss. Previously we had discussed issues in impact testing related to hammer tip, trigger delay and double impacts. There are other issues related to overload/underload of the analog to digital converter, poor utilization of the digitizer, and difficulties with testing nonlinear structures that are additional concerns. In order to try to explain the issue of range settings and their impact (no pun intended) on the analog to digital converter (ADC) setting, several typical measurements discussed previously will be used.

Figure 1 shows an impact measurement where the input force excitation does not adequately excite the entire frequency range of interest. Approximately half of the frequency range does not see sufficient force input to excite the structure and therefore both the input and output signals are very low over this frequency range. But at the lower frequencies, the input force signal is strong as is the response signal.

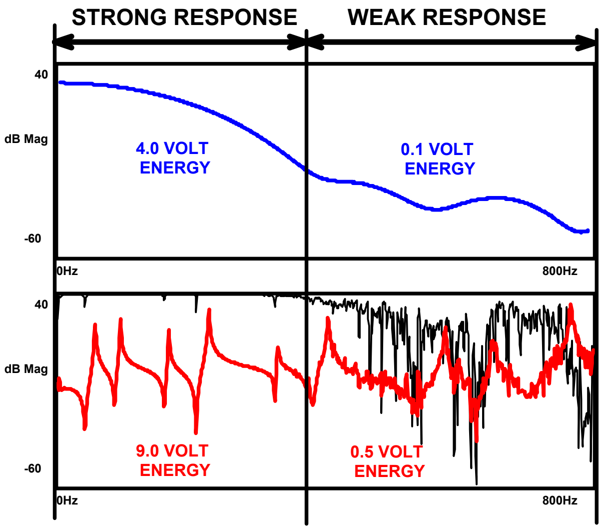

Figure 1 - Hammer Input Only Excites a Portion of Spectrum

The low frequency components dominate the energy of the signal. Now the real issue is how the energy is distributed over the frequency range (which is essentially an assessment of the area of the curve for discussion purposes). For the sake of argument, let's say that the input force spectrum (blue) has approximately 4Volts in the low frequency range and 0.1Volts in the higher frequency range and has a total of 4.1Volts. Let's also say that the response (red) is distributed as 9Volts and 0.5Volts in the low and high frequency ranges, respectively. Clearly, the total voltage is dominated by the low frequency range. In this case, the input channel and output channel may be set to 5 volts and 10 volts for possible ranges on each channel.

So what does this mean. Let's use a simple sine wave to explain resolution. For illustration purposes, a simple 6 bit ADC is set to full range and then set to a lower range to clearly show how the digitizer can affect the amplitude measured. (Please note that all values are approximate and rounded off for illustration purposes). Figure 2 shows a sine wave with 1.5 V peak amplitude and an ADC set to a maximum of 10 Volts. Figure 2 only shows the portion of the ADC which contains the signal. Notice that the resolution is poor and that the actual amplitude of the sine wave is not identified correctly due to quantization error. This would result if the ADC range setting was set much larger than the actual signal to be measured (in this case the full range of the ADC is 10V).

Now if the ADC range is set to 2.0 Volts as shown in Figure 3, the resolution of the signal is much better. This is because all of the dynamic range of the ADC is dedicated to the signal of interest (the ADC is set to 2.0 Volts to measure the 1.5 Volt signal).

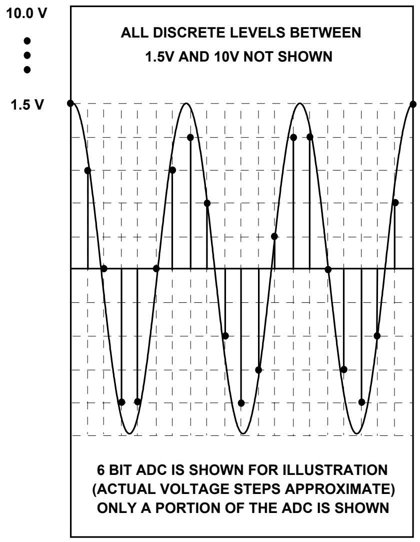

Figure 2 - Sine Wave with Poor Resolution

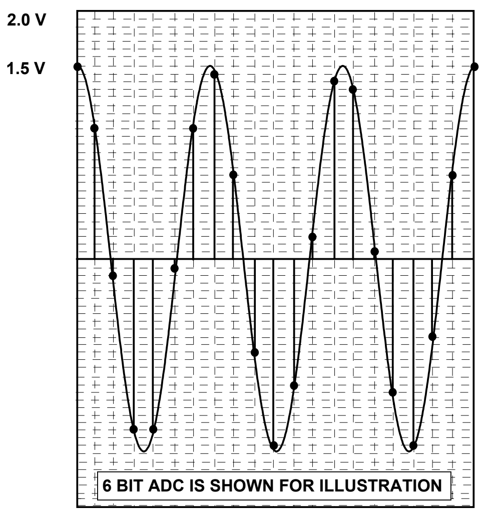

Figure 3 - Sine Wave with Good Resolution

Now let's consider one more case where there are two sine waves at different frequencies and different amplitudes to be measured simultaneously. The same 2.0 Volt range is used. In Figure 4, it is very clear that the larger of the two sine waves dominates the ADC setting. However, it is very important to note that the smaller of the two signals will suffer from quantization error more than the larger signal. This is very common in frequency measurements that are made on structural systems. There is no way to avoid it. But imagine how much worse the quantization error would be if the ADC were set to a 10 Volt max range.

Now that we have some idea about range setting for a simple sine wave, we can better understand the problem with the measurement in Figure 1. The higher frequencies are not well excited and there is little response of the higher modes. The measurement at the higher frequencies suffers from quantization errors. This problem in Figure 1 at the higher frequencies is analogous to the problems cited in Figure 4.

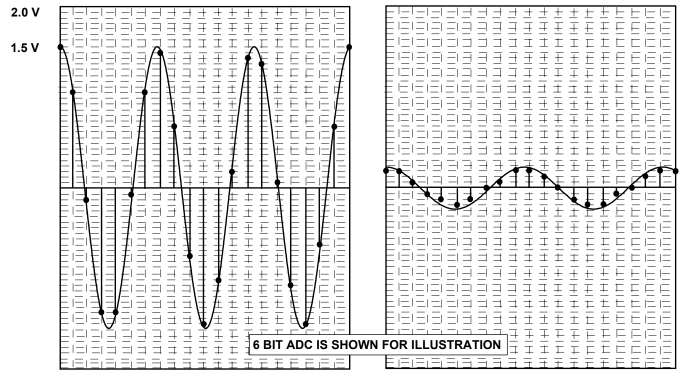

Figure 4 - Two Sine Waves with Possible Resolution Problems

Now let's consider one more case where the impact to the structure excites modes well beyond the frequency range of interest (128 Hz) as seen in Figure 5. For the sake of argument, an assumed energy distribution between the desired (lower) frequency range and the higher (excited but outside the range of interest) frequency range. Notice that the transducers will measure the entire response (energy) of the system even though only a portion of that energy is actually used in the digitization for the frequency information. What happens is that the ADC must be set much higher than actually needed since the total voltage from the transducers is actually heavily affected by the higher frequencies. This implies that the ADC will be set much higher than needed to accommodate these higher frequencies - the result is that the lower frequencies will suffer from quantization errors.

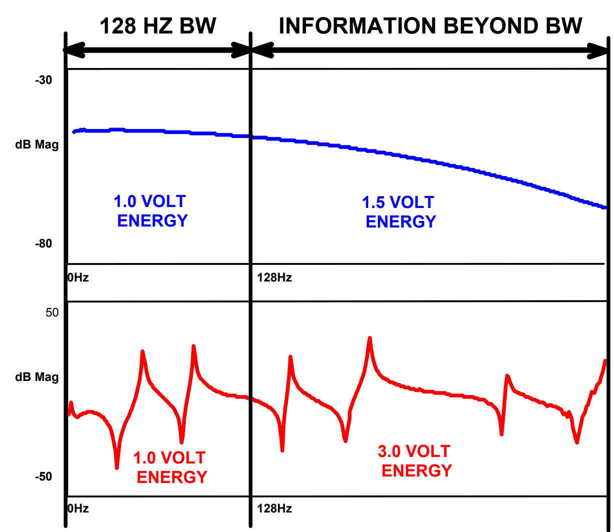

Figure 5 - Exciting Modes Outside the Band of Interest

I have tried to answer your question about digitizer settings in a round-about way using a typical measurement that might be collected for a structural system. I hope this helps to explain this important part of taking measurements. If you have any other questions about modal analysis, just ask me.