MODAL SPACE - IN OUR OWN LITTLE WORLD

by Pete Avitabile

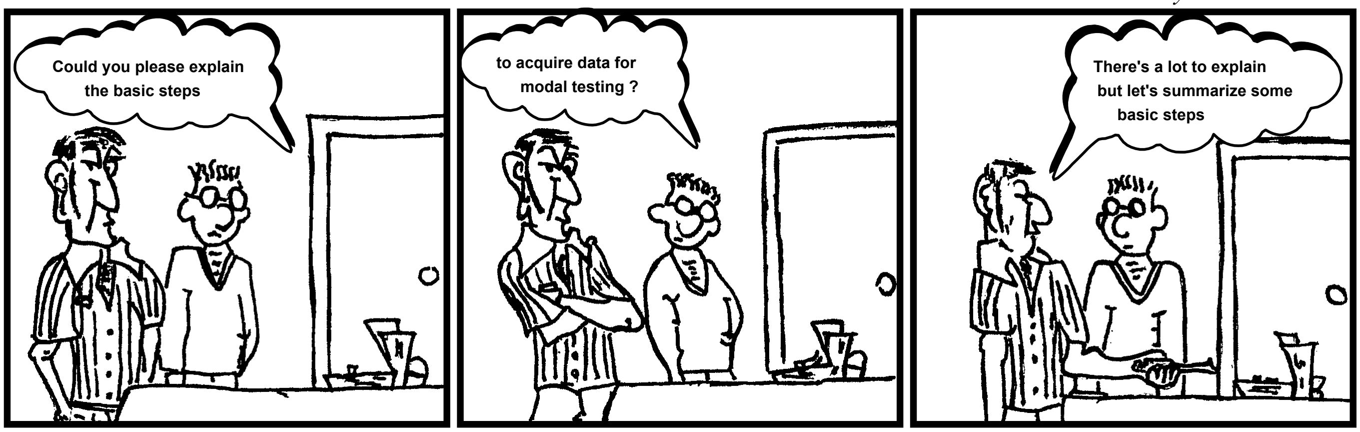

Illustration by Mike Avitabile

Could you please explain the basic steps to acquire data for modal testing?
There's a lot to explain but let's summarize some basic steps.

The basic data acquisition process has several steps. These steps for impact and shaker testing are slightly different and will be discussed separately.

For impact testing, the excitation is applied to the structure using a hammer or some type of impacting device where the force transmitted to the structure is measured. The response of the structure is often measured using an accelerometer but sometimes a laser or other measuring transducer is used. Typically, the force used to excite the structure is measured on the lowest channel of the data acquisition system. Although this is not a requirement on many data acquisition systems today, many test engineers still follow this practice. The response signal(s) is measured on the remaining channel(s) (depending on whether a dual or multichannel system is being used). In order to start the data acquisition measurement, typically the measurement is started from a trigger from the impact device. Some minimal voltage must be specified in order for the data acquisition system to start the measurement process. A trigger level of 10% to 20% of the maximum voltage of the measured force is a good value to use for most tests performed. In many data acquisition systems, a pretrigger delay is specified to capture the entire transient of the impact device. By using the pretrigger delay feature, none of the impact force pulse is omitted.

The transducer data is collected and this data is always passed through a low pass, analog filter before any digitization is performed. This is done mainly to filter out high frequencies that are not of interest and to prevent aliasing from occurring. These analog filters, often referred to as anti-aliasing filters, remove high frequencies which might otherwise contaminate the measured frequencies.

This data is then passed into the analog to digital converter (ADC) where the data is sampled and converted into digital form. Two concerns exist at this point. The data must be sampled at a rate so as to adequately characterize the time data for conversion to the frequency domain. Generally, the data must be sampled at least twice as fast as the highest frequency of interest for transformation to the frequency representation. If time data processing is needed to evaluate time characteristics of the structure, then sampling should be performed at least 10 to 20 times faster than the maximum frequency of interest in order to adequately interpret the system characteristics. In order to properly characterize the amplitude of the signal correctly, the ADC must be set to an appropriate voltage level to characterize the signal. If this is not done properly, then quantization errors in the measured signal may pose a problem. In many data acquisition systems, a feature referred to as autoranging assists in setting appropriate voltage levels for all of the data acquisition channels. The ADC levels can also be set manually but care must be exercised to assure that the acquisition channels are set properly. Otherwise, the signal may suffer from quantization error if the levels are set to high or from clipping and overloads is the level is set too low.

At this point, the digital data describing the impact and response is available in raw digitized form. Depending on the character of the actual time signals, windows may need to be applied in order to minimize any leakage that may otherwise result. Leakage will occur during impact testing if the entire transient is not captured during the acquired sample of data. If there is significant noise on the impact channel, then a force window may be used to minimize this if necessary. If the response signal does not decay sufficiently to zero by the end of the sample interval, then an exponential window may be necessary to avoid distortion of the signal due to the Fourier transformation process.

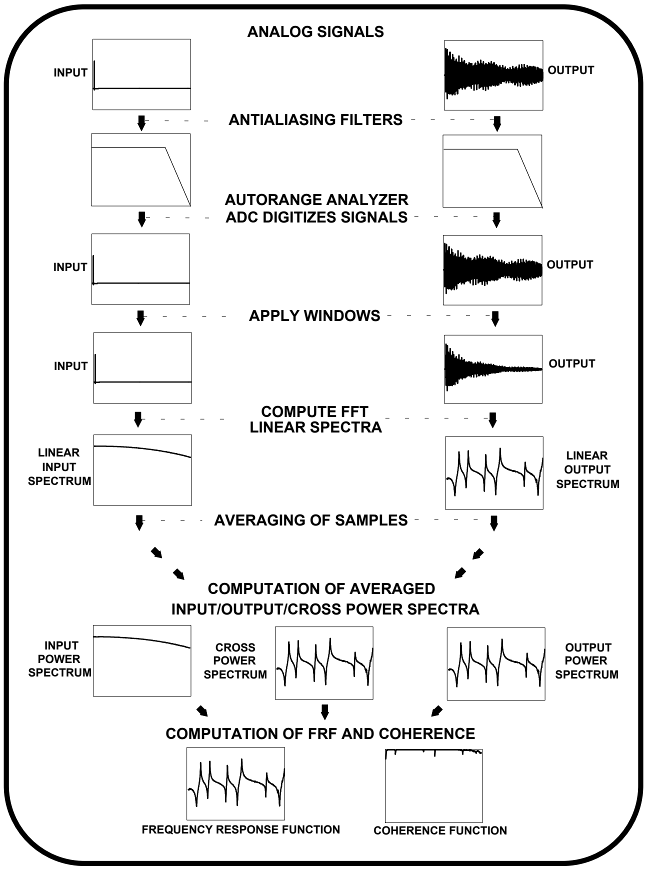

Figure 1 - Impact Test Flow Diagram

Before an exponential window is applied, two additional signal processing features should be used. In order to allow more time for the response signal to naturally decay to zero, the bandwidth of the measurement can be reduced or the number of spectral lines increased; both of these parameters will ultimately lengthen the total time required for the measurement. This will allow more time for the response signal to naturally decay thereby minimizing the need for application of a significant damping window.

For shaker testing, the excitation of the shaker is typically measured at the lowest channel of the acquisition system (again while this may not be required, many follow this practice). The response transducers are measured in the remaining channels of the data acquisition system. Depending on the excitation used, triggering will vary. For random excitations, a "free run" mode is typically used. However, other excitations (such as burst random, sine chirp, etc.) will start from a signal source or force trigger. In addition, sometimes a pretrigger delay is specified for burst random excitation.

For many shaker excitations used, no window is applied since these signals usually have "special" characteristics that are employed in order to provide leakage free measurements that satisfy the FFT requirements. However, if any arbitrary signal such as random excitation is employed, then a window such as a Hanning window, is used to minimize the leakage effects.

For either impact or shaker testing, the time captured data must be transformed to the frequency domain using the FFT and the transform algorithm. The FFT provides the linear Fourier spectrum of the input and output(s) signals. (Note that these functions are complex valued functions.) This then provides the input spectrum (Gxx), output spectrum (Gyy) and cross spectrum (Gyx). These three spectra are then averaged using all the individual data records collected. Once the Gxx, Gyx and Gyy are obtained then the frequency response function and coherence are computed. While different forms of the frequency response function are available, H_1 is the most popular form of the frequency response function employed in the majority of single input modal testing performed today. Figures 1 and 2 depict the measurement process for impact and shaker testing, respectively.

While frequency response functions are the only measurements required for development of an experimental modal model, many times the auto- and cross-spectra along with the coherence are saved as part of the dataset. (With the abundant availability of disk drive storage, there is no reason to not save all of the measurements!)

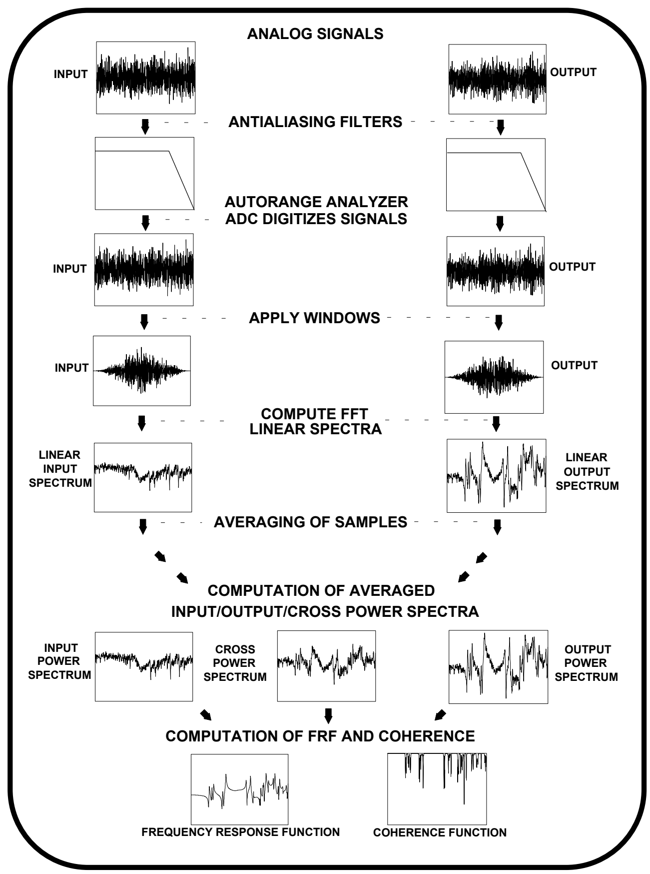

Figure 2 - Random Shaker Test Flow Diagram

Obviously, there is much more that could be discussed but I hope this helps to explain some of the basic steps in the overall measurement process for experimental modal testing. If you have any more questions about modal analysis, just ask me.