Setting up your caraudio system
DSP A8 and Room Equalizer Wizard V5

Part 3

8) Measurement data processing

The passenger compartments of cars are very specific environments and therefore require a specific analysis of the data measured with the microphone. Actually, looking closer at our measurements, it's impossible to distinguish the original signal (i.e. directly from the speaker to the microphone) from the signal reflected by the environment (coming from the speaker, reflected by the environment and measured by the microphone with some time delay) as the reflecting surfaces are either too close to the signal source itself or are used on purpose as for instance in dash-panels or seat-box installations. For the ease of comprehension we will consider that all signals are more or less influenced by the car interior.

The parameters of signal analysis are known as *windowing of the impulse response*. In fact, for an impulse response to be analyzed, we need to define a precise time window for the signal we want to analyze. We need to define the *time zero,* i.e. the start of our time window, the moment when the microphone starts recording the sound from the speaker. This parameter will allow us to obtain our phase response curve. The other parameters are the size and form of excess data before and after the time zero. Those will be used to calculate the frequency response and sharpen the measurement results.

What is impulse response *IR* ?

It's the representation of the energy perceived by the microphone with respect to time when a signal of dirac type is applied to the speaker. A dirac is a signal that contains all frequencies at maximum level and ideally is as short as possible. Imagine a very fast switching ON – OFF switch directly on the speaker. In practice it's not that easy to achieve though.

The *REW* software is based on a very high performing measurement method called *logarithmic sine sweep* and can generate a specific measurement signal that is later compiled by the software to represent the impulse measurement as if we had used a dirac signal.

Applying a mathematic formula to the *IR* measurement called *FFT* (Fast Fourier Transform) and depending on the windowing parameters we will obtain a result both in the frequency and time domain. In the frequency domain we will obtain our frequency response curve as we know it and in the time domain we will obtain our phase response curve.

Now let's have a look at what the *IR* looks like in *REW* and how to set the parameters mentioned above.

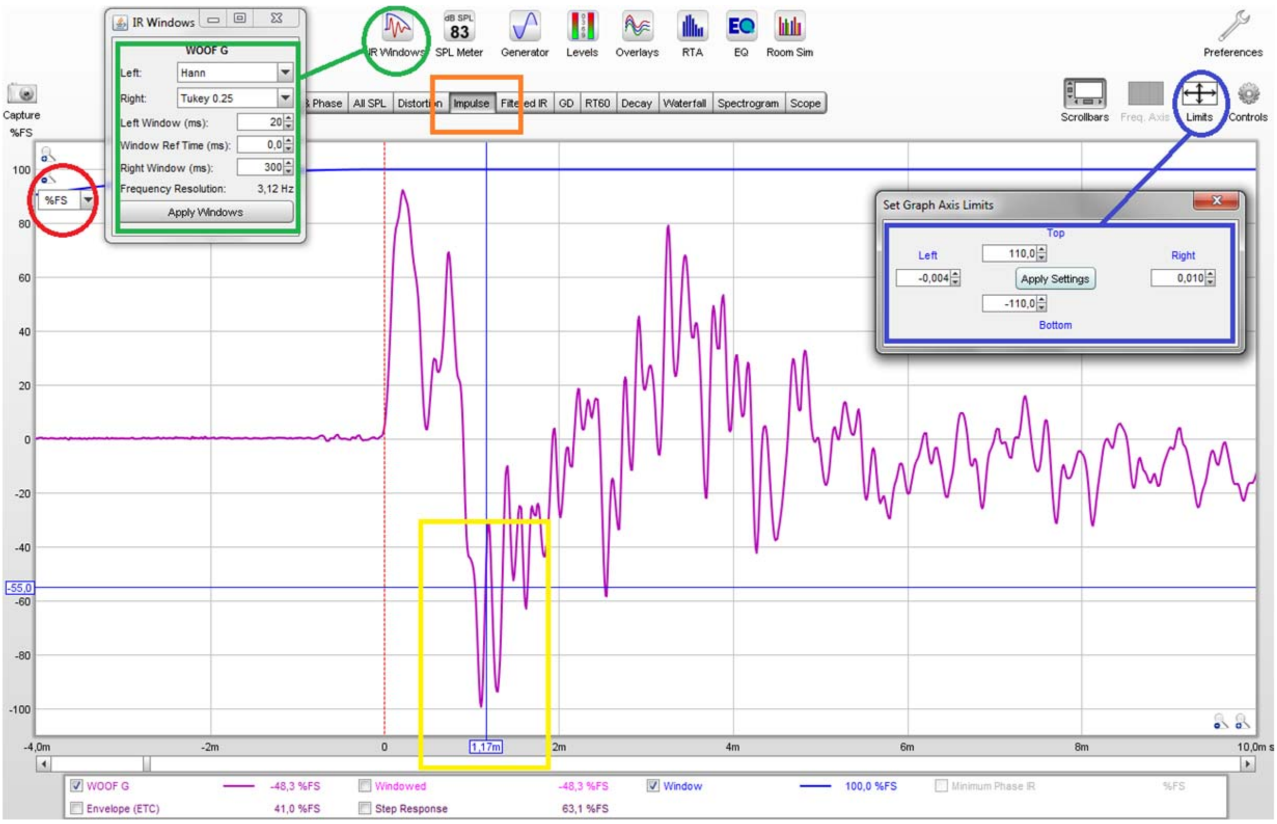
a) WINDOWING THE MEASUREMENTS

Open the *IMPULSE* tab (orange box in the screenshot)

Select *%FS* mode (red circle in the screenshot)

Click on *LIMITS* (blue box in the screenshot) and adjust the parameters to obtain an overall view of the IR and close the panel.

Click on *IR Window* (green box in the screenshot) to open the control panel for the windowing and leave it open until the end of this chapter for tweaking the parameters if needed.



The curve shown in the screenshot represents an impulse response. The graphic shows energy / time.

The energy is represented by the vertical axis, time on the horizontal axis. This type of graph is not very helpful for our purposes, it contains far too many information. Indeed the high frequencies exhibit pretty heavy spikes while the amplitude on the lower frequencies is hardly noticeable. Nevertheless we can deduct some basic data. In the yellow box we can see an area with a strong negative energy, almost as strong as the first positive energy spike; this is due to a very strong reflection of the signal. Looking at the time axis we can see that the negative signal appears around 1.17ms (0.017 seconds) after the initial impulse, that is a wavelength of 850 Hz (wavelength in seconds = 1/frequency). The response curve both in frequency and phase will most probably be perturbed in that area.

b) SETTING THE *TIME ZERO*

To obtain the response curve in the time domain, namely a correct phase response curve, we need to define the starting point of our analysis window. There are multiple ways to define the *time zero,* I'll present one of the most common methods used. In a controlled environment (read where the first reflections appear late, for instance in a large room) the impulse is often concentrated around the main peak representing the high frequencies and it's pretty easy to set the time zero at that point.

In a passenger compartment it's almost impossible to avoid very early reflections and the IR is somewhat modified. It can show multiple peaks and sometimes reflections are superposed to the direct signal resulting in a higher delayed peak that the initial signal. This phenomenon means that all measurement tools that define the time zero automatically cannot be used without a minimum of precautions. The method used to define the time zero automatically (highest peak, first peak, etc…) cannot operate properly. As a workaround we will manually set the *time zero* at the very beginning of the rise of the (initial) impulse peak.

Zoom in close to the beginning of the impulse rise until you reach a vertical graduation of 5%. Now extend the response window with the magnifier tab on the bottom of the screen. Once you are happy with the zoom open the *Controls* tab (red box on the screenshot).

Using the parameters in the red box, place the curve so that the 0 (zero) of the horizontal time axis to meets the impulse where it reaches 5%FS as shown hereunder.

To move the impulse to the right, enter a negative value; otherwise enter a positive value to move it to the left. When modifying the time zero that way, the frequency and phase response curves will be altered automatically in the *SPL & Phase* tab.

If you find the result hard to obtain, make use of the *Step response* curve by selecting it at the bottom of the screen.

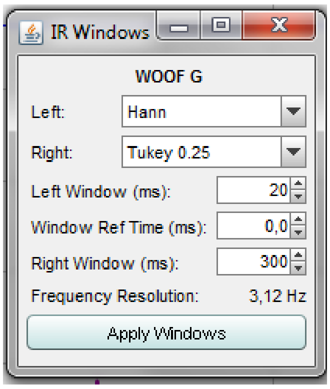
Perform these settings for every measurement. It’s a pretty time consuming task so don’t forget to save your work…

c) IMPACT OF WINDOWING

If we want the *REW* software to generate exploitable curves we need to define the time frame of the signal analysis. In fact, to analyze the impulse of a digital signal properly the software needs to know where to start and to end the analysis around the time zero.

Depending on the wavelength of the signal emitted by the speaker (1 wavelength of 20 Hz = 17.15 ms) we need to adjust the time window after the time zero to obtain a sufficient resolution in the lower frequencies.

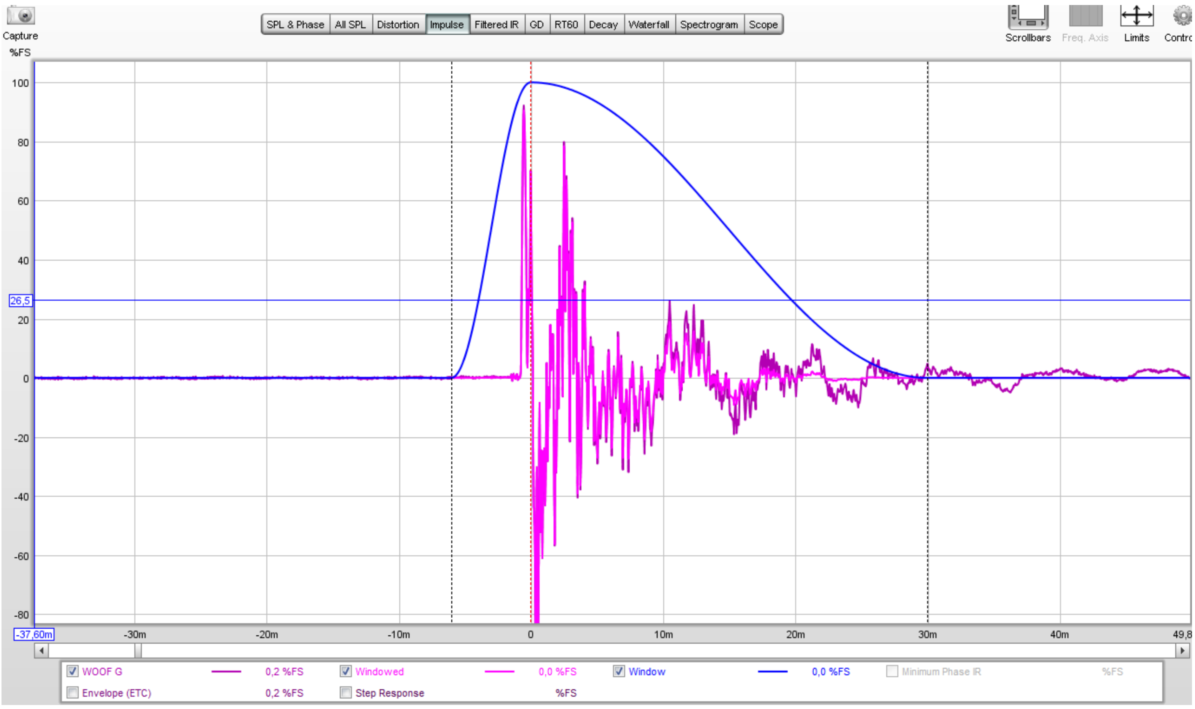
In short, the bigger the time window the more precise the measurement of our low frequency response is. *REW* shows the resolution in the *IR* Window depending on the selected parameters. For the parameters used in the screenshot it shows 3.12 Hz; which equals to saying that we have one measurement every 3.12 Hz. You have probably noticed that a 3 Hz precision is far too high at a frequency of for instance 10 kHz and will gather loads of information, but on the other hand will just be enough for the low frequencies. The more you shrink the time window the less low frequency information you collect. Sizing the time window for the frequency and phase response curve is nothing more than applying a frequency variable smoothing.



In a car the acoustic response curve from the speaker contains the signature of the passengers compartment transfer function, it's impossible to distinguish the direct signal from the reflected signal. Thus we need to use rather long time windows, say 50 to 80 ms to be sure to include the entire reflected signal in our measurement.

In general the passenger compartment presents a strong absorption; it will naturally limit our time window anyway. To obtain a satisfying precision in the lower frequencies the use of time windows up to 300 ms can be necessary.

Different window types can be used. You can check the effect of the chosen window type on the *IR* by looking at the *window* curve representing the window itself and the *windowed* curve showing the *IR* depending on the selected window. The impact of the selected window on the frequency and phase response curves will be shown automatically in the *SPL & Phase* tab.



You will find a multitude of information on what kind of window to use depending on the signal to be analyzed on the internet; we will not dig further into it as it's not the goal of this document.

The next steps are by far the most interesting and will require your attention.

