DML, extraction the panel material quality factor from the electrical impedance.

ChristianV (Homeswinghome@diyAudio)

19 Jun. 2025

Abstract

The quality factor is a key parameter to model a panel. This paper opens a way to extract it from an impedance measurement

Contents

Disclaimer : this paper is written in the context of DIY DML building with the target to identify some design rules to help in the panel construction. This document is not written in the context of any academic or scientific work. Its content is reviewed only by the feedback it can get while posting it in audio DIY forum like diyAudio.

This document was exported from a markdown file with pandoc. Done : June 19, 2025.

1 Introduction

As free DML simulation tools like PETTaLS are available, the quality factor of the panel material is a key figure to model the damping property of the material.

Although it is possible to adjust this parameter by trial/error, this paper proposes an extraction from an impedance measurement.

In addition to the possible use of the result, it shows the link between the model and the electrical impedance of such a panel.

2 A bit of theory

2.1 Mechanical admittance at the driving point

Such simulation tools are based on a modal decomposition. The plate displacement is known for each frequency as the sum of the contribution of the plate modes.

For a given frequency f ($\omega = 2\pi f$), the plate displacement w is then calculated :

$$w = \sum_{modes} Ws_{mode}\Phi_{mode}$$

where Ws_{mode} is the mode shape of one mode and $\Phi mode$ is the modulation function for this mode with:

$$\Phi mode = \frac{Ws_{mode}(x_0, y_0)}{ModalMass_{mode}H_{\omega,mode}}.Force$$

where:

$Ws_{mode}(x_0, y_0)$ is the value of the mode shape at the driving point (x_0, y_0)

$ModalMass_{mode}$ is the modal mass

$$ModalMass_{mode} = \sum_{panel} {Ws_{mode}}^2 \mu dxdy$$

and

$$H_{\omega,mode} = {\omega_{mode}}^2 + \frac{j\omega\omega_{mode}}{Q_{mode}} - \omega^2$$

Q_{mode} being the quality factor of the mode, the value expected from the extraction.

The speed of the plate in the frequency domain is:

$$v = j\omega w$$

We can define the mechanical admittance at the driving point as:

$$y_m = \frac{v}{Force}$$

So it comes y_m can be expressed as:

$$y_m = \sum_{modes} A_{mode} \frac{j\omega}{{\omega_{mode}}^2 + \frac{j\omega\omega_{mode}}{Q_{mode}} - \omega^2}$$

Where A_{mode} is a kind of gain of the considered mode.

So the Q factor is related to the mechanical impedance $y_m} thanks to a sum of second order responses which is the basis of the mode decomposition.

2.2 Electrical impedance

In parallel to that, an electromagnetic exciter is so that its electrical impedance is:

$$Z_e = R_e + X_e + y_m.BL^2$$

Where R_e is the DC resistance, X_e is the frequency dependent part of the electrical part of the impedance responsible of the increase of the impedance with the frequency. X_e models the voice coil inductance and the Eddy current effects.

BL is the force factor of the exciter with the 2 basic relations:

$$Force = BL.i$$

i being the current (Laplace law)

$$v_{emf} = v/BL$$

v the voice coil (so the panel) speed and v_{emf} the voltage due to the coil movement.

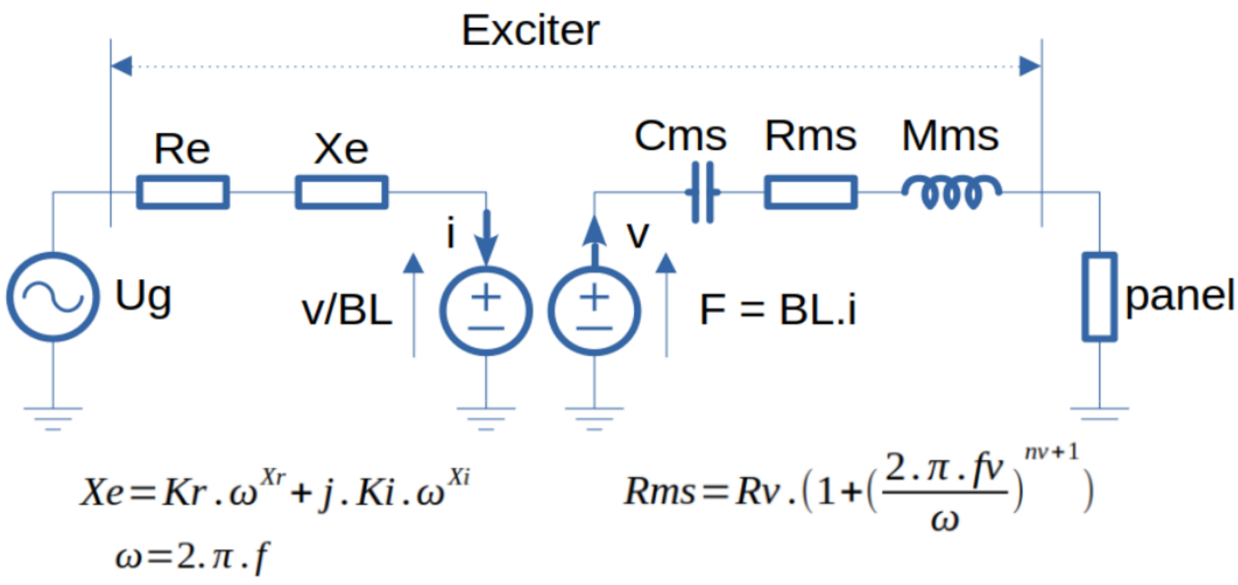

Figure 1: Exciter electrical model

So it comes:

$$y_m = \frac{Z_e - (R_e + X_e)}{BL^2}$$

R_e is directly readable on the impedance plot as the impedance at very low frequency.

X_e might be ignored in the mid frequency but it is better to get an estimation thanks to a model of the exciter. It is the Wright model which is used (see figure).

Of course the exciter is included in this admittance so the method suppose it has minor role on the damping which needs some demonstration.

3 In practice

3.1 Extraction principle

The panel impedance measurement is measured with REW. The data are exported from REW to a txt file (no header, no comments, content is a frequency, module and phase table). See below an example of the exportation window.

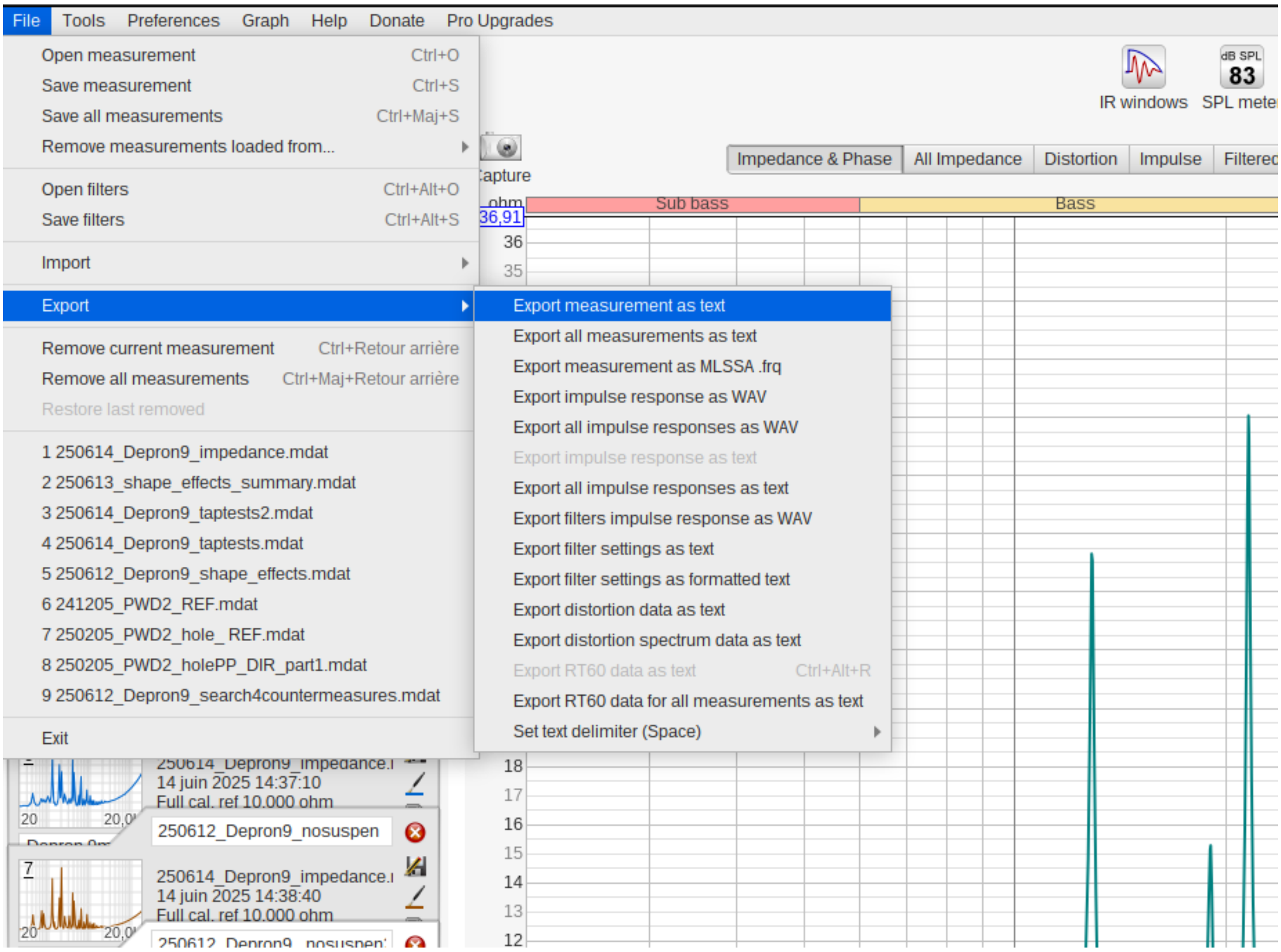

Figure 2: REW export

Then the txt file is imported in a script in which the exciter model is known.

The $R_e + X_e$ part is removed from the impedance, the result is divided by BL^2. The major peaks are selected.

A direct extraction of the Q for each peaks was tested but didn't give the best results.

As we can read in articles about Q evaluation for other vibration domains, because of the influence of one mode on the other ones, a global curve fitting approach is better.

This is the role of the script.

3.2 Output

The main output of the script is the Q factor.

It was tested first on 2 practical cases:

- a plain clear polystyrene 2mm thick panel clamped on all the edges with a DAEX25FHE (PS2 in the figures)
- a free edge panel made of Depron (XPS) 9mm with a DAEX25FHE (Depron9 in the figures)

Even if the model allows the curve fitting process a certain change of the Q factor versus frequency, the first results were a constant Q over the considered frequency range (<2000Hz).

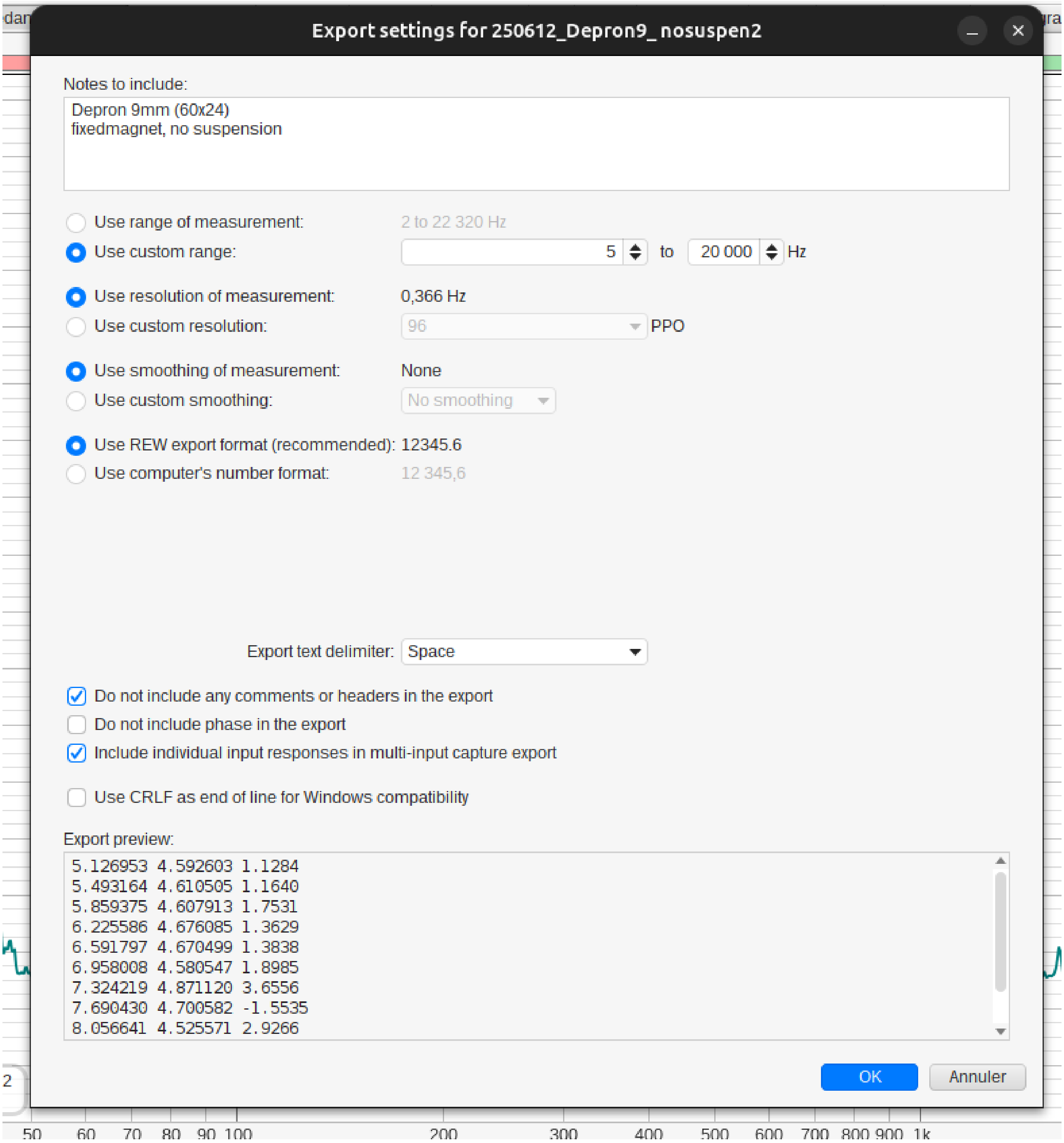

Figure 3: REW export settings

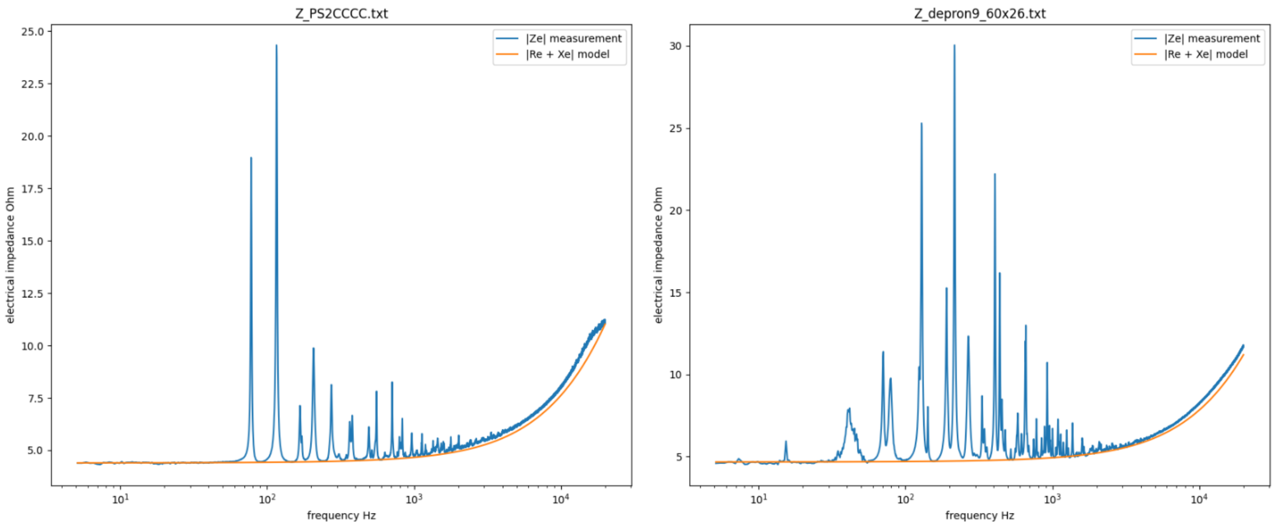

Figure 4: Impedance measurement and exciter model

Mechanical admittance and peak selection

Figure 5: Mechanical admittance and peak selection

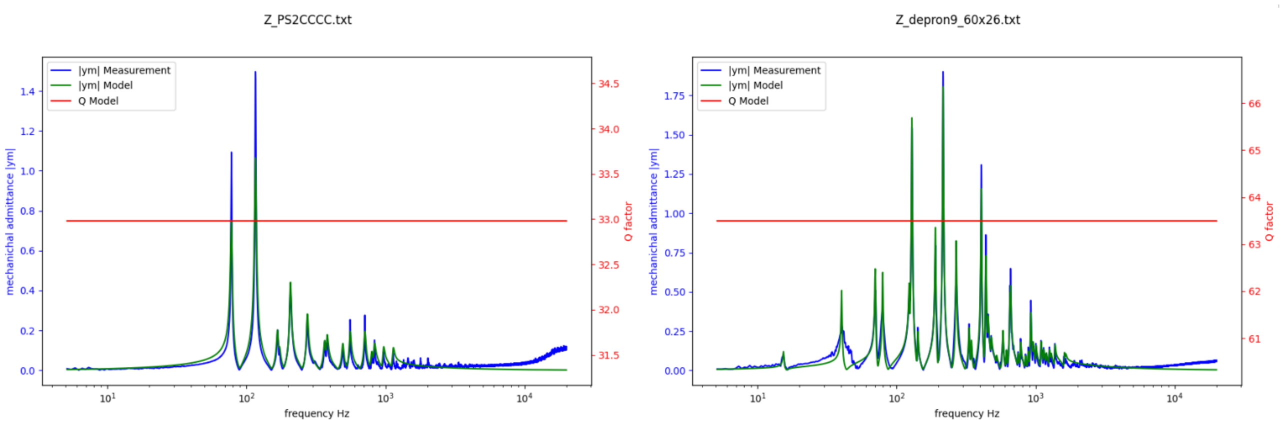

Figure 6: Curve fitting output

4 Conclusion

It is to early to have conclusion except the extract seems possible. The resulting impedance curve matches not too badly with the measurement.

The 2 first values extracted seem above the values used in PETTaLS.

This is not a big surprise as it is visible from PETTaLS output that a higher Q might be suitable for the impedance result but probably not for the SPL output… Which is another question!