# DML basics and material graph

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**Abstract**

Distributed Mode Loudspeaker (DML) : results of tests around efficiency

## Contents



## 1 Introduction

This paper shows the results of some tests made on DML to understand what leads the efficiency.

Those results were originaly posted in diyAudio forum in the thread A Study of DMLs as a Full Range Speaker. See the posts 4664, 5459.

## 2 Academic and technical background

The DML is said to have the property of a SPL that decreases with the distance slower than a classical cone loudspeaker.

For the efficiency the litterature like Kerem Ege's thesis [1] or the patent Heron's patent WO1992003024A1 [2] shows it is related to the Young modulus $E$ of the material and its density $\rho$ independantly of the thickness thank to the parameter $R$.

$$R = E/\rho^3 \tag{1}$$

The Heron's patent [2] works with a parameter $T$

$$T = B/\mu^3 \tag{2}$$

B being the bending stiffness in Nm

$$B = Eh^3/12 \tag{3}$$

With E the Young modulus in Pa, h the thickness in m;

µ being the areal mass in kg/m².

$$\mu = \rho h \tag{4}$$

With $\rho$ the density in $kg/m^3$ and h the thickness as above.

R and T are independant of the thickness of the material.

$$T = R/12$$

# 3 Measurements

The measurements were done in a living room by feeding the panel with a pink noise with a limited bandwidth (200Hz to 5kHz).

The levels were measured with a UMIK1 USB mic connected to laptop running under Linux Manjaro with REW. The mic calibration file according to the frequency was used but the absolute level was not calibrated.

The exciter was a Dayton Audio DAEX25FHE-4.

For comparison (ie in the evaluation of the SPL according to the distance) a small Visation FRS8 8cm cone full range in a 1.2l closed box is used.

# 4 SPL according to the distance

The SPL according to the distance was measured for 3 panels

- PWD3 : 3mm poplar plywood 1.2 x 0.45m (2 sets of measures)
- XPS20 : 20mm XPS 1.2 x 0.6m
- canvas : 0.41 x 0.31m

And the Visaton FRS8 (2 sets)

See the table and graph below.

**Conclusion** : the SPL decreases more slowly with DML than with a cone speaker

| | level SPL dBA | | | | | |
|---|---|---|---|---|---|---|
| distance (m) | PWD3 | XPS20 | FRS8 | FRS8 (2) | canvas | PWD3 (2) |
| 0,25 | 45 | 53 | 45 | 45 | 45 | 43 |
| 0,5 | 40,5 | 50 | 40 | 40 | 40 | 40 |
| 1 | 38 | 46 | 35 | 35 | 37 | 37 |
| 2 | 35,5 | 44 | 32 | 32 | 34 | 34 |

Figure 1: SPL versus distance - table

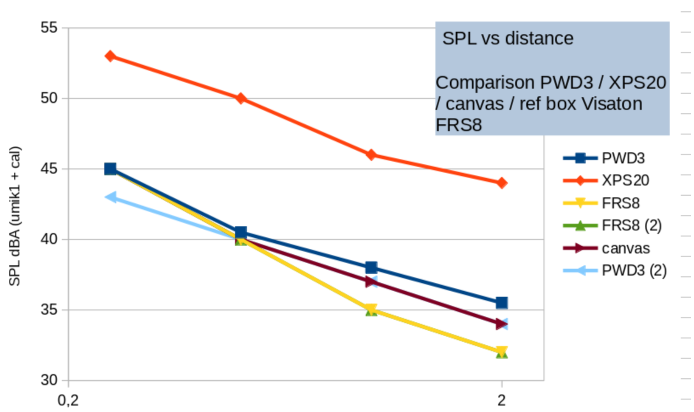


Figure 2: SPL versus distance - graph

# 5 Efficiency versus dimensions

The XPS 9mm (Depron) panel was divided several times in 2 parts starting from 0.6 x 0.8m then 0.6 x 0.4 then 0.3 x 0.4 and so one.

**Conclusion** : the bandwith changes with the area not the efficiency.

# 6 Efficiency versus thickness and material

Several panels of different material, dimensions and thickness keeping the distance fixed (1m) were tested.

The dimensions and the weight of the panels were measured to determine their density.

The Young modulus was estimated from different sources (web or previous tests). This might be a source of error in the evaluation of T.

The graph of $log(T)$ versus the SPL was done. The points of the graph are quite nicely aligned showing 3 areas :

- high density on the right with acrylic
- mid density with the plywood
- low density with PS

**Conclusion** : the efficiency is driven first by $B/\mu^3$ which is the same as $E/\rho^3$, not by the thickness or the area (to be checked for a second order effect). The area drives the bandwidth in the lower frequencies.

An simple heuristic can even be extracted : $Eff = 83 + 5.log(T)$ in dB... no proof it works or at least no ideas of the limitations.

An other paper relates the efficiency to the form ratio of the panel. Even if not described here (where are my notes?), it was not seen.

| μ | B/μ3 | log10( B/μ3) | heuris-tic | SPL dB/1W/1m | SPL | material | weight | W | L | h | rho | E | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| kg/m² | (m²Hz)² | - | dB | dB | dB | | kg | m | m | m | kg/m³ | MPa | Nm |
| 0,365 | 82,54 | 1,917 | 92,6 | 93,6 | 56,6 | EPS 20mm | 0,175 | 0,6 | 0,8 | 0,02 | 18 | 6 | 4,00 |
| 0,773 | 21,62 | 1,335 | 89,7 | 93 | 56 | XPS 20mm | 0,58 | 0,6 | 1,25 | 0,02 | 39 | 15 | 10,00 |
| 0,254 | 44,40 | 1,647 | 91,2 | 92 | 55 | XPS 9mm | 0,122 | 0,6 | 0,8 | 0,009 | 28 | 12 | 0,73 |
| 0,125 | 53,97 | 1,732 | 91,7 | 88 | 51 | XPS 5mm | 0,06 | 0,61 | 0,79 | 0,005 | 25 | 10 | 0,10 |
| 1,599 | 4,95 | 0,695 | 86,5 | 86,2 | 49,2 | plywood 3mm | | 0,45 | 1,2 | 0,003 | 533 | 9000 | 20,25 |
| 5,465 | 4,59 | 0,662 | 86,3 | 84,3 | 47,3 | Plywood 10m | 2,35 | 0,5 | 0,86 | 0,01 | 547 | 9000 | 750,00 |
| 2,793 | 2,20 | 0,343 | 84,7 | 84,1 | 47,1 | Plywood 4m | 0,61 | 0,39 | 0,56 | 0,004 | 698 | 9000 | 48,00 |
| 1,336 | 0,11 | -0,965 | 78,2 | 79,7 | 42,7 | Acrylic ? | 0,935 | 0,7 | 1 | 0,001 | 1336 | 3100 | 0,26 |

Figure 3: SPL versus material - table

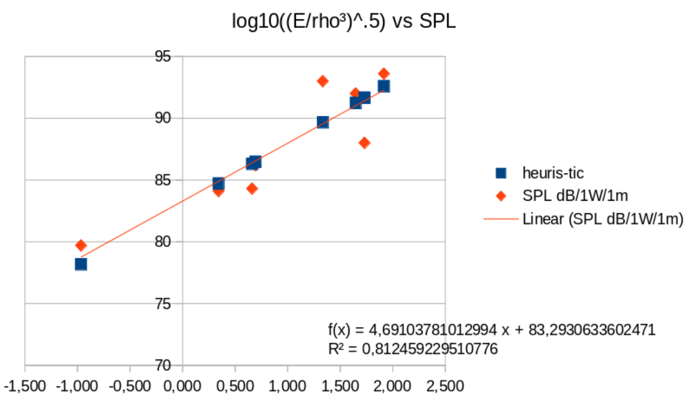


Figure 4: SPL versus material - graph

The Heron's patent [2] gives a range [10..100] for $T$ (see extract below for the lower limit). We can see that fits quite well with the DML builders experiences where :

- Plywoods ($T$ around 5 for $\rho$ around 500kg/m²) is acceptable but a little better would be appriciated.

- PS ($T$ around 50 or even more) is said with a good efficiency.

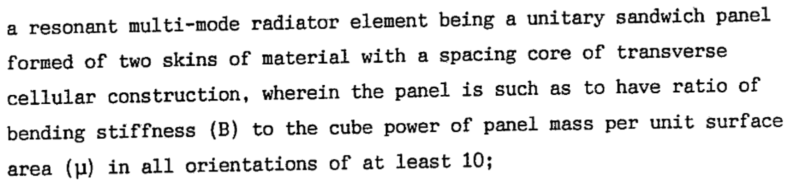
a resonant multi-mode radiator element being a unitary sandwich panel formed of two skins of material with a spacing core of transverse cellular construction, wherein the panel is such as to have ratio of bending stiffness (B) to the cube power of panel mass per unit surface area (μ) in all orientations of at least 10;

Figure 5: Patent extract

# References


[1] K. Ege, “La table d’harmonie du piano – études modales en basses et moyennes fréquences,” PhD thesis, 2009. Available: https://www.researchgate.net/publication/41663333_La_table_d%27harmonie_du_piano_-_Etudes_modales_en_basses_et_moyennes_frequences

[2] K. H. Heron, “Panel-form loudspeaker.” Google Patents, 1992. Available: https://patents.google.com/patent/WO1992003024A1/fi%20US4325121.pdf