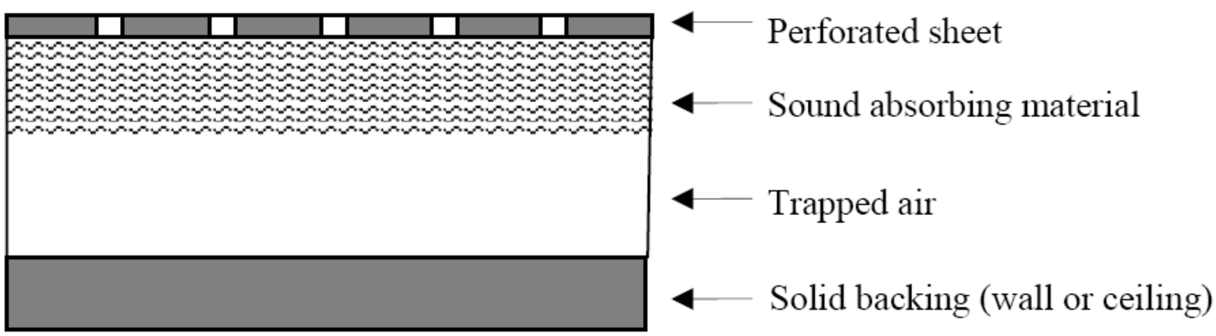
If the inside of Helmholtz resonator cavity is then made absorptive (*n.b.* increasing the resonant width Γ_r /decreasing the Q_r -factor), the stored sound energy inside the resonator is (ultimately) dissipated as heat energy (albeit very small amounts thereof).

Thus, sound energy from problematic, low-frequency room mode resonances (*n.b.* oftentimes these are the lower-frequency axial modes {100, 010, 001, *etc*.}) in a small listening room can be ameliorated via the use of Helmholtz-type resonator/absorbers, strategically placed within the room – where pressure anti-nodes for these room modes exist, *e.g.* along/at the walls, for the axial modes, and/or in the corners of the room for the tangential and/or oblique modes. Note that some centuries-old churches in Scandinavia used clay pots embedded in the walls to act as Helmholtz resonators to control their low-frequency room resonances!

Rather than placing actual Helmholtz-type resonators around a home listening room, a more practical way to achieve the same type of low-frequency absorption is to use so-called perforated (or micro-perforated) panel absorbers, which operate on the same principle as a Helmholtz resonator. These so-called distributed Helmholtz resonator devices are made by covering *e.g.* a rectangular box-type cavity with a perforated panel, and using one (or two) layers of absorbing materials (*e.g.* fiberglass insulation) inside the cavity, as shown in the figure below:



The resonance frequency of the fundamental associated with the perforated panel absorber is $f_r = (v/2\pi)\sqrt{N_h A_h/(Vh')}$ where v = 343 *m/s* is the speed of sound, N_h = # of holes on the panel, $A_h = \frac{1}{4}\pi d_h^2$ is the cross-sectional area of each of the holes in the perforated sheet, h' is the effective hole length (= thickness of perforated sheet, h + 0.85×hole diameter, d_h), $V = L \cdot W \cdot D$ is the internal volume (m^3) of the perforated panel absorber, L and W (m) are its <u>transverse</u> dimensions, $D = D_{air} + D_{abs}$ is the internal <u>depth</u> of the perforated panel absorber. Defining the <u>hole</u> <u>fraction</u> of the perforated sheet as $F_h \equiv N_h A_h / A_{sheet} = N_h A_h / L \cdot W$, the expression for the perforated panel absorber's fundamental resonance frequency is also $f_r = v/2\pi \sqrt{F_h/(Dh')}$.

A plot of the measured *vs*. calculated sound absorption coefficient *a*(*f*) vs. *f* is shown below for a typical multi-layer perforated panel absorber whose fundamental resonance frequency was chosen to be f_r ~ 500 *Hz*.