Relevance and treatment of the low frequency domain in room acoustics

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Introduction

A new room acoustic standard [1], which tends to perpetuate the traditional view of the low-frequency (LF) domain being irrelevant if "only speech" is communicated in a room gives acute reason to focus on LF problems and ratings in room acoustics.

LF sound emission

Noise control at the source is easier at high than at low frequencies. The resulting LF dominance in many sources has technical reasons but is also provoked by the A-weighting of emission spectra underestimating some 20 dB in power below 100 Hz as compared to that at 1 kHz.

LF sound transmission

When noise traverses a solid wall, its LF component at 100 Hz is raised by as much as 20 dB relative to that at 1 kHz. The twofold single-number rating of emission and transmission (according to [2]) often obscures what is the real cause for annoyance, if the actual noise problem (e.g. from road or air traffic or neighbour's subwoofer) has a strong LF component [3].

LF sound shielding

In open-plan offices and call-centres one often finds funny little barriers against interfering sounds. An estimate of their shielding effect, see [4, eq. (3) and Fig. 12], however, shows that it is almost negligible at low frequencies. Since the absorption of neighbouring surfaces, necessary for effective shielding, is normally absent below 125 Hz, LF grumbling is known to "fill" the whole room.

LF room resonances

A finite number of strong, since undamped, LF resonant room modes according to [3, Figs. 2 + 3] may cause amplifications by more than 20 dB of sound generated in the room or penetrating through its windows, doors, walls or ceilings. The excitation by outdoor sources may yield disastrous indoor amplitudes whenever a transmission resonance couples with a neighbouring room resonance. Having described the limitations of abating, isolating and shielding of LF sound, it appears attractive to tackle certain LF noise problems in enclosures by rigorously damping their modes. Mode excitation also creates severe disturbances in any kind of verbal communication. One may find strong indications of low-frequency sounds of high amplitude masking high-frequencies [4] Recommendations in [1] consider an optimization of the geometric layout of small rooms; even the idea of inclining walls in order to avoid standing waves is revived in [1] – both measures, for obvious reasons, with no chance of a practical realization. Massive LF damping in the room, instead, provides the most promising procedure to tackle this problem at its roots.

LF sound absorption

Double-leaf plasterboard partition walls with a narrowband absorption at 80 Hz cannot solve the problem [5, chap. 6.1]. Conventional Helmholtz or panel resonators, when tailored to fit the LF domain, would take too much of the valuable space and rare surface of smaller rooms. Porous linings, on the other hand, can only be made 30 to 60 mm thick, just thick enough to fit the references curves A-E for an easy qualification according to [6] (Figure 1).

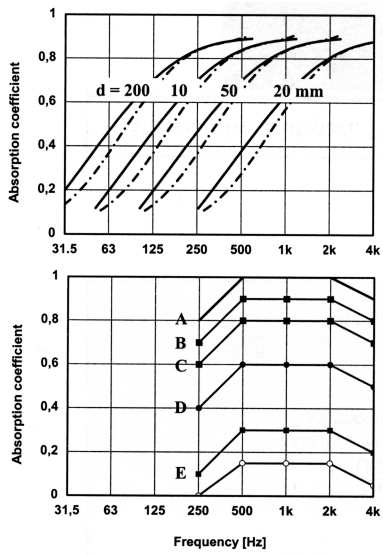

Figure 1: Absorption coefficient α of porous absorbers of varying thickness d at normal (-·-) and random (——) incidence and reference curves according to [6].

The aim is much better achieved by the Compound Panel Absorber CPA [3]. Its absorption reaches maximum values between 63 and 250 Hz for a 1 mm thick steel panel in an intimate compound with a porous or fibrous absorber, Figure 2.

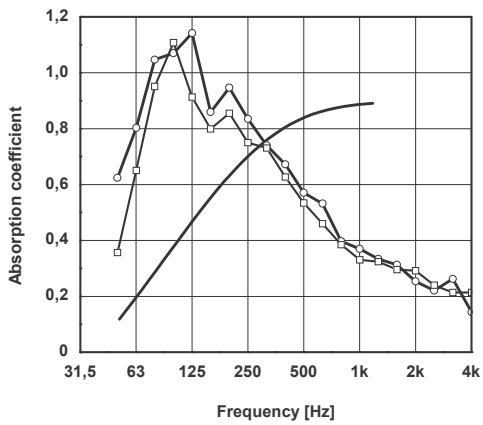

Figure 2: Absorption coefficient α_s of 1 mm steel on melamine resin foam (□) and polyester fleeze (○) as compared to a homogeneous porous layer of equal total thickness.

A constant absorption over the entire frequency range of interest in room acoustics may be achieved by applying a thin absorptive layer on top of the CPA thus forming a

Broadband Compact Absorber BCA of comparable thickness and size (preferably about 1.5 x 1 m) [7, Fig. 3].

The development of a practicable LF treatment strategy began with improvements at the workplaces of (classical) musicians [8]. Meanwhile a number of orchestra pits and rehearsal rooms have been treated to the full satisfaction of their users [9, 10] and an innovative LF design has even found its way into a large opera house [11].

Small rooms: What the pits for musical, are the glass cabinets for verbal communications [5]. With reverberation times above 1.5 s (Figure 3) a room with a volume of only 22.5 m^3 is unacceptably booming. According to [1] the 0.3 s achieved with a few LF absorbers (CPA) in the corners and transparent microperforated foils under the ceiling satisfy highest demands for speech intelligibility since an increase towards 63 Hz is strictly avoided by the retrofit measures which do not really spoil the optical appearance of the cabinet.

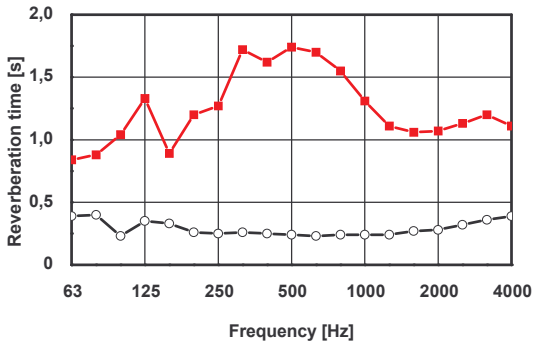

Figure 3: Reverberation times measured in a 3 x 3 x 2.5 m glass cabinet with ○ and without ■ applying novel broadband sound absorbers on parts of the walls and ceiling.

Large flat rooms: In open-plan offices with thermally activated ceilings one may try very hard to install some absorption at least in the furniture but still be left with intolerable reverberation times of 1.3 s (Figure 4). With merely 180 m^2 of CPA and BCA modules, corresponding to only 15 % of the ground surface, it was made possible to reduce the room response to very comfortable 0.7 – 0.8 s over the whole range of frequencies.

Large high rooms: Historically valuable buildings are reconstructed and refurbished as representative congress centres and public assembly halls [12]. Quite often these are treated with totally inappropriate materials with the omnipotent argument that the ancient building would not allow alternatives. On the other hand, modern communication processes – especially in foreign languages – require an unprecedented high degree of syllable intelligibility. Several more LF acoustic design examples for multi-purpose halls with an equally attractive modern architectural design are described in [13].

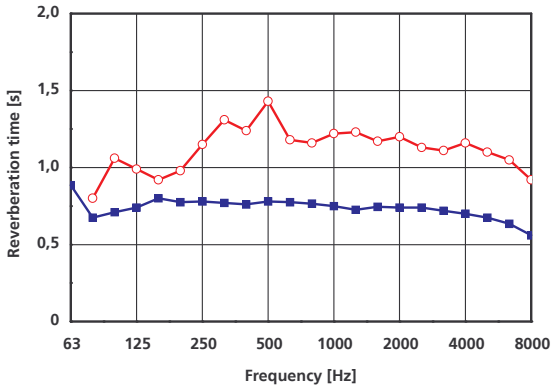

Figure 4: Reverberation times measured in an open-plan office (22 x 48 x 5 m) with ■ and without ○ a minimal CPA and BCA treatment.

References

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