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Deep Diffusorbers: Real World Application & Scalability of Amplitude Grating Diffusers Covering Ultra-Wideband Absorbers in Small to Medium Sized Venues

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ABSTRACT

Modern sound systems are capable of reproducing audio at substantial levels down to 20Hz. It is therefore of major interest to control room decay rates down to the lowest octaves even in the most demanding situations. To overcome space requirements and performance limitations of velocity-based absorbers below 80Hz and at the same time provide sufficient diffusion and tailor-made absorption characteristics at mid and high frequencies ultra-wideband diffusorbers have been emerged. Real world application together with before-after measurements of such devices individually constructed of layered amplitude grating diffuser panels, porous absorber elements, and metallic rectangular Kirchhoff plates with free boundaries on resilient sheet show their performance and scalability in a variety of rooms ranging from 900 to 280,000 cubic feet volume.

1 Introduction

This paper looks at various real world applications of differently manufactured wideband to ultra-wideband (20Hz to 20kHz) absorbers covered with 1D and 2D amplitude grating diffusors [1] typically most effective in the upper midrange (500Hz to 2KHz) based on the ideas described in [2] [3].

Figure 1. AV-studio at Lewitt Audio HQ, Vienna.

Other than maximizing absorption in all bands these diffusorbers (they may as well be called *abfusors*) shape absorption characteristics to limit absorption towards higher frequencies and extend substantial absorption down to 20Hz to achieve broad consistency in RT60 (diffusive range) and T60 (modal range) figures incorporating both velocity based and pressure based absorbers.

Whereas the concept was originally suggested for small venues such as control rooms our concern is with the scalability of this concept for acoustically up to medium sized rooms such as rehearsal rooms, recording spaces, music clubs, multi-purpose studios (Figure 1), and the like.

2 Construction

A typical design scheme for absorbing diffusors or diffusing absorbers for a space efficient yet broadband acoustic device would look like Figure 2 which proved to be a quite flexible and docile construction that may be slimmed as well as further expanded according to actual needs regarding performance, floor space, and budget.

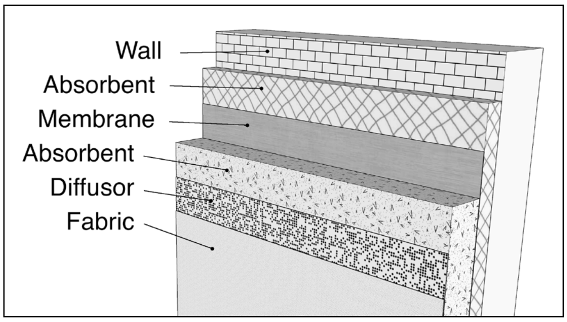

Figure 2. Basic layered 2D diffusorber.

3 Venues

We discuss six different venues ranging from 29m^3 up to 7.890m^3 (about 900 to 280,000 cubic feet) volume and widely differing utilization (Table 1) and construction methods (Table 2).

	Usage	L [m]	W [m]	H [m]	A [m^2]	V [m^3]
A	Testing	4.1	3.1	2.3	58	29
B	Mastering	7.4	5.1	3.2	154	119
C	AV-studio	8.2	6,3	3.8	213	195
D	Music club	16.2	10.4	4.2	559	702
E	Rehearsal	16.0	13,3	6.4	801	1,362
F	TV studio	34.7	23.0	9.9	2,735	7,890

Table 1. Six different venues A to F.

	Description
A	Mostly concrete with cavity brick ceiling
B	All concrete
C	Concrete floor and ceiling with 2-leaf drywalls
D	Concrete with one 3-leaf drywall
E	All concrete
F	Concrete floor and ceiling with drywalls over brick

Table 2. Construction methods.

4 Measurement chain

All the actual measurements were carried out by the author himself utilizing a Mac Book Pro with virtual Windows 7/10 (Parallels), ARTA Measurement-software, REW Analysis-software, a Focusrite Scarlett 2i4, a iSEMcon EMX-7150 Measurement Microphone, and with various sound systems.

5 Methods

We discuss before/after room decays looking at ARTAs *Reverberation time* (T30, ISO3382, Truncation) above the transition frequency [4]

$$f_s = \frac{2\,c_0}{\sqrt[3]{V}} \qquad (1)$$

and at the predominant mode decays T60 below f_s with the alternative absorption coefficient [4]

$$\alpha_e = 0.16\frac{V}{S_A}\left(\frac{1}{T_{n,m}} - \frac{1}{T_{n,0}}\right) \qquad (2)$$

6 Discussion

Test room Venue A features T30 figures (Figure 3) for the empty state (a), with one 2m^2 VPR [4] made of 1.5mm steel sandwiched in 10cm thick absorbent and mounted in the corner of one shorter wall (b), and with the same VPR covered with a BAD-panel (c) [1]. T60 for the lowest mode at $f_{1,0,0} = 42.5$Hz drops from 9.48s (a), to 1.45s (b), and further to 1.33s (c) which gives a final $\alpha_e = 1.48$ (it is a known fact that absorption figures for α_e may rise well above 1.0 due to the nature of the calculation).

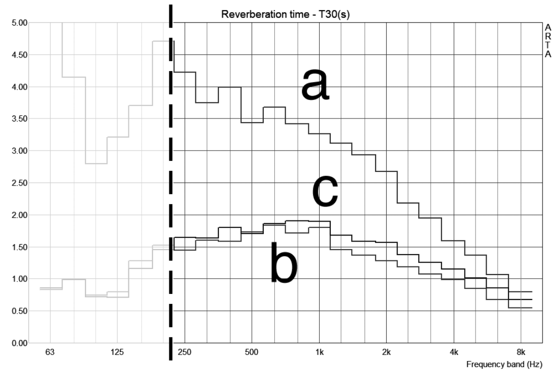

Figure 3. Venue A, T30, $f_s = 225$Hz.

The all concrete mastering room Venue B shows the expected heavy modal activity in the empty state (Figure 4, a) with $T60_{1,0,0} = 11.6$s at $f_{1,0,0} = 23.3$Hz, and $T60_{0,1,0}$ = 8,0s at $f_{0,1,0} = 33.8$Hz for the two deepest modes.

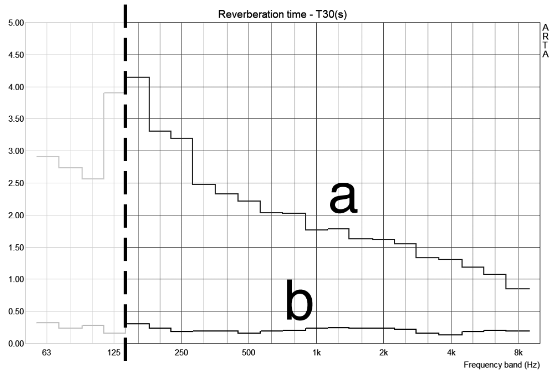

Figure 4. Venue B, T30, f_s = 140Hz.

Figure 5. Venue B acoustics.

After the acoustic installation (Figure 5) with basically 30cm deep absorbers and diffusorbers on all walls and the ceiling together with 4m^2 of straddling VPRs behind the front wall and 4m^2 of flush mount VPRs on the front wall (Figure 4, b) no more modes could be seen in the waterfall diagram with an overall wideband T60 = 190ms.

Multi-purpose AV-studio Venue C got measured in an empty state (Figure 6, a) and after installing straddling VPRs in the front corners (Figure 6, b; Figure 7) and after the complete acoustic installation (Figure 6, c). This modules incorporate 4m^2 steel membranes and cover a total of 8.1m^2 front absorbent with a total thickness of 25cm. T60 for the lowest mode at $f_{1,0,0} = 21.0$Hz drops from 2.63s (a), to 2.33s (b) with $\alpha_e = 0.19$, to 1.24s (c). T60 for the second mode $f_{0,1,0} = 27.4$Hz drops from 3.45s (a), to 2.57s (b) with $\alpha_e = 0.39$, to 0.84s (c). T60 for the tangential mode $f_{1,1,0} = 45.6$Hz drops from 1.89s (a), to 0.84s (b) with $\alpha_e = 2.55$, to 0.58s (c).

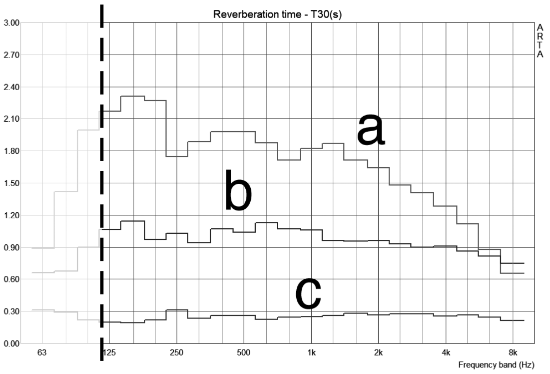

Figure 6. Venue C, T30, f_s = 119Hz.

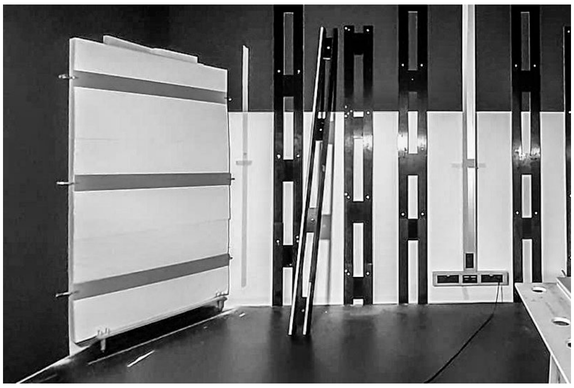

Figure 7. Venue C, straddling VPR.

The acoustic treatment included a 50cm deep velocity based absorber in the back of the room, low-mid membrane absorbers and a total of 68 hexagonal shaped 8cm thin diffusorbers covering large parts of the front/sidewalls and the ceiling which resulted in a uniform overall wideband T60 = 300ms.

Music club Venue D could only be evaluated after the massive acoustic installation had been done (Figure 8): 35m along three walls and two corners basically 30cm deep VPR-based diffusorbers were implemented with a n=10 based MLS 1D Slat diffusor.

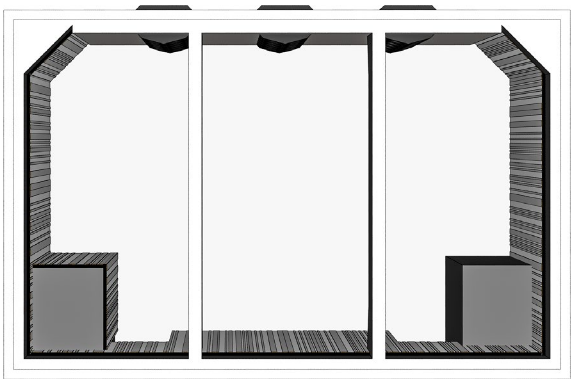

Figure 8. Venue D, slat diffusorber.

T30 has been measured in the finished but empty club with both a dodecahedron/sub speaker (Figure 9, a) and the massive sound-system itself (Figure 9, b). Whereas all the horizontal modes are very well controlled the vertical modes stand out due to the hard reflective ceiling. T30 at $f_{0,0,2} = 82.6$Hz measures 0.83s (a), and 0.75s (b), probably because the sound-system concept incorporates a cylindrical wave-front in the bass region. With a broadband T60 of 430ms even without the damping effect of the audience this room easily meets AES criteria for control rooms.

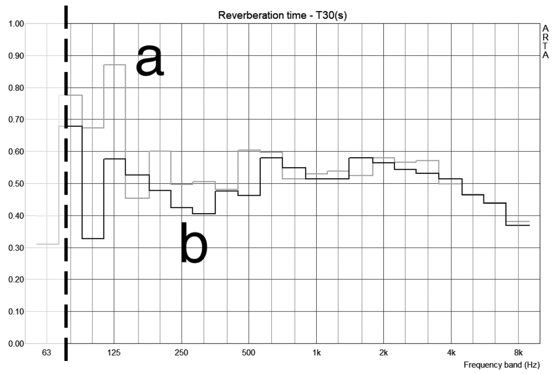

Figure 9. Venue D, f_s = 77Hz.

The all concrete rehearsal room Venue E features cost-effective diffusorbers, namely 62 ceiling mounted cloud panels with as little as 5cm of absorbent behind a 2D diffusor panel. The panels cover an absorption area of 109m^2 and are mounted 60cm below the ceiling. 44 wall modules add another 139m^2 of absorption and diffusion. T30 comparison (Figure 10) shows the empty room (a) and after the cloud has been installed (b) and in the final configuration (c). Even the horizontal mode at $f_{4,0,0} = 43.1$Hz drops from 2.15s (a), to 0.92s (b) with a resulting $\alpha_e = 1.25$

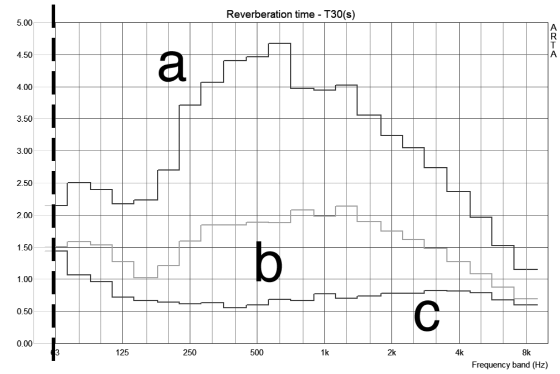

Figure 10. Venue E, T30, f_s = 62Hz.

The comparably flat wall elements (Figure 11) of 10cm thickness and various MLS-based slat covers control low-mid to high frequency reverberation and furthermore prevent flutter echoes. Broadband T60 gets to 830ms with 60 players.

Figure 11. Venue E, rehearsal situation.

TV-studio Venue F utilizes 540 (Figure 12) 5cm thin diffusorber panels equally distributed (Figure 13) on the walls and on the ceiling, mounted with 30cm to 50cm distance from the boundary covering about 20% of the total surface. Figure 14 compares before (a) and after (b) T30 measurements.

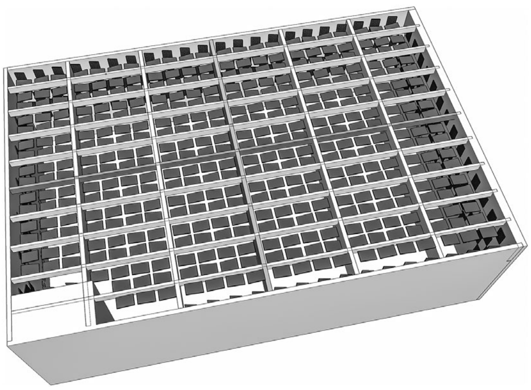

Figure 12. Venue F, module distribution.

Figure 13. Venue F, chessboard layout.

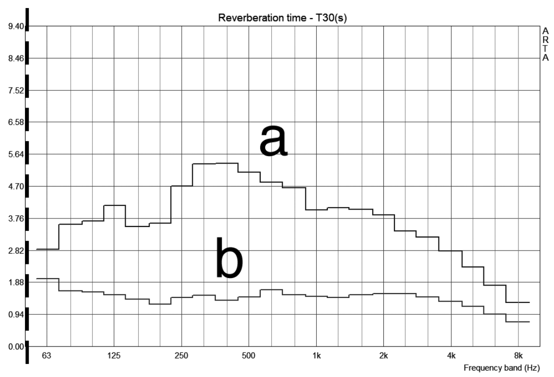

Figure 14. Venue F, T30, f_s = 35Hz.

7 Conclusions

The concept of wideband absorption covered with 1D/2D amplitude grating diffusers has proven to scale very well from small to medium sized rooms as already suspected by the original authors [2].

Integration of pressure based absorber layers with 1mm to 3mm thick metallic rectangular Kirchhoff plates with free boundaries (VPR) further enhances absorption in the critical and especially demanding 20Hz to 80Hz region.

We would particularly like to point out that special attention should be paid incorporating these layers as they are susceptible to appropriate positioning according to the modal activity below f_s calculated from (1). Therefor we see the most efficient absorption potential at modal frequencies $f_{m,n,o}$ where $f_{m,n,o} < f_s$ and $20\text{Hz} < f_{m,n,o} < 80\text{Hz}$.

References

[1] Trevor Cox, Peter D'Antonio, *Acoustic Absorbers and Diffusers, Third Edition: Theory, Design and Application*, CRC Press (2016).

[2] B. Petrović, Z. Davidović, "Acoustical design of control room for stereo and multichannel production and reproduction, a novel approach", AES Convention Paper #8295, presented at the *129th AES Convention*, San Francisco, 2010.

[3] B. Petrović, Z. Davidović, "A novel approach of multichannel and stereo control room acoustic treatment, second edition", AES Convention Paper #9526, presented at the *140th AES Convention*, Paris, 2016.

[4] Helmut V. Fuchs, *Applied Acoustics: Concepts, Absorbers, and Silencers for Acoustical Comfort and Noise Control*, Springer (2013).

[5] Fuchs, H., Hunecke, J., Zha, X. (1996), *Europäische Patentschrift EP 0 811 097 B1*. Munich, Germany: European Patent Office.