AN ORCHESTRAL REHEARSAL ROOM IN THE GREAT LICEU THEATRE: A NEW PHENOMENON IN 3D-GRID DIFFUSER

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ABSTRACT

The Room of Rehearsal of Orchestra of the Great Theater of the Liceu, inaugurated together with the whole new theater, in October of 1999, allowed to job a medium orchestra but it was not appropriated for a great orchestra, due that the dimensions neither volume had at least a value appropriated. The urban planning conditions of Barcelona had limited to all workspaces rehearsal rooms and other spaces in Theatre built. This initial deficiency has been corrected in many aspects in the Rehearsal Room of orchestra with a new acoustic planning conception. With this new acoustic planning we developed by a 3D-Grid diffractor designed by us, we have obtained an increase of Reverberation Time in the room and moreover we got to avoid that different instruments were mixed excessively, avoiding the confusion and trouble among the musicians.

1. INTRODUCTION

The Orchestral Rehearsal Room in the Liceu Theatre, inaugurated together with the whole new theatre, in October of 1999, was fine for the purposes of a medium-sized orchestra, but was not appropriate for a larger orchestra, as dimensions could not accommodate an orchestra of this size. The urban planning conditions of Barcelona had put limitations on the building of workspaces, rehearsal rooms and other spaces in the Theatre. This initial deficiency has been corrected in many ways in the Orchestral Rehearsal Room with a new concept in acoustic planning. With this new acoustic planning technique, we developed a 3D-Grid diffuser, obtaining an increase of Reverberation Time within the room and have managed to eliminate the issue of differentiating different instruments, which was incredibly off-putting and confusing for musicians.

In July of 2007, we delivered our acoustic project, carried out two years previously to the owner of the Liceu. Refurbishment work was carried out in August. The main purpose of these measurements is to carry out an acoustic comparison before and after refurbishment. The concept, the planning and the execution control of the building works were carried out by Dilmé - Fabré Architects, Barcelona, with collaboration from acoustic consultant “Arau Acustica”.

GEOMETRY ROOM:

CASE 1) Rehearsal room before refurbishment
Air volume in the room: V = 1433.60m^3
Floor surface: 277.9 m^2
Mean height: 5.16 m

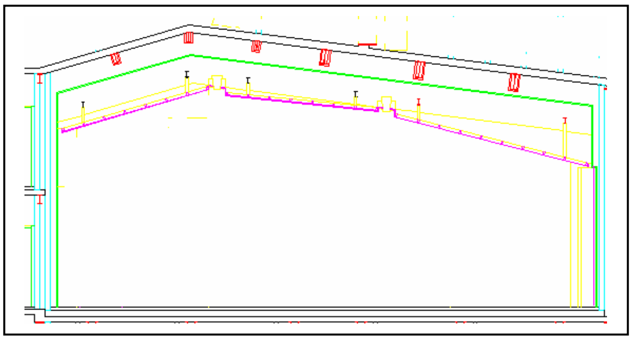

Figure 1a: Long. section of room before refurbishment

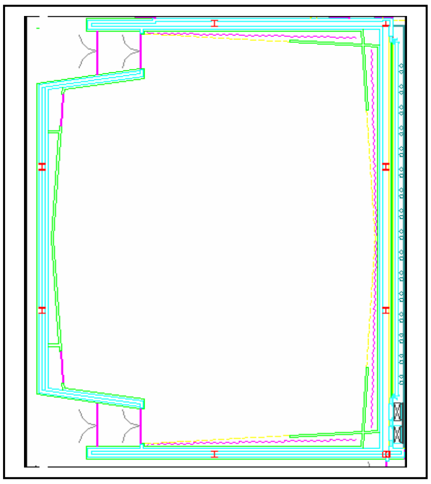

Figure 1b: Ground Section

The wood ceiling (red colour) was removed, see case 2) and the volume increased marginally:

CASE 2) Rehearsal room during refurbishment (without diffuser)
Air volume in the room: V = 1747.99m^3
Floor surface: 277.9 m^2
Mean height: 6.29 m

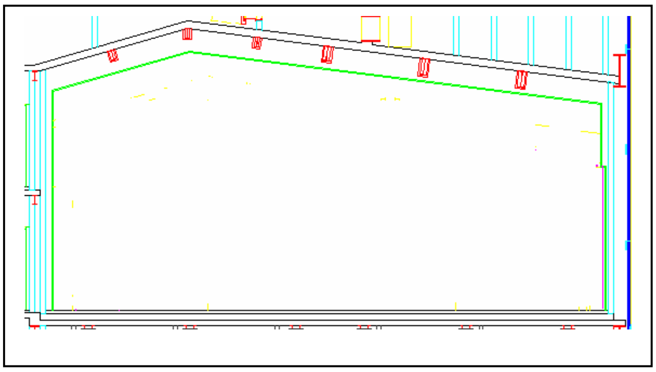

Figure 2: Longitudinal section of room after refurbishment (without diffuser).

The first scientific acoustician, Michael Rettinger,[1], explored the following question: What volume should a rehearsal room have for N musicians? He wrote:

$$V= 11.75\, N^{1.17} \quad (1)$$
$$N=0.1216.V^{0.855} \quad (2)$$

He wrote these expressions in English units, though here we have written them in MKS. In our case, for N ≥ 100, what is V according to Rettinguer? Volume V should be: V≥ 2561.7 m^3. However, we can observe here that this volume is not achievable in our case. Then we carry out the next solution:

CASE 3) Rehearsal room after refurbishment:(with diffuser)
Air volume in the room: V = 1747.99m^3
Floor surface: 277.9 m^2
Mean height: 6.29 m
We put the 3D-grid diffuser

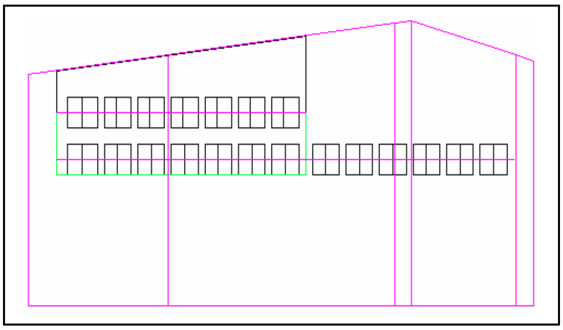

Figure 3: Long axis of room after refurbishment with diffuser.

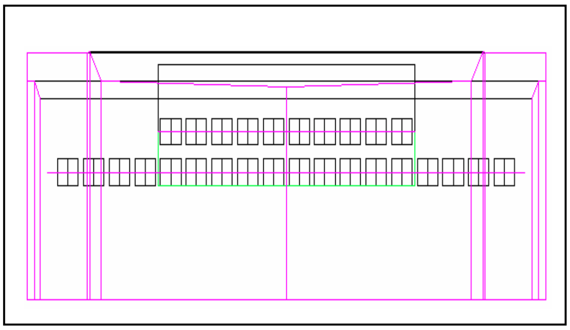

Figure 4: Transversal section of room with diffuser.

Architectural details: Last details
Walls: Plaster board, *ceiling:* Plaster board + diffuser floating ceiling to floor. *Floors*: wood parquet.

2. DESCRIPTION OF THE 3D-GRID DIFFUSER

Air volume in the room: V = 1747.99 m^3
Floor surface: 277.9 m^2
Mean height: 6.29 m.

We put the 3D-grid diffuser. The 3D-grid diffuser is a matrix of polycarbonate plates, supported by a pattern of iron squares of 200 mm x15 mm. Each diffuser plate measures 800 mm height x 800 mm wide x 10 mm thickness. The entire system is hung from one iron structure from the ceiling. The main design criterion is a reflector/ diffuser in grid format that covers all possible directions to eliminate excess noise between the hall's ceiling and floor, scattering diffracted sound in all directions. The horizontal structure of the support system is 200 mm wide, the laminate plates measure 800 mm x 800 mm. The composition of plates are polycarbonate compact of 10 mm thickness.

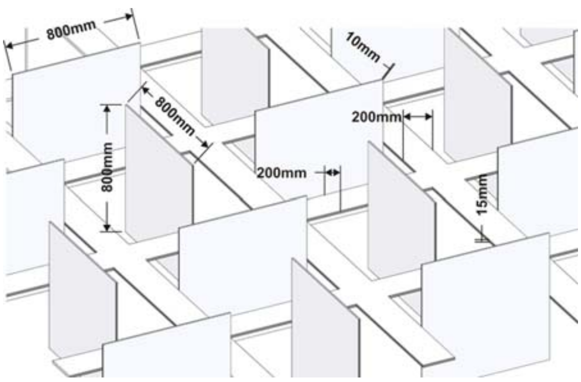

Figure 5: Detail of 3D-grid diffuser

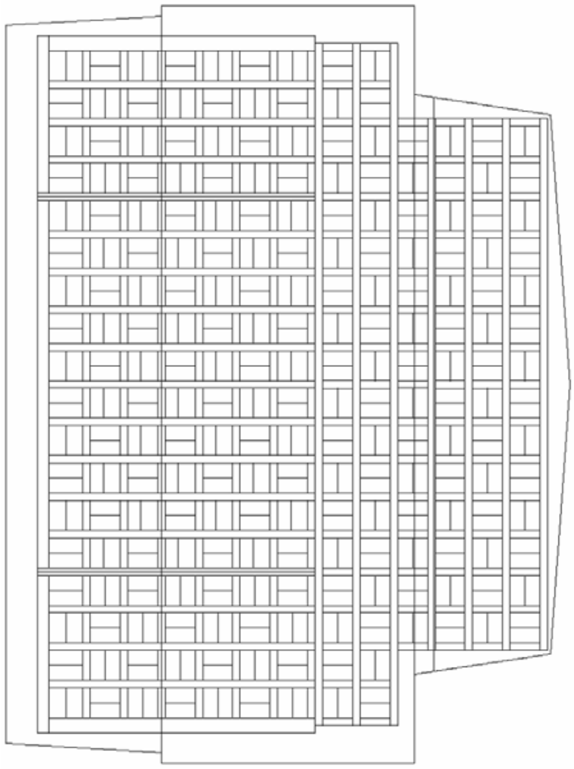

Figure 6: Overhead view of 3D-grid diffuser

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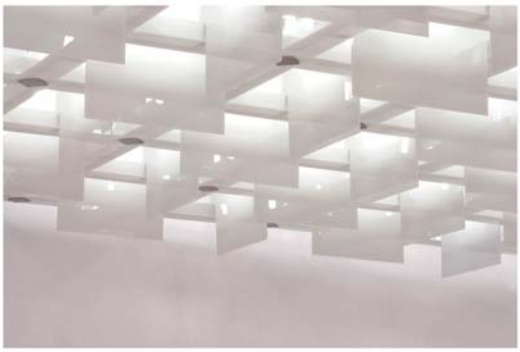

Figure 7: Detail of 3D-grid diffuser

Figure 8: View after refurbishment

3. MEASUREMENT METHODOLOGY AND SYSTEM

The experimental procedure was carried out according to the ISO 3382-1,[2], where monophonic impulse responses where measured using sweep signals in the 125-4000 Hz octave band range. The measurements were performed to find the following magnitudes, or parameters through the impulsion response:

The measurements were carried out to find the following magnitudes:

Parameter
Reverberation Time T_{30}
Early Decay Time EDT
Support objective of Stage ST1

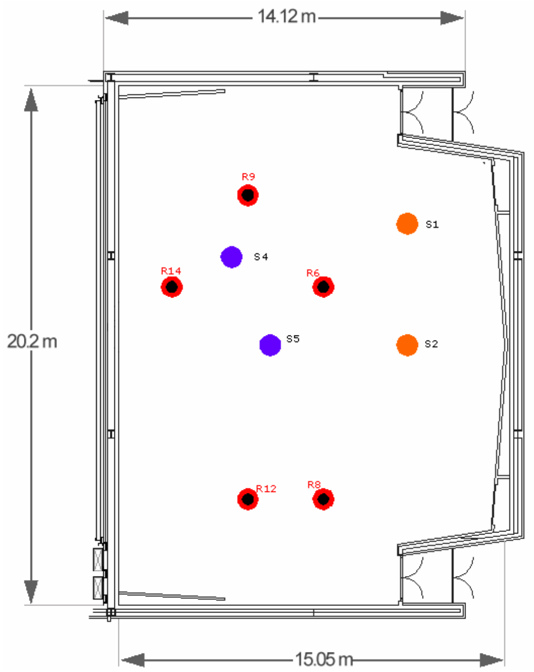

Figure 9: Position of sources and receivers

The measurements we had of the floor of rehearsal room, in all cases 1), 2), 3), chairs and music stands installed.

1. The reverberation time T is measured by T_{30} and EDT was measured at each Si source and Rj receiver indicated in the figure 9, finally taking the average value of overall points:

S1_1m	S2_1m	S4_1m	S5_1m
S1_R8	S2_R9	S4_R6	S5_R6
S1_R9	S2_R14	S4_R12	S5_R12

When we write, for example, S1_1m, this means that the receptor, namely the microphone, is at 1m distance from the sound source. When we write S1_R9, this means that source S1 is distant from receptor R9, as indicated in Figure 9.

Both early decay time and reverberation time are derived from the slope of the octave band integrated impulse response curves. EDT is obtained from the initial 10 dB of the decay and T is obtained from the portion of the decay curve between -5 dB and -35 dB, below the maximum initial level in the case of T_{30}.

<u>Equipment used:</u>
WinMLS 2004, Morset Development
Microphone Bruel & Kjaer 4942
Preamplifier of microphone Bruel & Kjaer 2690
Sound Card digigram vxpocket v2
Omni power sound source BRÜEL & KJAER model 4296
Power Amplifier Brüel & Kjaer model 2716, 300 W

2. The ST1 or ST_{Early} was measured at the following sound sources Si, i =1 to 4, to 1m gap microphone and source and receiver height of 1.2 m were used and all the quoted values were over the 0.25-2 kHz octave band. The arithmetically averaged result of the four octave bands from 0.25 to 2 kHz and of three positions at least are calculated as a single result of the stage.

4. BEFORE AND AFTER COMPARISON.

REVERBERATION TIME (T) AVERAGE VALUE ALL SOURCES

Reverberation Time T(s)	125	250	500	1000	2000	4000	RT_{mid}	RT_{low}	RT_{high}
$T_{30\ CASE\ 1)}$	0.91	1.03	0.89	0.86	0.86	0.85	0.87	0.97	0.85
$T_{30\ CASE\ 2}$	1.10	1.25	1.10	1.05	1.07	1.03	1.07	1.17	1.05
$T_{30\ CASE\ 3)}$	1.53	1.81	1.92	1.78	1.75	1.67	1.85	1.67	1.71
COMPARISON ΔT_{21} ΔT_{21}=T30 $_{CASE\ 2)}$ – $T_{30\ CASE\ 1)}$	0.19	0.22	0.21	0.19	0.21	0.18	0.20	0.20	0.20
COMPARISON ΔT_{32} $\Delta T_{32}=T_{30\ CASE\ 3)} - T_{30\ CASE\ 2)}$	0.43	0.56	0.82	0.73	0.68	0.64	0.77	0.50	0.66
COMPARISON ΔT_{31} $\Delta T_{31}=T_{30\ CASE\ 3)} - T_{30\ CASE\ 1)}$	0.62	0.78	1.03	0.92	0.89	0.82	0.97	0.70	0.86

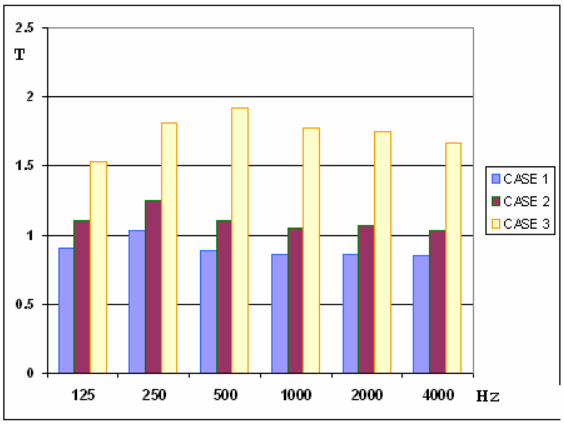

Figure 10: T_{30} Reverberation graphic for cases 1), 2) and 3).

On examining figure 10, we have observed that case 3 with a diffuser has a clearly greater reverberation time than before the refurbishment, where no diffuser existed.

Here we show the normalized filtered Schroeder curve for two any cases on two frequencies 500 and 1000 Hz.

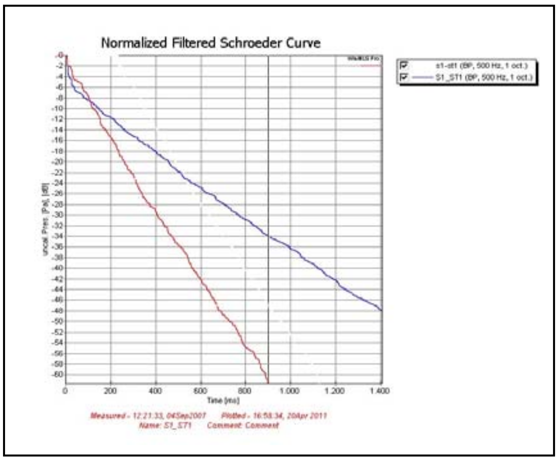

Figure 11: S1-1m, 500 Hz. Blue colour is case 3)
case 3) Red colour is case 1)

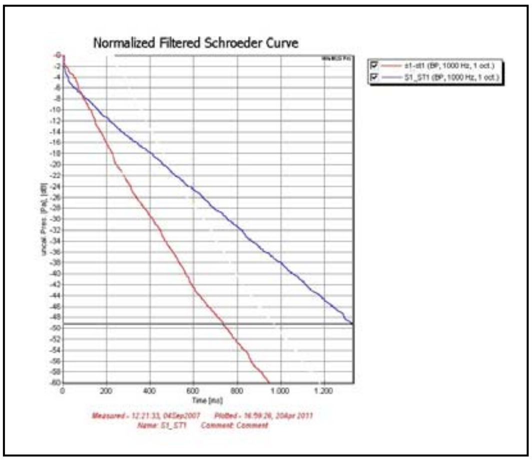

Figure 12: S1-1m, 1000 Hz. Blue colour is
Red colour is case 1)

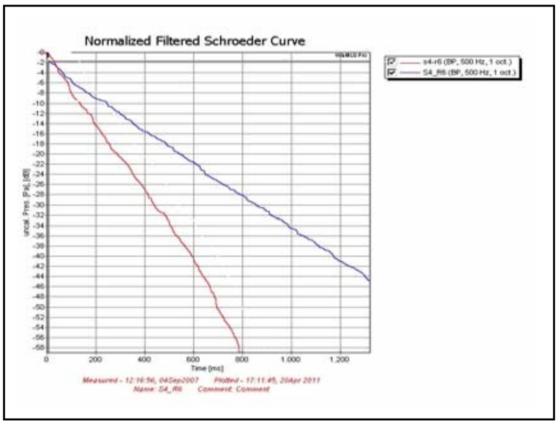

Figure 13: S4-R6, 500 Hz. Blue colour is case 3) Red colour is case 1)

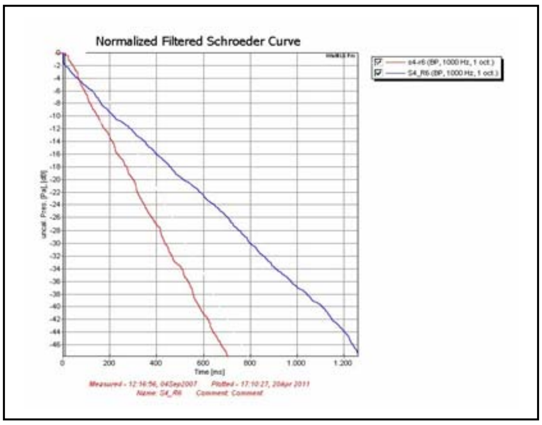

Figure 14: S4-R6, 1000 Hz. Blue colour is case 3) Red colour is case 1)

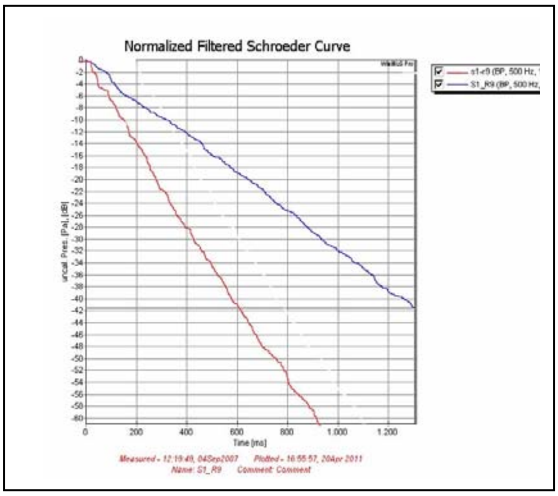

Figure 15: S1-R9, 500 Hz. Blue colour is case 3) Red colour is case 1)

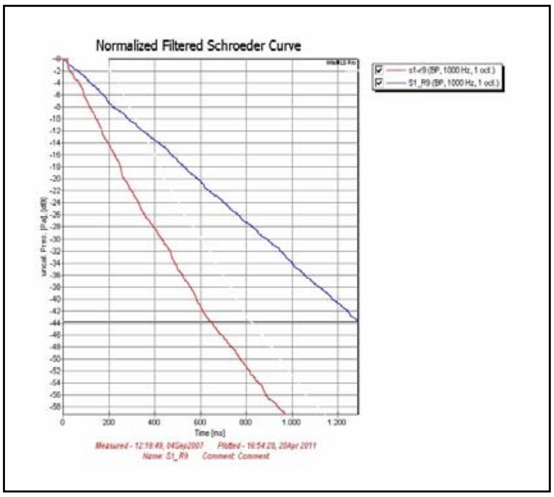

Figure 15: S1-R9, 1000 Hz. Blue colour is case 3) Red colour is case 1)

In all demonstrated figures 11 to 15, and those undemonstrated in all cases analysed, we can see that the sound decrease gradient is softer in the hall with a diffuser than when there is none. This goes some way to demonstrating that the hall reverberation has increased, despite not understanding the physical law that applies in this case.

EARLY DECAY TIME (EDT) AVERAGE VALUE ALL SOURCES

Early decay time EDT	125	250	500	1000	2000	4000	EDT_{mid}	EDT_{low}	EDT_{high}
$EDT_{CASE\ 1)}$	0.90	0.73	0.78	0.77	0.75	0.72	0.78	0.82	0.74
$EDT_{CASE\ 2)}$	1.10	0.95	0.90	0.95	0.90	0.85	0.92	1.02	0.87
$EDT_{CASE\ 3)}$	1.03	1.44	1.68	1.65	1.60	1.41	1.67	1.24	1.51
COMPARISON ΔEDT_{21} $\Delta EDT_{21}=EDT_{CASE\ 2)} - EDT_{CASE\ 1)}$	0.20	0.22	0.12	0.18	0.15	0.13	0.15	0.20	0.13
COMPARISON ΔEDT_{32} $\Delta EDT_{32}=EDT_{CASE\ 3)} - EDT_{CASE\ 2)}$	-0.07	0.49	0.78	0.70	0.70	0.56	0.75	0.22	0.64
COMPARISON ΔEDT_{31} $\Delta EDT_{31}=EDT_{CASE\ 3)} - EDT_{CASE\ 1)}$	0.13	0.71	0.9	0.88	0.85	0.69	0.89	0.42	0.77

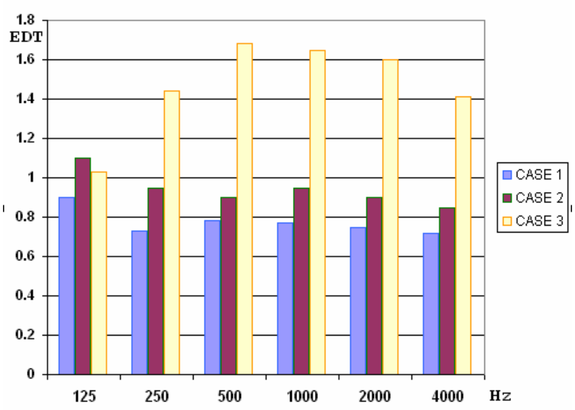

Figure 16: Early decay time EDT graphic for cases 1), 2) and 3)

STAGE SUPPORT (ST1)

The early support relates to ensemble, i.e. ease of hearing other members of an orchestra.

Stage Support ST1 (dB)	Average
$ST1_{CASE\ 1)}$	**2.52**
$ST1_{CASE\ 2)}$	**0.5**
$ST1_{CASE\ 3)}$	**-7.26**

5. CONCLUSIONS IN LICEU

Remark 1, T: In mid frequencies, the relative increment of Reverberation Time between case 3 and 2, ΔT_{30}= 0.77, is: $\varepsilon = [\Delta T_{30} / (T_{30\ case2})] = 0.72$; 72 %.In this case we have considered only the effect of the 3D-Grid diffuser, in low frequencies we have $\varepsilon = 0.42$; 42 %. In high frequencies we have $\varepsilon = 0.63$; 63 %.

Remark 2, EDT: We saw that EDT behaves in a similar manner to T.

Remark 3, ST1: *We noticed in case 3 that the values of ST1 are much better than in cases 1 and 2, coinciding with the music perception. In this case, Gade's criterion is good, as is coincides with the subjective perception of musicians.*

6. LAST CONCLUSION

With this diffuser, or others similar, we have obtained by chance a new method to increase the reverberation time of a room. It is especially applicable to small rooms in conservatory of music and also little chamber halls, concert halls, reverberation chambers or also for design a new spaces where we wish to obtain a great volume by audible subjective sensation against a reality well different. A new time of researching and experience in acoustics must to arise in this field; field very connected to the sound waves phenomenon in where in reality we know very few about this subject.