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Establishment a methodology for an objective-subjective acoustic analysis in a multifunctional hall: Paraninfo of the Polytechnic University of Valencia

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This study presents a methodology for the acoustic analysis, from a comprehensive study of a multifunctional hall, of the Polytechnic University of Valencia, as a pilot hall in a Spanish Coordinated Project.
The acoustic parameters studied were those who the most acoustics experts consider of interest. In the objective measures were use the equipment and methods conforming to ISO 3382. The questionnaire used to analyze the subjective response has been patented in Spain, by the research group that developed the project. The correlation between objective and subjective results, along with the accurate simulation of the hall provides a valid tool for design, restoration and improvements the enclosures where the sound quality is preferred.

1. Introduction

The study of concert halls acoustics is fascinating but difficult to quantify. If we take into account also the opinions of listeners, the problem becomes more complicated. Once we started on this study, we discovered that knowledge of the audition halls and the quality parameters study, must take into account:

1) - the objective measures.

2) – the questionnaires about the subjective perception of the people.

3) - related between the physics of concert halls and its perception.

This research was made in Paraninfo, of the Polytechnic University of Valencia, established as “pilot room” for the project “Establishment of objective acoustic parameters qualifying the concert room quality. Application in the new building and rehabilitation projects", approved by Inter-ministerial Commission of Science and Technology, ref. BIA2003-09306-C04-01[1]

According to ISO 3382 [2], there were carried out, in situ tests as objectives measurements. The subjective evaluation was made, testing the music experts in order to compare their opinions.

2. Objectives

The principal objective of this work is to present a methodology to determine the acoustic qualities of a hall, in this case of Paraninfo of Polytechnic University of Valencia. The subjective and objective results and a comparison between them will be present.

3. Methodology

Considering the requirements of ISO 3382, in order to obtain the desired objectives, the work methodology supposed to follow the denominated “Measurement Protocol”. The principal lines are: studied the hall which will be measured, carry out the objective tests in the hall, following the protocol established for each measurements, accomplishment accurately the questionnaires for the subjective measurement, interpretation of results and evaluation of the correlation between subjective and objective measurement.

Measurement protocol

A detailed protocol has taken into consideration the following aspects:

a)-a technical sheet with: the map of the hall, where will be represented the points where will be make the measurement, photos of the hall, dimensions of this, and another characteristics, materials, etc.

b)-instructions about the equipment, how to use it and with scheme specifying the connections between them. Usually, this is numbered to have a rapid access and identification, allowing an easy use. Very important and helpfully is to grouping of the equipment in packs, according to it use.

c) - specified a work method for each type of measurement carried out, equipment used and how we make the connections for specific measure. Can be use more types of standardized noise and different equipment, and combination between them like: digital head acoustic and sine sweep noise, multi pattern capacitor microphone and G.R.A.S. microphone, and sine sweep noise, G.R.A.S. microphones and pink noise, G.R.A.S. microphones and sine sweep noise. Explanation about used acoustic software contains information with: volume of input and output levels, impulse frequency response data,, measurement settings, total duration of measurement, setup loaded. An example of a specified window is presented:

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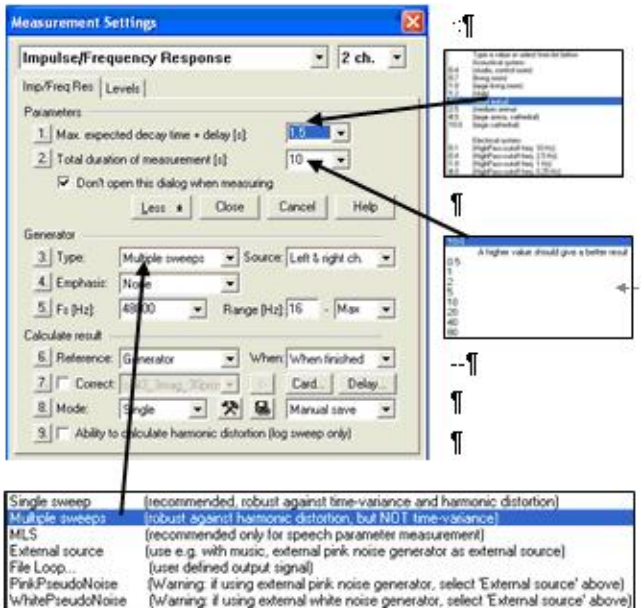


Fig 1-Protocol about the software

d) - the objective measurements: the measurements will be carried out, with sine-sweep noise and pink noise, in several points of the halls, taking into consideration all the preparing steps previously enumerated.

e)-the subjective measurements are carried out through the questionnaires, given to the listeners in the hall, for the evaluation of the sound perception by the part of audience , when the concert was performed.

Hall information

A technical sheet with the Paraninfo characteristics, we present. Include the information required in hall protocol.. The number of measurements in Paraninfo was 24 points.

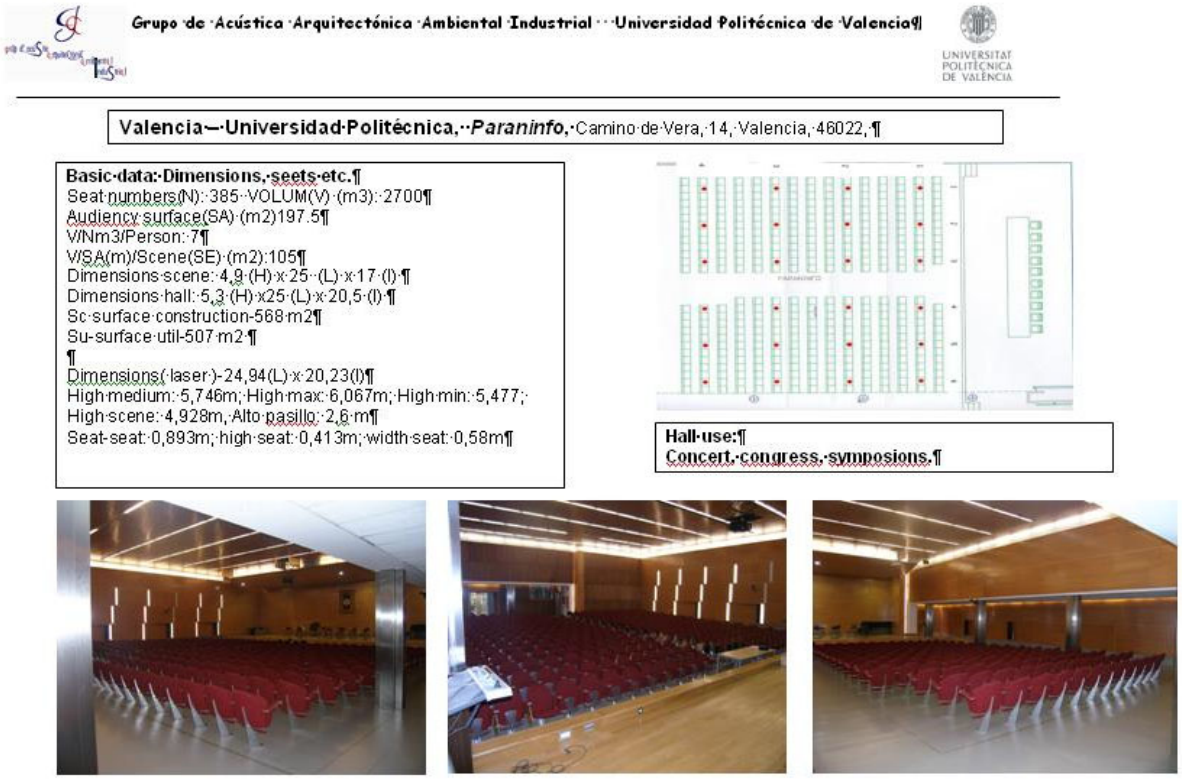


Fig.2-Tehnical sheet of Paraninfo

Equipment

The measurements were carried out, with the last generation equipment (Fig.3), mentioning among them:

-Head acoustic HMS III.0 (transmission range: 3 Hz-20 kHz, -3dB/+0.1 db; dynamic range: typ. >118 dB, max SPL 145 dB).

-Multi pattern capacitor microphone AT4050/CM5 (frequency response: 20-20.000Hz, sensitivity: 15.8 mV, polar patterns: cardioids, omni directional, figure-of-eight).

-Dodecahedral loundspeakerDO12 (Rated power 600W, Sound Power>120dB, Frequency range: 80 Hz-6.3 kHz, directivity: nearly spherical).

-Microphones G.R.A.S. Type 40 AK (Sensitivity at 250Hz 50 mV/ Pa, Frequency Response (±dB): 3.15 Hz-20 kHz, Upper Limit of Dynamic Range (3% Distortion): 164 dB re. 20µ Pa, Lower Limit Dynamic range: 14 dB, re. 20µ Pa

-Microphones preamplifier G.R.A.S Type 26AK (Frequency Range: 2Hz-20 kHz, Noise: A-weight :< 2.5µV).

-Power amplifier M-1000 (Power output level RL=4Ω: 520W+520W).

Powerful acoustic software that allows emitting standardizes noises (sine sweep, white, pink or others) and to process instantaneous the obtained data, to analysis and post process of the acoustic measures data, was used. The acquired software represents one of the most important parts of the system.

Objective measurement

The objective measure is one of most important part of the acoustic hall qualifying. Before started the measure must carry out with the conexions between equipments (most part of them connected by cables) (Fig 3). With this equipment, Paraninfo of Polytechnic University of Valencia was been studied and, conform with ISO 3382 norm, were been determinate acoustic parameters presented in the table 1.. .All the measurements were carefully recorded, making the security copy, too, and interpreted, later, with specialized software.

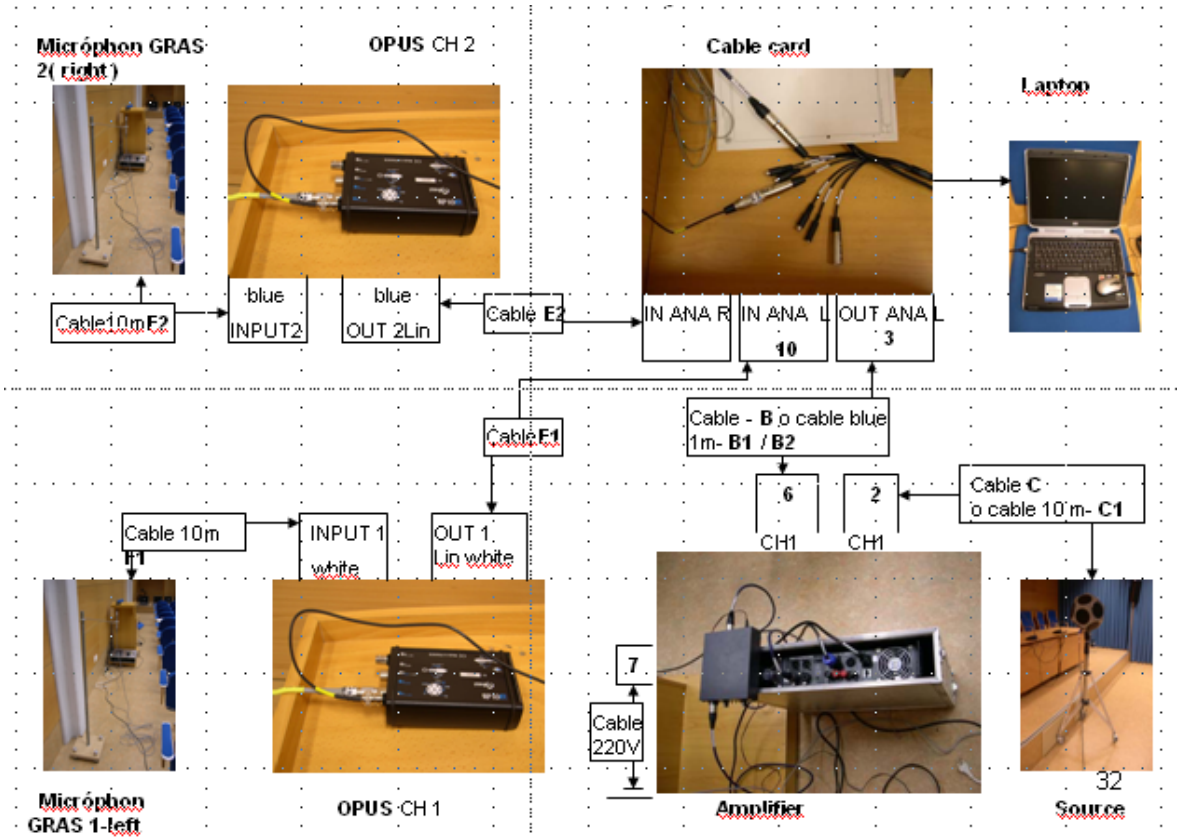


Figure 3.- Equipment and measurement

Parameter	Calculus
Reverberation Time (TR_{30}):	$TR_{mid} = \frac{1}{2}\left(TR^{500\,Hz} + TR^{1\,kHz}\right)$
Bass Ratio:	$BR = \frac{TR^{125\,Hz} + TR^{250\,Hz}}{TR^{500\,Hz} + TR^{1\,kHz}}$
Brilliance:	$Br = \frac{TR^{2\,kHz} + TR^{4\,kHz}}{TR^{500\,Hz} + TR^{1\,kHz}}$
Early Decay Time:	$EDT_{mid} = \frac{1}{2}\left(EDT^{500\,Hz} + EDT^{1\,kHz}\right)$
Center Time:	$T_C = T_{C1kHz}$
Clarity (music):	$C_{80} = \frac{1}{3}\left(C_{80}^{500\,Hz} + C_{80}^{1\,kHz} + C_{80}^{2\,kHz}\right)$
Clarity (speech):	$C_{50} = 0.15 \cdot C_{50}^{500\,Hz} + 0.25 \cdot C_{50}^{1\,kHz} + 0.35 \cdot C_{50}^{2\,kHz} + 0.25 \cdot C_{50}^{4\,kHz}$
Strenght:	$G_{mid} = \frac{1}{2}\left(G^{500\,Hz} + G^{1\,kHz}\right)$ (calculada a partir del sonido directo)
Lateral Fraction:	$\begin{cases} LF_4 = \frac{1}{4}\left(LF^{125\,Hz} + LF^{250\,Hz} + LF^{500\,Hz} + LF^{1\,kHz}\right) \\ LFC_4 = \frac{1}{4}\left(LFC^{125\,Hz} + LFC^{250\,Hz} + LFC^{500\,Hz} + LFC^{1\,kHz}\right) \end{cases}$

Interaural Cross Correlation (Early):	$IACC_{E3} = \frac{1}{3}\left(IACC_E^{500\,Hz} + IACC_E^{1\,kHz} + IACC_E^{2\,kHz}\right)$
Stege Support:	$ST1 = \frac{1}{4}\left(ST1^{250\,Hz} + ST1^{500\,Hz} + ST1^{1000\,Hz} + ST1^{2000\,Hz}\right)$

Table 1-Measured acoustic parameters

Subjective measurements

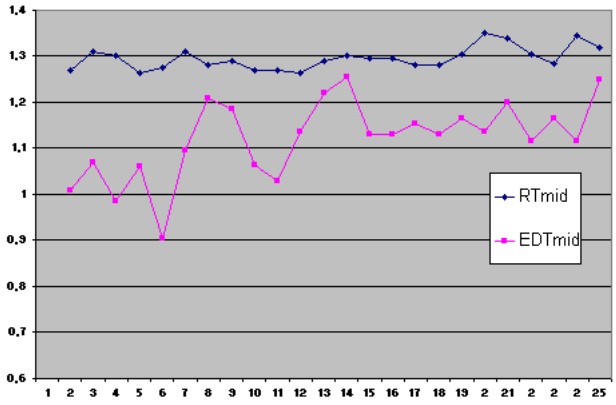
In parallel with the objective measures, was asked a group of experts in music, (not acoustic), to have a opinion about the acoustic quality of the hall, responding to the items of a questionnaire specially designed for them [4]. Using this questionnaire, musicians (teachers and students) of Superior Conservatory of Music of Valencia, give their impression, about the hall, in three concerts in the hall.

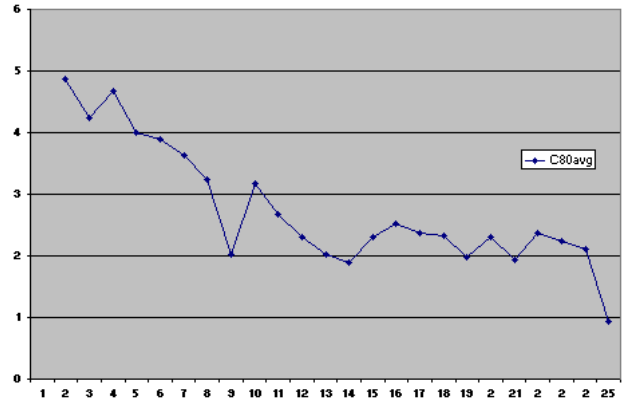
The questionnaire has been organized in 58 questions divided in 6 sections, 3 of them directly related to the hall and the acoustic perception in this and the other 3 corresponding to sociological data, musical tastes, etc. of the listener and, therefore, directly related to the person who answers the questionnaire.

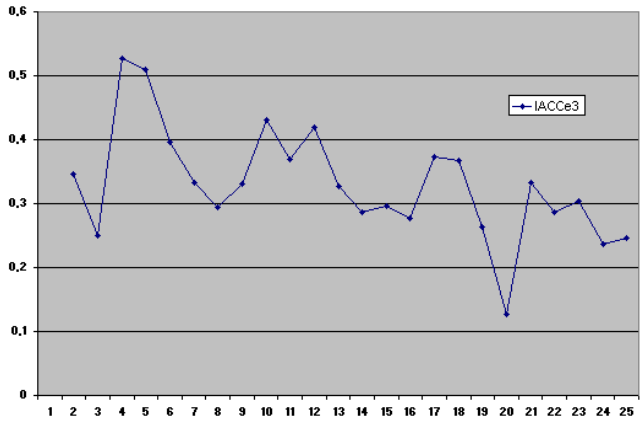
Essential for the evaluation, was the position of the seats of the listeners, which have been tested. These corresponded, usually, with the location of the microphones, to avoid the differences, in perception of the sound.

Interpretation of the results

Results of the objective measurement are presented in the figures 5-7. The values, (averaged 500-1000 Hz) for RT, EDT, C80 and IACC, .for the analysed measuring points, are represented.







Figures 5-7-Representation of, RT, EDT, C80; IACC

For subjective results, we have collected 116 questionnaires in Paraninfo, 44, 29 and 43, in the 3 concerts studied.

The analysis of the number of answers, "Do not know / no answer," shows that question: B63: "Find the sound of the room intimate?" with a 71% do not know, is more difficult interpretation by the expert in music.

The room gets, on 5, an average score of more than 4 points, in the items for clarity of perception (Will clearly distinguish the sounds of different instruments? Does distinguishes the soloist? How perceives the orchestra?) while scores obtained 2.4 and 2.7, respectively, "" Find the sound dry in the room? "and" The concert it produces a feeling of pleasant music? ", receiving intermediate values in the remaining items.

Comparative objective/ subjective

This fact is compatible with the design for multipurpose use of this hall and with the values of the objective parameters (RT, EDT, C80 and IACC.) that have great relevance to quantify these aspects.

Simulation

Finally, an acoustic simulation of the hall is recomandated. This can be important to offer some solutions, to improve the acoustic qualities of the hall. A 3 D geometric simulation, with acoustic software, is presented. in figure 8-9.

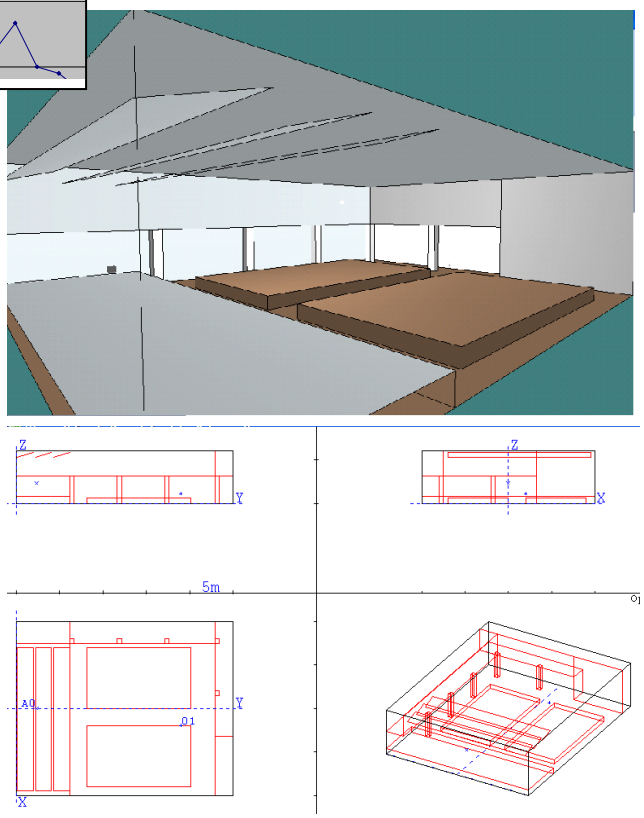


Fig. 8-9-Geometric acoustic simulation of Paraninfo

Conclusions

Studying the results, of this pilot hall can be concluded that:

The questionnaire developed to obtain the subjective response of the listener in concert halls; it is also a valid tool for assessing a multipurpose room, such as this auditorium.

The study of the number of non-responses in some items has helped redefine the question, add a brief explanation of its meaning acoustic, which has improved the number of responses to these items in subsequent uses of it.

The values of objective parameters such as RT, EDT are low for hearing music, concordant with the answer given by experts, while the Clarity parameters are adequate in keeping with the high valuation of the items related questionnaire

Acknowledgement

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