



19th INTERNATIONAL CONGRESS ON ACOUSTICS
MADRID, 2-7 SEPTEMBER 2007

THE AUDITORIUMS OF THE POLYTECHNIC UNIVERSITY OF VALENCIA LIKE PILOT HALLS TO ESTABLISH THE PROTOCOL AND MEASURES IN A COORDINATED PROJECT

PACS: 43.55.Mc

Lacatis, Radu George; Giménez Pérez, Alicia; Romero Faus, José; Cerdá Jordá, Salvador; Navasquillo Hervás, Barba Sevillano, Arturo
Grupo de Acustica Arquitectonica, Ambiental, Industrial, Universidad Politécnica de Valencia, Camino de Vera S/N, 46022

rala1@doctor.upv.es, agimenez@fis.upv.es, arrakis@fis.upv.es, salcerjo@mat.upv.es,
joaquin.navasquillo@uv.es, arbase@arq.upv.es

ABSTRACT

Determination of the acoustic parameters is relevant for the quality classification of the concert halls and amphitheatres and was the main objective of a great Spanish national investigation project. In this study, part of the project mentioned above, we intend to present the methodology and the protocol developed, in order to carry out the objective and subjective measurements.

A series of objective measurements were performed, according to ISO 3382 [1]. In the same time was accomplished the subjective evaluation by testing the audience (experts), in order to compare their opinions and correlate it with the measurements obtained. The paper describes all the process necessary to set up the tests, as well as the objective and subjective results obtained in three rooms of the Polytechnic University of Valencia, focusing on following aspects: physical measurements in-situ, protocols of measurements, equipment and interpretation of data obtained, using specialized acoustic software.

Keywords: acoustic parameters, concert halls, objective and subjective measurements, protocols of measurements.

INTRODUCTION

The present study is part of the investigation 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, period 1.12.2003 -30.11.2006.

It was a project at great scale in Spain, bringing together researchers from different Independent Communities: Andalucía, Navarra, País Vasco, Aragón, Cataluña and Valencia (University of Seville, Public University of Navarre, Polytechnic University of Barcelona and Polytechnic University of Valencia, the last, coordinator of the project).

There were carried out, in situ tests as objectives measurements, according to ISO 3382. The subjective evaluation was made, testing the audience (music experts) in order to compare their opinions.

The paper aims is to describe all the process necessary to set up the tests, protocol of the objective and subjective measurements, obtained in three rooms of the Polytechnic University of Valencia, focusing towards the aspects where the participation of author, has been important (measurements in-situ, protocols of measurements, the equipment, etc), those constituting also parts of his doctoral thesis in developing.

The research were made in the following halls: Paraninfo, Assembly Hall of the Superior Technical School of Industrial Engineers, Amphitheatre of the Polytechnic City of the Innovation-6G of the Polytechnic University of Valencia, established as "pilot rooms" for the project. Also, all the participant groups in this project, of all Universities, was working in this hall to compare their initial results, to calibrate the equipments and to establish the common lines of investigation.

OBJECTIVES

The principal objectives, followed in the paper are:

- Establish the protocol of the measurements valid for all halls and each of the participant groups on the project.
- Carry out the tests in the pilot rooms and the necessary adjustments of the different elements from the measurement chain.
- Evaluation the influence of changes, in order to validate all the devices used for measurements.
- Accomplishment of questionnaires and the adjustment of the same ones until to the final state.

METHODOLOGY

To have an over view of the researches made in the field of acoustic, parameters measurements, in concert halls and amphitheatres [2], [3], a large theoretical study was performed, based on the great data basis of the Polytechnic University of Valencia.

In order to obtain the desired objectives, considering the requirements of ISO 3382, the methodology supposed to establish preliminary phases, that finally will constitute the denominated "Measurement Protocol", that cover all the aspects studied in the Project. To accomplish the objectives presented above, a rigorous methodology was elaborated and implemented, as measurements protocol, covering all the aspects necessary to obtain the best results.

The protocol for measurements and also for the equipment used is displayed below:

MEASUREMENTS PROTOCOL

The structure of the measurements protocol has the following components: objective measurements/in situ- they cover the physical determinations, with all its components: equipment, work method; subjective measurements centralizing the opinions of the experts; type of the tested halls -with all the aspects concerning: the typology, materials and dimensions.

Objective measurements

One of the most important part of the project, have constituted the objectives measurements – in situ, due to its novelty and significance for the Spanish research, involving a large area of testing (type of tests, variety on halls, space, constructions, interior design, etc). The physical measurements have been the subject of many working hours, including the calibration of the equipment used and the proper measurements. The measurements of the acoustic parameters, in different halls of the Polytechnic University of Valencia, with various characteristics and their different "feedback", allowed an objective evaluation and interpretation of the data, obtained with specialized acoustic software. To accomplish the objectives for this stage the following aspects have been taken into consideration:

a) The work method: this involved the elaboration of different protocols, for each type of measurement carried out, also for the equipment used and the connections between them. Accordingly it is essential to provide all the necessary data to optimize the measurements and to have the same method for each tested halls.

In this part we have files about:

- the software used with all the settings about: setup loaded, measurement settings ,impulse frequency response data, maximum expected decay time, total duration of measurement in ms, type generator, volume of input and output levels .
- the type measurements with:
 - G.R.A.S. microphones 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
 - digital head acoustic and sine sweep noise

b) The halls chosen to be tested: establish the measurements points and the position of the source, according to ISO 3382.

Before each measurement, the maps of the room, with the points of measurements (Fig.1, Fig.2) and also the identification sheets for each seat, have been prepared. In order to have a good image on the halls, the number of the realized measurements was superior to the minimum number required by norm.

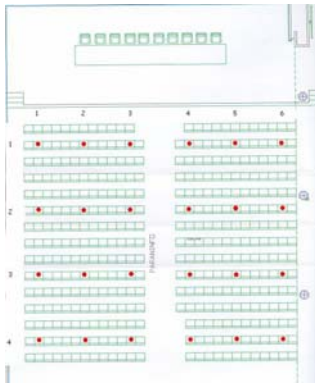


Figure 1.-Measurement points, Paraninfo



Figure 2.-Measurement points, Amphitheatre 6G

As a consequence the number of measurements in the tested halls was the following: in Paraninfo-24 points, Act Hall -16 points, Amphitheatre of the Polytechnic City of the Innovation 6G-40 points. All these data, concerning the halls, are detailed in the section "HALLS". Because the project is an investigation study, not just an acoustic inform (how required ISO 3382), we made more measurement, that required norm points. More, in this way we could verify the acoustic response, function of the symmetry (acoustic and geometric) of the hall, because they are depending function of: the studied room, the situation of the measurement point, and the frequency [6].

c) The equipment:-in this case, it is really compulsory to calibrate the equipment, carefully, at each measurement, knowing that any distortion could influence the results. For this, a multitude of measurements, calibrations and verifications have been done, until, all the chain of measurements, has been correctly calibrated.



Figure 3.- Equipments

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

- Microphones G.R.A.S. Type 40 AK (Sensitivity at 250Hz 50 mV/ Pa, Frequency Response (\pm dB): 3.15 Hz-20 kHz, Upper Limit of Dynamic Range (3% Distortion): 164 dB re. 20 μ Pa, Lower Limit Dynamic range: 14 dB, re. 20 μ Pa).
- Microphones preamplifier G.R.A.S Type 26AK (Frequency Range: 2Hz-20 kHz, Noise: A-weight :< 2.5 μ V).

-Dodecahedral loudspeaker DO12 (Rated power 600W, Sound Power >120dB, Frequency range: 80 Hz-6.3 kHz, directivity: nearly spherical).
-Power amplifier M-1000 (Power output level $RL=4\Omega$: 520W+520W).
-multi pattern capacitor microphone AT4050/CM5 (frequency response: 20-20.000Hz, sensitivity: 15.8 mV, polar patterns: cardioids, omni directional, figure-of-eight).
-Head acoustic HMS III.0 (transmission range: 3 Hz-20 kHz, -3dB/+0.1 db; dynamic range: typ. >118 dB, max SPL 145 dB).

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.

For each one of them, were provided detailed scheme, specifying the connections between the equipment, a number of each equipment and connection, to have a rapid access and identification, allowing an easy use, for any person implied in the work. Also, the grouping of the equipment in packs, according to its use, has been very important and helpfully.

d) The effective measurements: taking into consideration all the preparing steps previously enumerated, the measurements in situ, were carried out, in several points of the halls, with pink noise and sine-sweep noise. We, always, were very carefully with the calibration of all the system, like one of more important part of the measurement, to have, for each measure, the same bases. All the measurements were carefully recorded, making the security copy, too, and interpreted, later, with specialized software.

Subjective measurements

The subjective measurements, for the evaluation of the sound perception by the part of audience (lovers of music), are carried out through the questionnaires, given to the listeners in the hall, where the concert was performed. Such questionnaire, has been formulated in an understandable way and the questions are, directly or indirectly, related to the acoustics parameters.[4]. We use this pilot halls because "Paraninfo" is the hall where we are acting the Symphony Orquestry of Polytechnic University of Valencia, so were easy to complete and change the questionnaire, function of their opinions. Our acoustic specialists were musicians (teachers and students) of Superior Conservatory of Music of Valencia.

The questionnaire was structured initially in three differentiated blocks: first dedicated to identify the population, the second to value the "infrastructure" of the room and third to value the acoustic quality of listeners, with a total of 82 questions. Finally, the reviewed formulation 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 [5].

The opinions, having a subjective component, given by the affinity of the listener with the hall or orchestra, is necessary to be very carefully at the data processing, and to use a suitable statistical method, to obtain a viable opinion.

We have verified, that the questionnaires is a valid instrument, to value the subjective perception of the listeners of concert halls, with a good correlation in the evolutions, between experts and public in general, with a slight tendency of the public, to overvalue the acoustic quality of the rooms. [5]

For other part, 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.

Halls

In the process of data acquisition is necessary to know the characteristics of the halls, to collect the data of the maps in AutoCAD and if these are not available to make them or to complete them in 3D or/and make measurements with laser, maintaining the same dimensions with those missing on the map. For more details the photos are required.



Figure 4.- Paraninfo



Figure 5.-Assembly Hall Technical School



Figure 6. - Amphitheatre 6 G

For each hall, is provided a technical sheet, with its geometric characteristics (dimensions, volume, etc), number of measurements, audience and other specific data. It contains, also, photos (Fig.4, Fig.5, and Fig.6) and maps, with the points of measurement and the planes of the hall. The map of the hall is an indispensable tool, before making the objective measurements “in situ”.

In the Table 1, are shown, a comparative picture, of general characteristics of the halls, studied in present work:

Table 1-Characteristics of measured halls

Halls	Year	Audience	V(m ³)	m ³ /seat	Hall type	Measurements point
Paraninfo UPV	Built in 1978 1999-Last restoration.	385	2700	7	Rectangular, non symmetrical with respect to the central corridor	24
Assembly Hall -UPV	2000.- Last restauration.	142	434	3	Rectangular	16
6G- Amphitheatre	Built in 2000, Without restoration	475=380 Principal hall +95 Amphitheatre	3266	6.9	Rectangular with amphitheatre	40 10Amphitheatre 30 Principal hall

Finally, in Figure 7. a summary of Measurement Protocol and the most important components of this, we present.

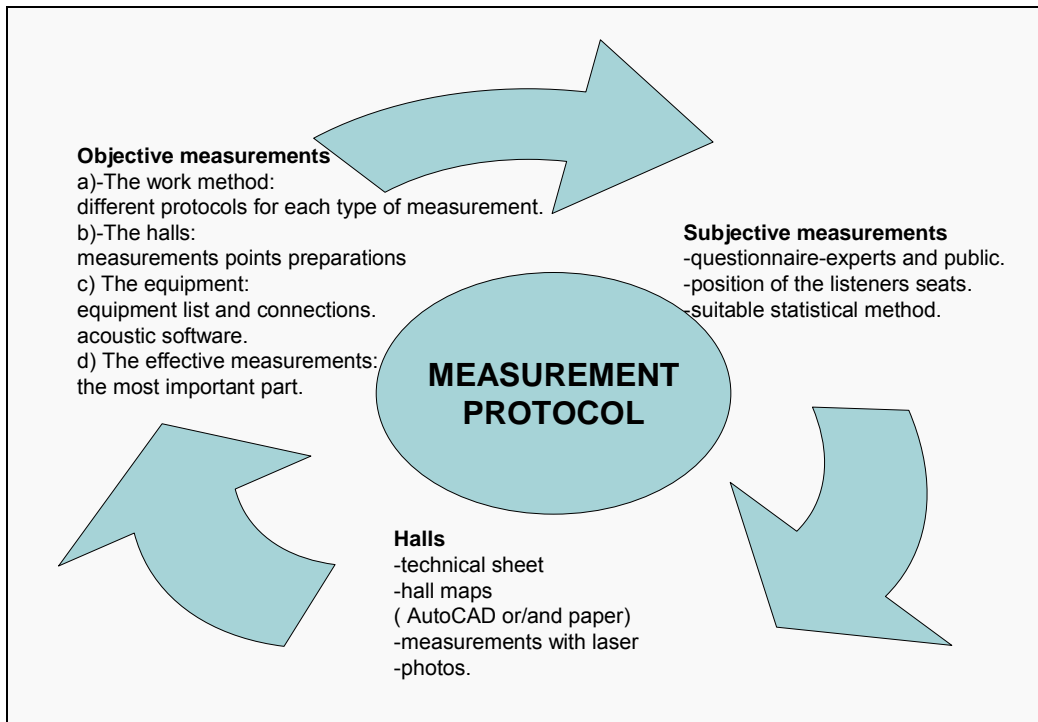


Figure 7. - Measurement Protocol summary

CONCLUSIONS

All the process/protocol of measurements and the equipment, used in this research, by the different groups from the project are validated. This validation is of vital importance, because it allows the comparison of the measurements, made in different halls distributed in Spain, and to obtain future correlations, that allow reaching the exigencies of the listeners/audience of our country. More, the subjective questionnaire was patented and like important tools, of the future studies, can be use.

References: [1]-UNE-EN-ISO 3382 (1997). Acústica: Medición del tiempo de reverberación en recintos con referencia a otros parámetros acústicos, 2000.

[2]-L.L. Beranek: "Concert halls and Opera Houses"-Springer-Verlag New York, 2004,ISBN 0-387-95524-0

[3]- A. P. Giménez, A. S., Marin, S.A. Sanchis, J.F. Romero, J.S. Cerdá, Ma. V. Jorge, "Estudio de la evolución de parámetros acústicos que miden la calidad de salas de conciertos"-TecniaAcustica, La Rioja, 2001

[4]- A. P. Giménez, J.J. Sendra, A. Vela, F. Daumal, R. Cibrian, T. Zamarreño., M. Arana, J. Romero, S. Girón, M.L. San Martín., S. Cerda, M. Galindo, E. Aramendía, R. Lacatis, P. Bustamante, R. San Martín., J. Segura, J. M. S. Muñoz., J.L. Miralles: "Proceso de elaboración de un test de respuesta subjetiva de oyentes en general y expertos musicales, como herramienta de valoración de la percepción musical en salas de conciertos, auditorios y teatros". TecniaAcústica 2006, Gandía, ISBN 84-87985

[5]-A. Giménez; J.J. Sendra, A. Vela, F.Daumal, R. Cibrián; T. Zamarreño, M. Arana, J. Romero; S. Girón, M.L. San Martín, .S. Cerda; M Galindo, E. Aramendía, R. Lacatis; P. Bustamante; R. San Martín J. Segura J, M. S. Muñoz .J.L.Miralles: "Respuestas de oyentes y expertos musicales a una encuesta para valorar la percepción musical en salas de conciertos, auditorios y teatros", TecniaAcústica 2006, Gandía, ISBN 84-87985

[6]-A. Giménez ; S. Cerda ; J. Romero ; J. Navasquillo ; R. Cibrian; R. Lacatis ; J.L.Miralles ; J.V.Garrigues .; P.E.Giménez ; A. Sanchis ; A. Marín ; C. Dema Grup d'Acustica Arquitectònica, Ambiental i Industrial. Universidad: "Importancia de la correcta orientación de un micrófono multipatrón para la determinación de la fracción de energía lateral",TecniaAcústica Terrassa, 2005

ACKNOWLEDGEMENT

This study was subsidized by the FEDER and the Ministry of Education and Science in the Plan Nacional I+D, within the coordinated research project, reference BIA2003-09306-C04.

First author would like express his grateful to The Spanish Agency for International Cooperation and The Ministry for Foreign Affairs of Spain, for the MAEC-AECI fellowship, obtained during the project. We thanks to the Polytechnic University of Valencia, to it Symphony Orquestry and to the Superior Conservatory of Music of Valencia.

