Acoustic Study of the Live Room of Laboratory of Music Acoustics Technology, Department of Music Studies, University of Athens

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ABSTRACT

This paper examines the acoustic characteristics of the Sound Studio Laboratory of Music Acoustic Technology (LabMAT) at the Department of Music, University of Athens. Following the up-to-date recommendations of ISO3382-1 standards (2009), the recent acoustic measurements provide more accurate and detailed information about the acoustic characteristics of the space. Eight acoustic parameters (T30, EDT, C50, C80, D60, Ts, IACC, LF) have been calculated across six frequency bands, which are obtained from impulse responses taken from eight listening positions and the variation of three acoustic configurations of the existing panels on the walls. The outcomes of this paper can be used as guidance for the users of the space at its current stage, offering choices of acoustic configurations of the panels for individual recordings.

Ακουστική Μελέτη της Αίθουσα Ηχογραφήσεων στο Εργαστήρι Ακουστικής του Τμήματος Μουσικών Σπουδών, του Πανεπιστημίου Αθηνών

ΠΕΡΙΛΗΨΗ

Η ακουστική του Studio Ήχου του Εργαστηρίου Μουσικής Ακουστικής Τεχνολογίας στο Τμήμα Μουσικών σπουδών, του Πανεπιστημίου Αθηνών εξετάζεται στην παρούσα έρευνα. Ακολουθώντας τα ISO3382-1 standards (2009), αναλυτικότερες και πιο ακριβείς ακουστικές μετρήσεις μπορούν να επιτευχθούν για τη μελέτη του ηχητικού πεδίου στο χώρο. Κρουστικές αποκρίσεις λήφθηκαν σε οκτώ θέσεις στο χώρο και διαφοροποιώντας τα ακουστικά χαρακτηριστικά του χώρου με τρεις συνδυασμούς των ακουστικών διατάξεων στους τοίχους του χώρου. Τα αποτελέσματα οκτώ ακουστικών παραμέτρων (T30, EDT, C50, C80, D60, Ts, IACC, LF) υπολογίστηκαν σε έξι ζώνες συχνοτήτων, και παρουσιάζονται εδώ ως κατευθυντήριες οδηγίες για τους χρήστες του χώρου ανάλογα με τις ακουστικές ανάγκες των ηχογραφήσεων.

Introduction

A recording space should not only be characterised as “good” based solely on the fitted equipment, but also on the acoustics of its live room. The acoustic signature of live rooms is often immediately recognisable by the listener and, due to its appealing, it has been used to create the characteristic musical sound of commercial recordings [1]. In addition, in multiple-purpose recording spaces, acoustic variability is desirable in order to cover the acoustic needs for different sound sources. However, no protocol is available to the acousticians for designing the acoustics of the space.

The Sound Studio of the Laboratory of Music Acoustics Technology (LabMAT) at the Department of Music Studies of the University of Athens is located on the 3rd floor at the School of Philosophy. It consists of three main spaces being the Mixing Suite, the Control Room and the Live Room. It is equipped with the state-of-the-art technology for recordings and sound production, and it is used for teaching, professional recordings and research activities. Its capacity is suitable to host teaching sessions, big musical ensembles or even a symphonic orchestra, while the soundproof booth, which is included in this space, provides a controlled acoustic environment for accurate recordings.

1. Acoustic Description of the Space

The acoustic design of the space was carried out by ETA Acoustics Ltd in 2001. The company installed rotating-wall acoustic panels, as well as a set of sliding acoustic panels mounted on a rail system approximately in the middle area. The sliding panels can be used to divide the space into two rooms and modify the acoustics of the space according to the user’s needs. Furthermore, there are three rows of skyline diffusers along the ceiling to prevent colorations and create a diffuse field within the space.

*Table 1 Estimation of the reverberation time provided by ETA Acoustics for the largest section of the divided space for two scenarios (all panels are absorptive and all reflective panels in use, *except for one of absorptive walls by default)*

	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz
All Absorptive						
RT60 (by Sabine)	0.52	0.54	0.61	0.63	0.63	0.6
RT60 (by Eyring)	0.42	0.44	0.51	0.53	0.52	0.47
Reflective Panels*						
RT60 (by Sabine)	0.54	0.66	0.9	0.97	0.98	0.89
RT60 (by Eyring)	0.44	0.56	0.8	0.85	0.85	0.72

Considering the permanent fixtures and the multi-purpose use of the space, this paper focuses on the acoustic behaviour of the largest section of the divided space of the live room for three different configurations of the acoustic panels. ETA

Acoustics Ltd provided the estimated reverberation time for this particular part of the live room, by using Eyring and Sabine equations (table 1.1).

The present study aims to provide a more detailed acoustic analysis of the space, based on the state-of-the-art measurement techniques.

2. Acoustic Measurement Technique

The Exponential Sine-Sweep (ESS) method was used for capturing the impulse responses. This method offers significant advantages compared with previous techniques used for acoustic measurements [2]. Furthermore, ESS is the method recommended by the latest ISO3382 standards [3].

As sound source, an OmniPower Omnidirectional Sound Source Type 4292-L (dodecahedral) Brüel & Kjær speaker was used, while three microphones were used as the receivers. In detail, a Behringer ECM-8000 omnidirectional microphone (for the study of the monoaural parameters), a Neumann KU-100 dummy head for binaural measurements (for the study of IACC) and an Audio Technica AT4050 with a figure-of-eight polar pattern (for the study of LF in combination with the ECM-8000), all complying with the ISO3382-1 standards (2009). All measurements were performed with a sample rate of 96kHz and 24-bit bit depth.

The logarithmic sine-sweep excitation signal was generated from Aurora Plug-in in Audacity, with frequency range of 22Hz to 22kHz, and duration of 15 seconds. Logic Pro X was used for the recordings on a Mac Book Pro (2.3 GHz Intel Core i7) and an MBox2 USB was used as the audio interface. Aurora Plug-in was the post-processing tool for obtaining the acoustic parameters as it provides sufficient accuracy [4] for the purpose of this study.

3. Three acoustic configurations

An overview of the acoustic behaviour of the space and its potential variations with the use of the rotating panels was studied by carrying out measurements for three different acoustic configurations at the front part of the divided space. Due to the existing equipment and instruments, only the left side acoustic panels and the set of panels on the sliding rail could be altered, while the panels on the right are mainly reflective and the panels on the control room (window) side are absorptive by default.

For Configuration A, the acoustic panels of the three out of four boundaries were set to be absorptive. For Configuration B, the acoustic panels were set at their reflective side (three out of four boundaries) and for Configuration C, there was an alternation of reflective and absorptive panels following in succession on both boundaries (50% reflection-50% absorption).

As the space is not symmetric, a square grid of measurement positions was considered necessary. The speaker was placed in the middle of the square, while the microphones were placed at eight positions on a virtual square around the speaker, at a distance of 2 meters from each other (as shown in figure 2). The height of both microphones and speaker was 1.5m.

As reverberation time does not offer sufficient information about the "density" of the reflections across time, the present study aims to provide more detailed information about the acoustic behaviour of the space by calculating eight acoustic parameters, which can be used to guide the users of this space. The acoustic parameters were observed across the frequency bands of 125Hz-4000Hz (as presented in figure 3).

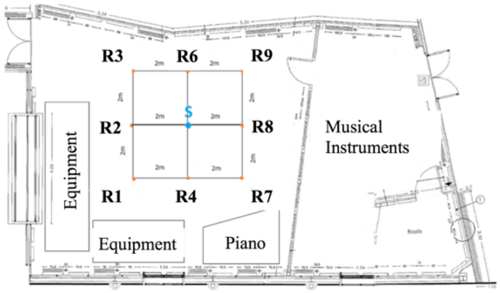

Figure 2 a) Floor plan of the live room. The receivers and source positions for this study are marked at the front (largest) part of the divided space by the sliding rail, b) The dummy head and the omnidirectional source during the measurements at position R6.

Reverberation time (T30) is related to the subjective impression of *Liveness* [5], while *Early Decay Time (EDT)* is the parameter, which is correlated more strongly with the perception of the reverberation in a space [3, 6]. From the results of these two parameters, it was shown that the space is very "dry", as expected for a recording studio. The slope of T30 and EDT for Configuration A drops gradually from low to high frequencies. This gives a unique acoustic character to this live room and offers a distinctive *timbre* to the acoustic result of the performances. According to Beranek [5], this negative slope of RT between low and middle frequencies is directly related to the perception of *warmth*. On the other hand, Configuration B and Configuration C offer a more *neutral* space, with EDT values not differentiating significantly across the frequency bands. Configuration B, however, is the most *reverberant* and *brighter* space as shown from the T30 values. Significant are the differences between the values of T30 observed by the ESS measurement technique and the estimated values by Sabine and Eyring equations. Comparing the reverberation time at the most reflective configuration (Configuration B) at 1kHz (table 2) as an example, the importance of carrying out measurements at the actual space after being constructed and by using well-established methods should be highlighted.

Table 2 Comparing the reverberation time values at 1kHz observed by the estimations from the Sabine and Eyring Equations, and by calculating the parameters from the impulse responses measured from the actual space.

Sabine	**Eyring**	**Measurements**
0.97s	0.85s	0.54s

Center Time (Ts) corresponds to the centre of the gravity of the squared impulse response. The small values of Ts observed from these measurements mean that there is more concentrated energy in the early part of the impulse response. The low values of Ts are directly correlated with the high values observed for Clarity and Definition parameters. *Clarity (C50 or C80)* and *Definition (D50)* are parameters that also give information about the ratio of the initial energy to the rest of the impulse response (C50 and C80); and the ratio of the initial energy to the total energy of the impulse response (D50). Both parameters help to describe the perceived intelligibility of words, music, and speech. Due to lack of information about the perception differentiations and JND values for these energy parameters for cases with reverberation time below 0.6s, it is not possible to compare clarity perceptual effects between the three configurations. However, the high values of clarity and definition in the diagrams (figure 3) indicate a space with very good clarity and intelligibility for all three configurations, suitable in general for speech, and operas [7, 8]. Intelligibility and clarity are also an ideal condition for a space being used for professional recordings. It is worth mentioning that Configuration B (the most reflective case) shows a considerably flat curve for clarity and definition values across the frequency bands. This could be a significant factor when a musical ensemble with a wide frequency range performs in the space.

The subjective listener aspect of Listener envelopment (LEV) and Apparent source width (ASW), and their combination, known as *Spatial Impression* [9], can be observed from the study of *Inter-Aural Cross Correlation (IACC)* and *Early Lateral Energy Fraction (LF).* These parameters describe the energy perceived by the two ears and the energy from lateral directions, respectively (ISO 3382 2009). For the calculations of IACC, the early sound has been used (0-80ms). The values for both $IACC_{(E)}$ and LF are quite low (which is unusual with high values of clarity). This ensures a good spatial impression and it is also a good indicator of musical acoustic quality [5, 8, 10]. Interestingly, the same “quality” is observed for all three configurations (however, it should be noted that the average values present wide standard deviation at low frequencies for IACC and high frequencies for LF, see figure 3).

An average value across the frequency bands is not recommended because acoustic parameters are frequency dependent. Similarly, average values across measurement positions do not offer a detailed representation of the acoustic behaviour of the space. Except for reverberation time, which is a global parameter, the rest of the acoustic parameters are position dependent. This can be observed from the charts in figure 3. For the purpose of this study, and with the aim of providing a general overview of the acoustics of the space at the various configurations, an average value across the positions was presented. However, the standard deviations of these results highlight the range of these variations across positions. It was also observed that only T30 and Ts values follow similar trend across frequencies for all the measured positions, while the curves of EDT and energy parameters vary across frequency bands. As example of these variations, figure 4 presents the results for C80 and T30 at Configuration A across the eight measured positions.

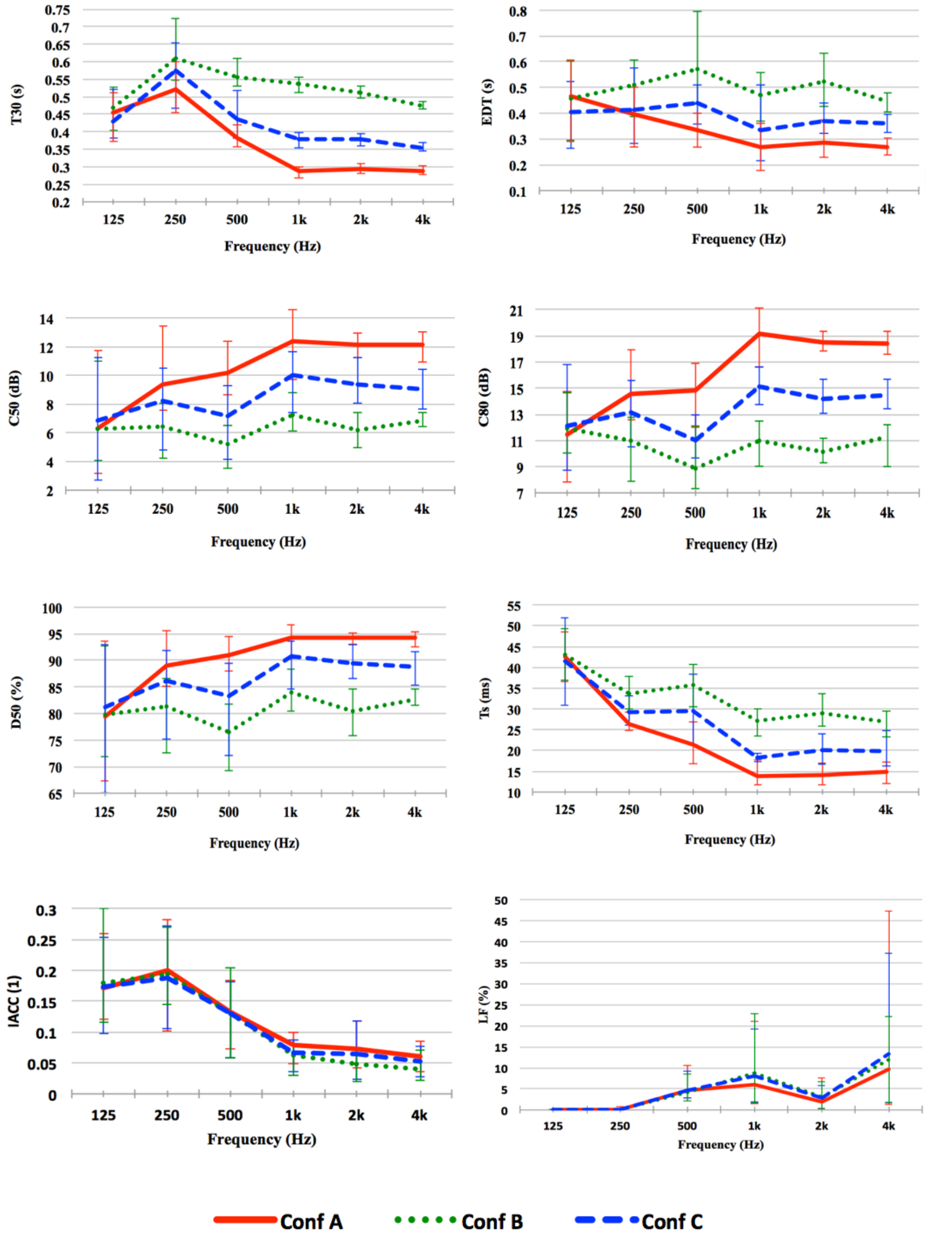

Figure 3 Mean values and standard deviation of T30, EDT, C50, C80, D50, Ts, IACC and LF observed across the six frequency bands and across the eight measured positions for Configurations A, B and C.

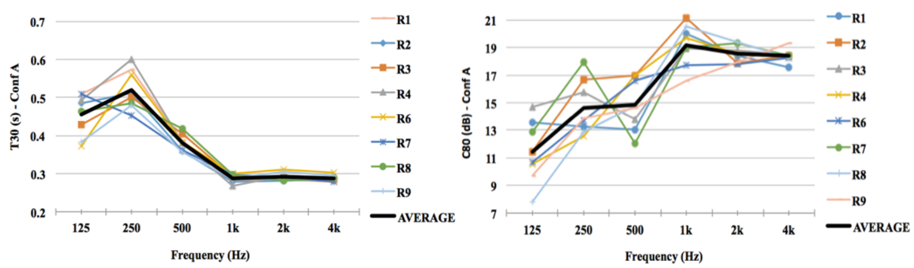

Figure 4 The results of the acoustic parameters T30, EDT, C50, C80, D50, Ts, IACC and LF are presented across the frequency bands for Configuration A.

4. Conclusions

The acoustic behaviour of the largest section of the divided spaces of the live room of the Sound Studio of the Department of Music Studies at the University of Athens was studied in this paper. Three acoustic configurations were examined by varying the acoustic panels of two of the boundaries. The acoustic parameters were obtained from the impulse responses captured in the space by using the Exponential Sine-Sweep method and the results have been analysed in order to provide guidance to the users on how to use the acoustic configurations at the current state of the Sound Studio. The overview of this analysis is presented in table 3.

Table 3 Guidance notes for the use of the acoustical panels based on the acoustic qualities offered by the three studied configurations.

	Panels	**Subjective Effect**
Conf A	Three walls absorptive and one wall reflective (right wall)	• The least *reverberant* space • *"Warmth"* and a characteristic *"timbre"* due to the uneven reverberation time across frequencies • High degree of clarity and intelligibility
Conf B	Three walls reflective and one wall absorptive (control room wall)	• The most reverberant space from all three configurations • The most *"neutral"* space as reverberation and clarity have flat response across frequency bands • Ideal for musical ensembles with a wide overall frequency range and for research activities requiring flat frequency response
Conf C	50% of the panels reflective and 50% absorptive	• A medium reverberant space • Clarity and intelligibility are even across frequency bands, but it is offering a characteristic *"timbre"* as well due to the slope of the reverberation time from low to high frequencies.

The impulse responses captured during the measurements and described above have been made available online on the Open Acoustic Impulse Response Library [11]. By accessing this library, the Sound Studio users can listen to the auralization results of the various positions and configurations, and choose the optimum combination for their recordings.

5. Acknowledgements

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