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Acoustical measurements in occupied rooms in Paris

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PACS: 43.55.Gx Studies of existing auditoria and enclosures.

ABSTRACT

Acoustics measurements in occupied rooms are relatively rare due to many kinds of difficulties. Therefore, no protocol for acoustics measurements is available in occupied rooms. During the year 2009, the room acoustics group at LAM (Équipe Lutheries-Acoustique-Musique, Institut Jean Le Rond d'Alembert, Université Pierre et Marie Curie, Paris) performed a series of acoustical measurements in music halls in Paris. The halls were chosen in consideration of their historic, architectural or acoustic importance. The fifteen rooms selected include quite different architectural designs. The measurements were made both in empty and in occupied rooms. A particular protocol was developed for the measurements in the occupied halls, which were carried out just before real concerts. This protocol is described in this paper. Critical decisions both at technical and administrative level are discussed. Technical decisions include among others the kind and the level of the source signal, as well as the number and the selection of the recording positions. Administrative decisions comprise the negotiation with the directions of the halls and the management of the public's behaviour. The main difficulties and the proposed solutions will be presented.

INTRODUCTION

To our very days, Room Acoustics literature is lacking documentation on the acoustic behaviour of occupied rooms. Despite the consensus that this behaviour changes compared to empty rooms, the nature of this change is not well-known.

Still lacking is a widely accepted and used protocol enabling the accumulation of a sufficient quantity of data and leading to objective conclusions on the acoustics of occupied rooms. For example, such acknowledged references on room acoustics as [1,2] do not propose any protocol, nor does ISO 3382 [3]. The reasons for this absence are not difficult to find, and observing their nature can help understanding why measurements in occupied rooms are so rare.

Rather than on the technical plan, difficulties mostly emerge on the administrative and logistic plans. Taking due account to these difficulties, we have implemented a protocol that allowed us to carry out a series of acoustic measurements in as much as 15 occupied theatres and halls in Paris, including the most important ones.

Our goal is not to suggest a universal protocol for measuring occupied room, but to share our experience with others in order to contribute to the elaboration of future campaigns.

PROTOCOLE

Preparing for the campaign

During the year 2009, the room acoustics group at LAM (Équipe Lutheries-Acoustique-Musique, Institut Jean Le Rond d'Alembert, Université Pierre et Marie Curie, Paris) performed a series of acoustical measurements in music halls and theatres in Paris. The halls and theatres were selected for their historical, architectural, or acoustic interest.

Having decided to include measurements in occupied rooms, several questions had to be answered: How to obtain the authorisation from hall managements? How to convince hall managements in cases of resistance? How to manage the noise from the public? How to ensure a satisfactory signal-to-noise ratio? Which excitation signal to use? How long should be the intervention? How many measurement positions would be possible?

At the beginning we were expecting many difficulties. Due to a lack of references adapted to our case, we were forced to test solutions as we advanced.

Technical decisions

We developed a specific protocol for the measurements in order to more easily obtain authorizations and consequently to increase the number of measured halls.

However, we wanted to respect room acoustical standards. Thus, we used same equipment for measurements in empty and occupied room: a dodecahedral source, a sub-woofer box, a sound card, a microphone, and a laptop computer.

We decided to make measurements right before concerts of the normal programming of each hall. The excitation signal was an exponential sine-sweep. Tests were carried out to choose levels comfortable for the public while ensuring sufficient signal/noise ratios for the calculation of acoustical indices. The selected levels were calibrated in an anechoic room

at L (p, 10) =59 dB and L (p, 10) =67 dB (depending on the volume of the rooms). Calibration was necessary because inverse filters for pre-equalisation were computed for each source level. The impulse responses obtained in occupied room were not used for auralisation, since the signal levels required for auralisation largely exceeds comfortable values for the public.

On the other hand, it was necessary to increase the signal duration to 30 seconds in order to improve the signal-to-noise ratio. The cost is a longer duration for the measurement session.

After discussion with a few hall managers, we concluded that the duration of the measurement sessions in occupied room right before a concert should not exceed 3 to 4 minutes. The number of positions of recording had therefore to be reduced to the minimum. Taking into account this optimal duration of a session and the duration of the signal, we decided to reduce the protocol to 2 positions of microphone, with two recordings at each of them, and one position of source on stage.

The requirement was therefore a team of 3 to 4 persons to remove the equipment after measurements in order to respect the 4 minutes' duration of the session. One person sits at the computer, one handles the microphone and the last one the source.

Asking for authorizations

The method chosen for obtaining authorizations was the sending of official letters to the technical directors, followed up by phone calls.

Much care was taken when writing the letters. Among the arguments, we highlighted the originality of the campaign, the importance of better knowing the acoustical behaviour of occupied rooms, the benefit for hall managements (since a detailed report was promised), the description of the technical protocol and the promise that the measurement session would not annoy the audience nor would delay the concert. Our association with the leading French research institution (CNRS) obviously helped as well.

Despite all these precisions, the letters were only the starting point for negotiations. A few days after their sending, we called the hall managements for a more direct contact and for finding a date for the measurements. We frequently met understandable hesitation from the managers, making it necessary to find persuasive and dedicated argumentation for each case.

We sent letters to 28 halls in the hope to receive positive responses from some 6 of them. To our surprise, the authorisations arrived one after the other until we reached 15 halls, and had to stop the demand because of agenda constraints. At that time, only two halls had answered negatively.

The halls involved in our campaign are: Salle Pleyel, Bastille Opera, Abbesses Theatre, Athenée Theatre, Chapelle Royal in Versailles, Châtelet Theatre, Salle Cortot, Japanese Culture Centre, Louvre Auditorium, Theatre of Porte Saint Martin, Auditorium of Orsay Museum, Maison de Radio France, Ranelagh Theatre, Theatre de la Ville, and the major hall of Cité de la Musique.

Managing public attendance

The very first measurement in occupied room was a failure. It took place at the Theatre of Porte Saint Martin in June 2009. The failure was due to the only variable which we could not control before experimenting the protocol in a real concert situation: the behaviour of the public.

We had agreed with the hall managements that *they* would inform the artists of our intervention and ask for their permission, whereas *we* would inform the public on site, right before the intervention.

Therefore, on the day of the first measurement, just before the start of the concert, a member of our team got on stage on scene and addressed the public with the following words:

> "Good evening, Ladies and Gentlemen! We come from the Musical Acoustic Laboratory and are making a series of acoustic measurements in the concert halls of Paris. During the next minutes, we will record some sound signals in this hall, then we will remove the equipment and the performance will start normally. It would be important that you remain silent during our intervention, please. Thank you very much. "

The sound signals recorded at the Theatre of Porte Saint Martin were never used, because the noise from the public was very loud.

Reflecting on the reasons of such behaviour from the public, we concluded to the low level of efficiency of our communication. Therefore, we decided to change our approach and be more rigorous and precise in our communication by emphasizing the importance of silence and explaining what we expected from the public. Moreover, we decided to have on stage one person who would raise his/her arm while the signal was played. Here is the final formulation of the address to the public:

> "Good evening, Ladies and Gentlemen! We come from the Musical Acoustic Laboratory, a research unit from CNRS. We are making a series of acoustic measurements in the concert halls of Paris, and today we have a particularly important task: measuring in an occupied hall. I explain in a few words: we will play a 30 seconds' sound signal. The signal will be played 4 times: 2 times for each microphone position. Then we will remove the equipment and the performance will start normally. Our full intervention will take 3 to 4 minutes at most. Your participation as a public is very important, and when the signal is played we really need your silence, otherwise the measurements will be useless. To help you, my colleague will raise his arm when the signal is played, because the beginning and the end of the signal are not audible. While his arm is raised, *please do not speak nor move*. Last but not least, we have been working on these measurements for a long time and this is the most important moment of the whole research. Therefore, I count on your collaboration. Thank you very much."

This new address, and especially the strategy to have one person on stage, ensured the success of the measurements in the following 14 occupied halls. The silence thus obtained was the more remarkable event of the whole series of measurements. The signal ratio/noise was sufficient enough for obtaining clean impulse responses and calculating the acoustic indices.

We can visualize some results in the following 3 spectrograms:

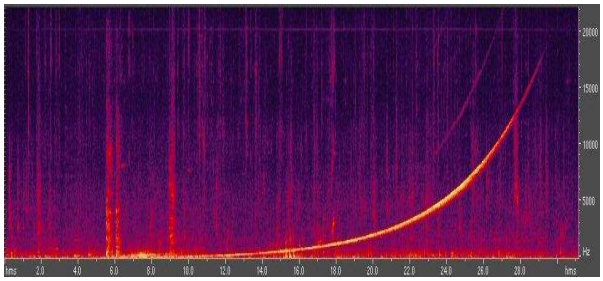

Figure 1. Spectrogram of recording in Theatre of Porte Saint Martin (public present: 414 people; capacity: 1000 seats).

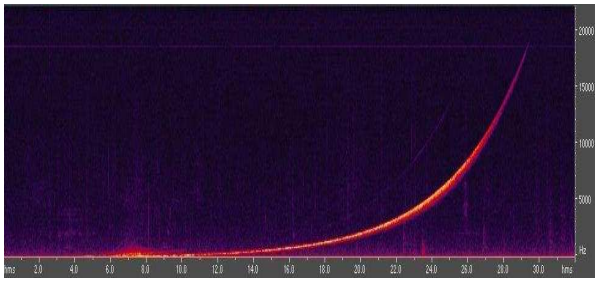

Figure 2. Spectrogram of recording in Theatre de la Ville (public present: 950 people; capacity: 1012 seats).

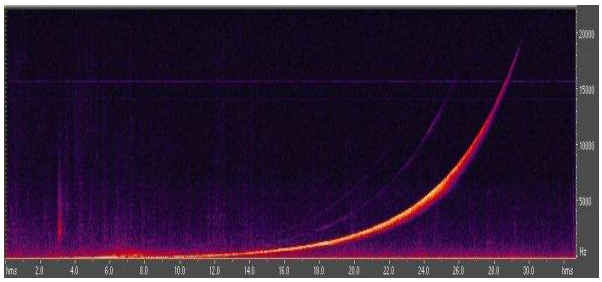

Figure 3. Spectrogram of the recording in the Châtelet Theatre (public present: 1500 people; capacity: 2300 seats).

The background noise produced by the public at Châtelet Theatre was 11dB lower than in Theatre of Porte Saint Martin. The difference reached 15 dB between Theatre of Porte Saint Martin and Theatre de la Ville. Notice that, compared to Theatre of Porte Saint Martin, the public at Theatre de la Ville (same seating capacity) was more than twice as large, and 3 times larger at Châtelet Theatre.

The presence of musicians on stage was ruled out from start because we feared that it would most probably decrease our chances to obtain authorizations for the measurements. Bastille Opera was the only room where the musicians were present during measurements. They remained in the orchestra pit, ready for the performance which took place right after our intervention. In this only case, the stage curtains were down, to prevent viewing the decors for the opera.

Figure 4. Picture taken during measurements at Theatre de la Ville.

Figure 5. Picture taken during measurements at Bastille Opera.

Figure 6. Picture taken during measurements Châtelet Theatre.

Figure 7. Picture taken during measurements at Cité de la Musique

CONCLUSIONS

The protocol presented in this paper made it possible to carry out a series of acoustical measurements in real concert situations in a few music halls and theatres in Paris. The technical decisions, the administrative approaches and the strategy for managing the public were the determining factors for the success of the campaign.

An unexpected result from the measurement campaign has been the recognition of our research group by all the managers of the concert halls and theatres visited. It is now easy for us to carry out specific measurements or even to take our students to visit the halls.

Quantitative results and their interpretations will be published in forthcoming papers.

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2 L. Beranek, *Concert and Opera Halls – How they sound* (Acoustical Society of America, New York, 1996)
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