NEW POSSIBILITIES IN ROOM ACOUSTICS MEASUREMENTS: REAL-TIME ANALYSER, DAT, COMPUTER: A COMPARATIVE APPROACH.

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Introduction

Electronics, with its unceasing progress, puts now in the hands of the acoustician a wide variety of powerful tools for an in-depth analysis of the acoustic quality of concert halls, theatres, conference halls, etc.
Each of these instruments seems to be suitable to record the main acoustic characteristics of a room; most of them offer also extensive capabilities of field processing, giving directly the values of the acoustical parameters. But actually, they do not have equivalent characteristics; so the proper instrument must be selected case by case, paying attention not only to its claimed capacity, but also to its unavoidable limitations and to characteristics such as transportability and simplicity of use.
In this paper, examples of the acoustic evaluation of existing halls are used to compare different measurement techniques, requiring not only different tools (analyser, DAT, PC-board) but also different kinds of acoustic excitation (stationary, impulsive, pseudo-random).
Remarks are made about the fact that sometimes the value, and the meaning, of an acoustic parameter depends on the technique used, and that there exist limiting cases for which the use of the "wrong" technique can lead to misleading results.

Measuring Techniques

In this work different types of measurement techniques have been considered: those based on the use of real-time analysers, impulsive techniques based on recording of impulse responses to pistol shots and subsequent analysis, and those based on the deconvolution of a pseudo-random signal. The main acoustic parameters are evaluated from the data obtained with the different techniques and the results are compared.

- Use of real-time analysers

The use of real-time spectrum analysers (FFT or third-octaves) enable users to measure directly a number of very important acoustic parameters, such as sound level, the sound spectrum produced by a source of pink or white noise (which give rooms their "colouring"), and reverberation times in the different frequency bands, all of them evaluated in different points of the room. It is usually not possible to calculate the values of clarity (relation between useful energy and late energy, or the centre time) if not through a link computer-analyser, driven by programs which have to be written for this purpose. As sound source, either a loudspeaker, fed by a signal coming from the analyser itself, or a pistol shot (which however enable the user to evaluate only the reverberation time) can be used.

- Recording of impulsive response and its successive analysis.

This technique is based on recording of the responses to pistol shots with a small portable digital recorder (DAT). Using both recording channels, it is possible to use a binaural headphone, and it is therefore possible, through the successive analysis of the recordings with a two-channel FFT analyser, to calculate also the value of the Inter-Aural Cross Correlation (IACC). From the responses to the impulses it is later possible to calculate almost all of the most important acoustic parameters : reverberation time, through Schroeder's backward integration [1], clarity relations (R, tb), etc. Since the sound source is not stable, and it

has a non-normalised spectrum, it is not possible to obtain information about the sound spectrum produced by the room, nor about the absolute value of the sound level, and the calculation of RASTI or STI (which can anyway be done) does not meet the requirements established by the standardisation, and therefore has only a comparative value.
In order for the elaborations of the impulse response to be carried out, it is necessary to transfer it from the DAT cassette to a computer memory; this can be done using an FFT analyser, or a data acquisition card inserted into the PC.

- Pseudo-impulsive technique with MLSSA
The recordings are carried out by using an IBM PC with an A2D160 data acquisition board. The PC is connected to a loudspeaker while the sound field is measured using a dummy head with MKE 2002 SET Senheiser microphones.
The A2D160 board generates a deterministic pseudo-random signal, which is linked to the signal received through the microphone. Using the Hadamard' fast transformation [2], it is possible to obtain the correlation function, which gives the seeked impulse response, directly in the time domain. This function is much longer than that obtainable, with a similar process, from a normal FFT analyser (32768 points against 1024), and therefore allows the analysis of the total decay of the sound field for a wide frequency field (up to 5 or even 10 kHz, for rooms of limited reverberation). The software included in the board, called MLSSA, allows the direct calculation of all the above-mentioned acoustic parameters, and of many others, as well as the evaluation of the Modulation Transfer Functions matrix, from which RASTI and STI can be obtained.

Experimental Results
In a previous work [3], it was shown that the value of the acoustic parameters obtained with the impulsive technique after recording the impulse responses with a DAT is very similar to the value obtained with the same impulsive technique without the DAT recording but analyzing directly the signal with the real-time analyser, and to the value obtained by analysing the same impulse response with the MLSSA software. For this reason, no further distinction is made between these three ways of carrying out the impulsive technique.
Figure 1 shows the values of the reverberation time obtained with three different techniques in two differently reverberating rooms. Room 1 is a general purpose theatre and Room 2 is a large sports arena. As it can be seen, in a highly reverberant room the pseudo-impulsive technique (MLS) shows its limitation. The length of the pseudo-random sequence employed for these measurements was 32k points, sampled at 30 kHz; this is too short for such a room. When the deconvolved impulse response lenght is shorter than the room's decay, the missing part of the response causes a "time aliasing" problem, being reinserted at the beginning of the data segment. This is a limitation of the MLS technique in the case of very long reverberation times. Now the problem can be avoided by employing 64k points responses, and reducing the sampling rate to 15 kHz (limiting in this way the analysed spectrum to 5 kHz).
In Room 1, which has a low reverberation time, the MLS technique gives results consistent with the other two. It must be noted that in both cases the Impulse recordings made with a pistol shot and a DAT recorder give reasonably good results.
From these data, no assumption can be made about deviations between reverberation times obtained from the decay of a stationary source and those obtained from Schroeder Backward Integration of Impulse Responses: in fact, in some cases one method gives larger values than the other, but in other cases the opposite is true.
Figures 2 and 3 show the comparison between the values of many well known acoustical parameters, measured with the two Impulse technique: DAT recordings of pistol shots and MLS deconvolution. This was possible by transferring the DAT responses to the same PC with A/D board used to acquire the MLS responses, and by

using the same MLSSA software to performs the parameter calculations. To do this, the A/D board was used in its "Scope" emulation mode, triggering the shot by an external circuit. The software was then "fooled", changing the data type descriptor, so it was compelled to treat both responses as MLS deconvoluted ones.
In the first point analysed the two techniques give nearly the same results: the difference between the values is small in comparison with their typical uncertainity. In the second point, however, large differences appear between the different parameters. In this case the impulse response obtained from the pistol shot had a large quantity of background noise. The parameters depending on the total energy were very different but the parameters depending principally on early energy, like RASTI or EDT, were not influenced.

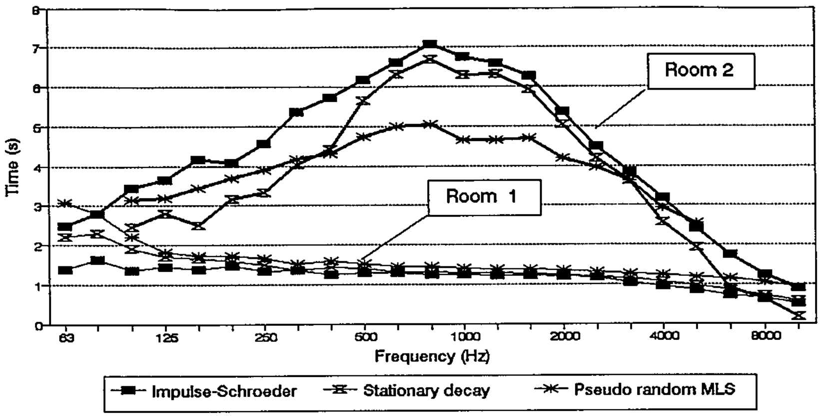

Fig.1: Values of the reverberation time obtained with three different techniques in two differently reverberating rooms; room 1: general purpose theatre; room 2: large sports arena.

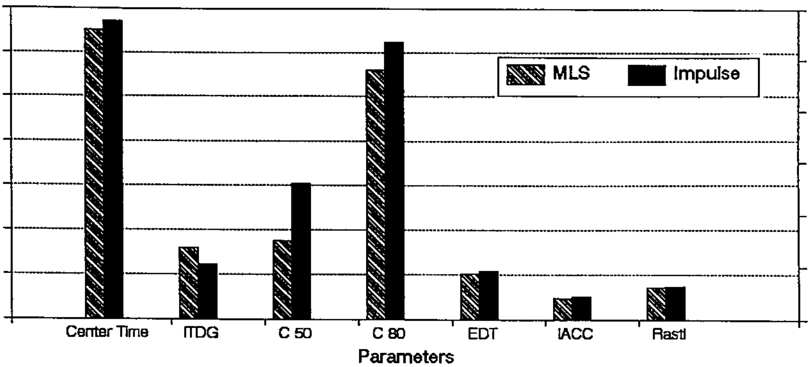

Fig.2: Room 1 - Point 1 : comparison between the values of acoustical parameters obtained with DAT recording of pistol shot and MLS deconvolution techniques

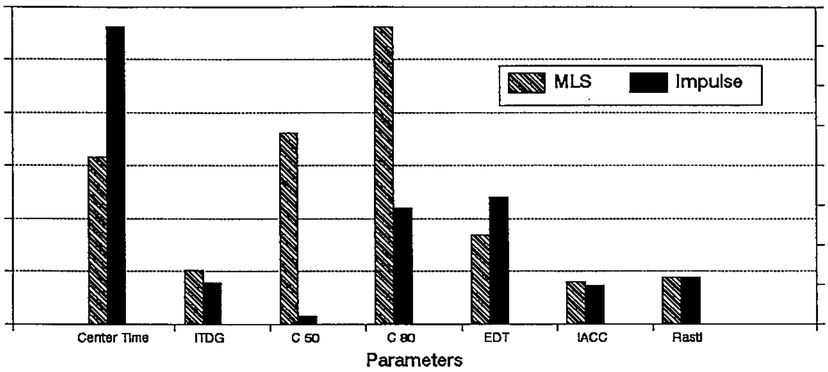

Fig.3: Room 1 - Point 2 : comparison between the values of acoustical parameters obtained with DAT recording of pistol shot and MLS deconvolution techniques

Discussion

The recording of the impulse response to a pistol shot with a digital recorder has some important advantages:
- it is possible to use different techniques for evaluating the acoustic parameters from the recorded data;
- small, lightweight hardware is needed on the field;
- the acquisition is fast and easy.

There are also some disadvantages in the use of impulse response to a pistol shot:
- it is not possible to have information about the spectrum modification produced by the room;
- it is not possible to obtain the absolute value of the sound level in the different places of the room;
- the post-elaboration is longer with respect to the real-time analyser;
- the signal-to-noise ratio can limit the reliability of the measured parameters, and a check is always necessary.

The MLS pseudo-random technique has some advantages over the traditional real-time analyser, sharing with it the same need of a large loudspeaker with power amplifier, cables, etc. . Although the traditional spectra and decay curves are obtained not in real time, but after some minutes of elaboration, the capacity to measure almost all the acoustical parameters, including full STI and Modulation Transfer Functions is certainly attractive.
The use of a dummy head with binaural microphones enable the calculation of the IACC, a very important parameter in room acoustics, particularly for the quality assessment of concert halls [4].

References

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