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IMPULSE RESPONSE CHARACTERISTICS OF SIMPLE ROOM GEOMETRIES

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Introduction

Most studies of sound propagation through buildings have been carried out by measuring point to point attenuation using continuous sound. Such methods assume that all the energy from a source will contribute positively to its loudness/detectability. However, where speech is concerned, and perhaps with other impulse sources also, it is only the energy which arrives within a relatively short interval after the direct sound that makes a positive contribution to intelligibility; the remainder has an effect which is either negative or zero.

To date, the analysis of the impulse response of rooms to yield the various energy fractions has generally been applied only to auditoria. However, it appears likely that the detailed information that this approach provides would also be useful in noise control applications and work on this subject has been in progress at the Welsh School of Architecture for a number of years. The main paper will give a summary of the present state of progress. The aim of this abstract is to provide an introduction to the general approach being adopted and the nature of the results which are being obtained.

Experimental Techniques

The experimental work falls into two distinct parts: a period of on-site recording and the processing of the recordings in the laboratory.

The basic on-site work consists of generating a pulse at one point in a room and recording the resulting echogram at one or more receiving positions on an FM tape recorder. A monitor microphone is used at a fixed distance to allow the results for individual pulses to be normalized to a standard value. The microphone system consists of a B & K Type 4135 $\frac{1}{4}$" cartridge and associated preamplifier feeding into a Type 2606 Measuring Amplifier. The tape recorder is a B & K Type 7003.

The first stage of the analysis consists of digitizing each echogram and recording it in the memory of a PDP11 computer. Processing the data digitally gives a much higher degree of flexibility than would be possible with analogue techniques. Initially, the transfer from tape to computer took place through a B & K Digital Event Recorder and paper tape but more recently direct interfacing has been incorporated which has considerably reduced the processing time.

The second stage of the analysis consists of deriving the energy characteristics of the echogram. This is done by simply squaring and integrating the pressure history.

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There is some disagreement in published work on how the useful energy content should be calculated from an impulse response. Differences of opinion arise over how long an interval should be taken - suggestions vary from 50msec to 95msec after the arrival of the direct signal - and whether or not the later energy in the interval should be weighted or unweighted. In the present study, we have concentrated on analysing arrival patterns during the first 100msec and calculated the received energy both unweighted and when weighted in a similar way to that proposed in Reference 1 i.e. the weighting function has value 1 for $0 \leq t \leq 35$msec, $(t-35)/60$ for $35 \leq t \leq 95$msec, and 0 for $t \leq 95$msec.

Example of results

Figures 1 and 2 show the basic form in which the energy history of an echogram is produced. The measurements were taken using a blank cartridge placed at a height of 1.2m as a source with the receiving microphone at the same height and positioned at distances of 2m, 5m, and 15m. The results have been normalized to a source intensity of 97.5dB at a distance of 2m and the ordinate scale is expressed in terms of energy/unit area and as an energy level/unit area. Figure 1 shows the energy received in each 5msec time interval except the first for which the periods 0-1msec and 1-4msec are shown separately. This allows the level of direct energy to be distinguished from that of the reflected energy in this interval. Figure 2 shows the same data but presented in cumulative form. The parameter on both graphs is the distance from the source.

When comparing one situation with another, the information shown in Figures 1 and 2 is too detailed to allow general patterns to be readily discerned and we have found it to be more useful to divide the received energy into three components:

i. direct energy, 0-1msec
ii. early reflected energy, 1-5msec
iii. early reverberant energy, 15-100msec

Examples of the results which are obtained with this approach are given in Figures 3 and 4 which show the received energy components as a function of distance. The measurements were carried out in an empty, reflective, medium sized office (25m x 7m) for conditions of (a) uninterrupted propagation and (b) with a single reflective screen, 2.4m wide and 1.2m high, placed 5m from the source.

It can be seen that the direct energy falls off (as expected) according to the inverse square law, but that both early reflected and early reverberant energies decrease at a much lower rate. As a result, the total 'useful' energy is virtually independent of the direct sound over most of the distances measured falling by only 4.8dB over a distance from 2m to 17m. The introduction of the screen increases the level of both reflected and reverberant energies by about 1dB at a distance of 2m by virtue of the fact that the source is more enclosed, and reduces the levels by 2-5dB at positions on the other side of the screen. These results show that the way in which a screen modifies the sound field in a room is more than simply one of reducing the level of the direct sound

Reference: J.P.A.Lochner and J.F. Burger. 1964. J Sound and Vibration 1, 416-454. The Influence of Reflections on Auditorium Acoustics.

FIGURE 1

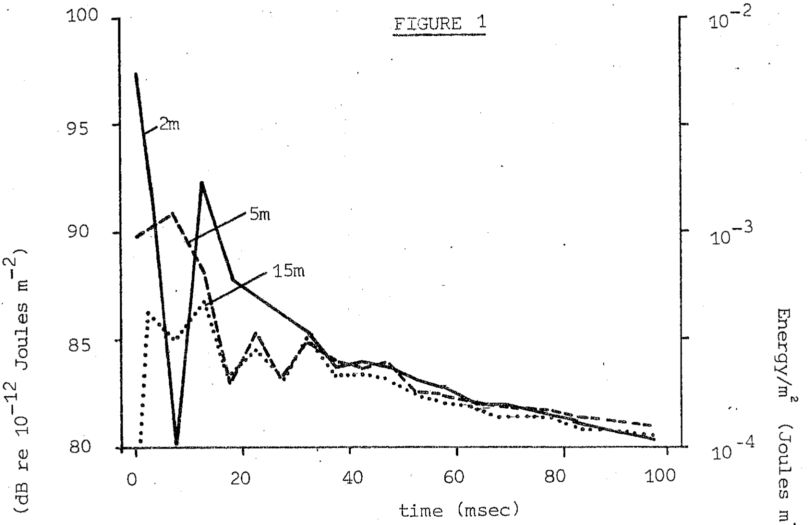

FIGURE 2

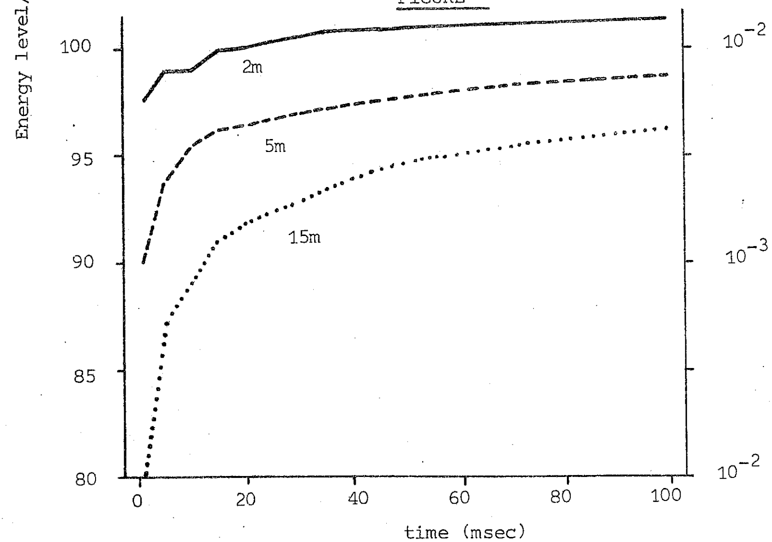

FIGURE 3

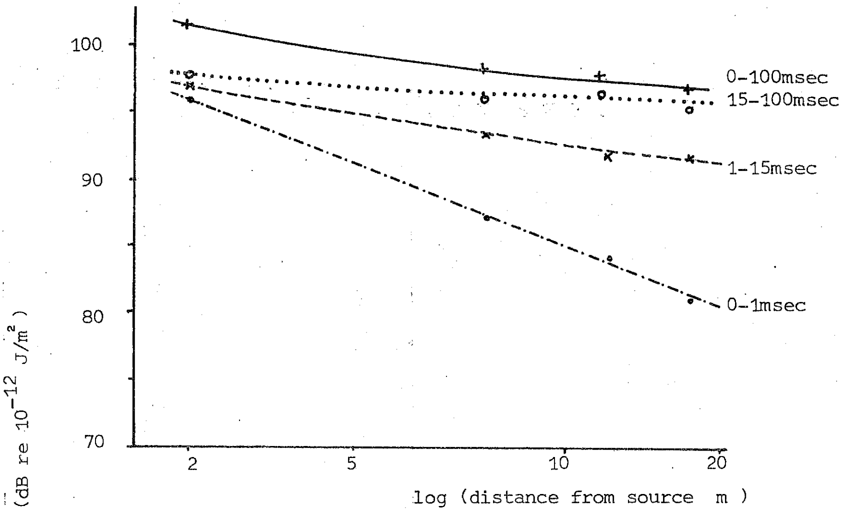

FIGURE 4