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MEASUREMENT OF GENERAL CHARACTERISTICS OF SOUND FIELDS IN ROOMS

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INTRODUCTION

The transmission of sound within a room is a comparitively neglected area of Building Acoustics. The conventional model of the sound field produced by a source in a room assumes that the energy received at a point may be divided into two components: a direct component, which varies as a function of position according to the inverse square law, and a reverberant component whose level is constant throughout the room. However, in many cases the assumptions on which this simple model are based do not apply in practice and the associated sound fields are therefore likely to depart from the direct/reverberant form also. For example, many rooms do not have all three dimensions of similar magnitude but have one which differs significantly from the other two, the absorption is concentrated on one or two surfaces rather than distributed uniformly around the room, and they contain large items of furniture which break up the volume into a number of connected spaces rather than a single space Although some work has been carried out on propagation of sound in such situations, no general understanding of the acoustic properties seems to have emerged.

A second limitation of the simple model relates to the nature of the sources found in buildings. The assumption of a constant reverberant field can only apply to the steady state conditions produced by continuous sound sources; in the case of impulsive sources, such as speech, the field is dynamic and must inevitably vary to some extent with position in the room.

The aim of the work described in this paper is to investigate the properties of sound fields associated with the more general spatial geometries found in working spaces in buildings and to evaluate the effects of major design variables, such as size and shape, on these fields.

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EXPERIMENTAL PROCEDURE

The general aim of the experimental work is to obtain, for each room studied, a series of energy maps, each of which shows how the energy produced at a point is distributed through the room as a function of space and of time. By normalizing these maps to a constant source strength, a direct comparison between the characteristics of different spaces can be made.

The importance of the temporal data is seen to be twofold: (i) the energy history data can be related to the geometrical characteristics of the room, and (ii) it allows the energy received to be weighted to reflect the integration characteristics of the human ear.

The instrumentation used is shown in Figure 1. Two sources of impulse sound are used, a spark discharge and an omnidirectional loudspeaker. The spark source operates at a voltage of 3.5KV and produces a clean pressure signature similar to a single cycle of a 6KHz tone. The loudspeaker consists of twelve KEF midrange units mounted in a dodecahedron cabinet of maximum dimension approximately 40cms, and driven by a conventional signal generator. The A/D converter employed in the processing of the recorded impulse responses is a 14 bit device which is operated by the associated software at a sampling rate of up to 50KHz. This rate is not sufficiently high to allow accurate sampling of the spark pulse since a sampling interval of 20μsec allows only some 9-10 points per signal to be obtained. The tape recorder is therefore operated at 1/10th speed for the first 100msec of the impulse response (in which strong discrete reflections are likely to be present) and a 20KHz sampling rate is used so that the effective sampling rate is 200KHz. This provides a sampling interval of 5μsec and gives some 36-40 points per spark signal.

The procedure adopted on site is as follows. For each room under study, a set of source positions and propagation axes are chosen. These reflect the particular geomtery of the room but generally include points near the centre of the room, adjacent to the centre of a wall and in a corner, and axes parallel to a wall and diagonal. For each source/axis combination, measurements of the impulse responses are carried out at a series of positions along the axis and the results recorded on one channel of the tape recorder. In addition, the impulse response at a reference distance, 2m, is recorded simultaneously on a second channel. (Because of the short duration of the spark pulse, < 200μsec, corresponding to a path length of < 7cm, the direct pulse at the reference microphone is unaffected by reflections in all but extreme cases and can therefore be used to normalize the energy measured by the 'roving' microphone to a constant source energy, generally taken to be 100 Joules/m² at 2m from the source).

The energy received from each pulse is squared, integrated and normalized. The data produced on each impulse response by the standard processing program used consists of:

- i. energy and energy level per 1msec interval up to 100msec
- ii. energy and energy level per 5msec interval up to 100msec
- iii. energy and energy level per 100msec up to 1000 msec.
- iv. energy and energy levels in a series of 'basic' time intervals including

including	0 – 0.2 msec	(direct energy)
	0.2 – 15 msec	(early reflected energy)
	15 – 50 msec	(early reverberant energy)
	50 – ∞	(late reverberant energy)

<u>Note</u> In these results, 'energy' is expressed in terms of μJoules/m², and the more useful 'energy level' as dB re. 10^{-12} Joules/m².

RESULTS

The technique is being used to build up a library of impulse response characteristics associated with different room geometries. Figure 2 gives examples of the results obtained for the 'early' energy received in rooms of different sizes with a similar set of surface finishes; early energy is taken here to be that which arrives within 50msec of the direct sound, the value considered by some authors to be the appropriate integration time for the ear to be used when estimating the intelligibility of speech in buildings.
It is evident that the energy level does not follow a direct/reverberant sound field pattern, the levels are different at 2m and fall at different rates as a function of log(distance from source).

FIGURE 1 Instrumentation for Field Measurement and Analysis

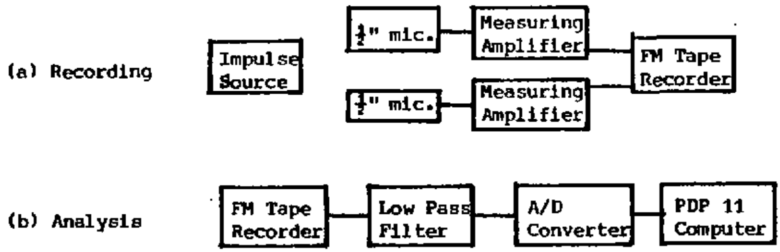

FIGURE 2 Examples of Early Energy/Distance Functions in Rooms with Average Absorption, Unobstructed Propagation