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THE SOUND FIELD IN LANDSCAPED OFFICES

B Day

While the heating, ventilating and lighting problems of "landscaped" offices present unusual requirements, because of the large plan area/height ratio, the design of these services may be carried through with the aid of conventional techniques. This is unfortunately not the case with the acoustic design, since the classical equations of room acoustics are no longer applicable. In addition there is evidence to suggest that human response to noise in this type of office may differ from that in conventional offices.

Our initial investigation of landscaped office acoustics arose as an application of acoustic scale model techniques, which we have been developing at Salford since 1966. The model measurements, which have been described elsewhere [1] yielded a number of interesting results. The most striking was the form of variation of level with distance from a single source radiating an octave band of noise centred on 4KHz. After an initial steep fall in the close vicinity of the source the rate of attenuation decreased, forming a "plateau" extending to about 15ft (1.5ft in the model). Beyond this the level fell rapidly again, descending ultimately into a residual reverberent field produced by reflection from the boundary walls.

Measurements in a real office (Building Design Partnership, Preston) were undertaken in order to verify the model study. Octave bands of noise were radiated from a loudspeaker placed at the centre of the room and the resulting level was measured at various distances from the source. With high frequency noise only a vestigial plateau was observed, the sound level falling smoothly with increasing distance but a clear plateau was observed at lower frequencies. Owing to the limited size of the office, measurements were restricted to distances up to 30ft from the source.

In trying to find a theoretical model for this behaviour we are on familiar ground, since similar situations arise in the propagation of radio waves in the layer between the ionosphere and the ground, and the propagation of sonar waves in underwater sound channels.[2] However, two factors stand in the way of the conventional approach: first we are more concerned with broadband noise effects than with single wavelength sound, and second the boundary conditions (i.e. the impedances of floor and ceiling) vary strongly with the angle of incidence of the sound wave. For these reasons we adopted a rather unsophisticated approach which rejected all phase information and regarded the noise source and the multiple images formed by reflection in the floor and ceiling as simple energy sources, with strength reduced by partial absorption at each reflection. (See fig.1). At small distances from the source the sound energy arriving by reflection from the floor and ceiling is negligible compared to the direct sound energy, so that an inverse square law is obeyed (6dB for distance doubling). At moderate distances the row of images begins to look like a line source, for which an inverse proportion (3dB for distance doubling) law holds. At large distances the limited length of the image row becomes apparent, so that an inverse square law attenuation is re-established (6dB for distance doubling again). This is illustrated in fig.2.

In order to follow up this model of the sound field a computer programme was written which computed the total sound energy arriving at points at various distances from the source, due to all the significant images, the source and observation point lying in the centre plane of the room. Appropriate values for the strength of the successive images were computed on the assumption that the floor and ceiling were local reactors; this determined the way in which reflection coefficient varied with angle of reflection (see fig.3). Input data fixed the boundary surfaces' normal impedance and the height of the room.

The results obtained indicated a somewhat similar structure to that observed in experimental measurements, but the changes in slope of the attenuation curve were not so marked, and the computer predicted a second decrease in rate of attenuation at very large distances from the source. This arises from the increase in reflectivity of a local reactor at very large angles of incidence.

If we ignore the finer detail of the experimental measurements and the computer calculations, the results for distances greater than 3ft from the source can be expressed to an engineering approximation by a uniform attenuation of about 4.5dB for distance doubling, corresponding to an inverse three-halves power law. This is a value which has been quoted by other workers on the basis of approximate measurements in other real offices.

Some thought has been given to the question of increasing this rate of attenuation of sound with distance; measurements made recently in the Home Office's prototype landscaped office at Kew do in fact exhibit attenuation rates in excess of 6dB for distance doubling at large distances from the source. Our rather primitive theoretical model suggests that this might arise either from the presence of a boundary which is not a local reactor and consequently has non-zero absorption at grazing incidence, or by cancellation of the direct sound by sound reflected at sufficiently large angles for phase reversal to occur. In order to pursue this second possibility further our computer programme is now being modified to take account of phase and non-coplanar positions of source and detector.

Reference 1. Applied Acoustics, vol 2, p. 161, July 1969.

Reference 2. Waves in Layered Media, L.M.Brekhovskikh, Academic Press, 1960.

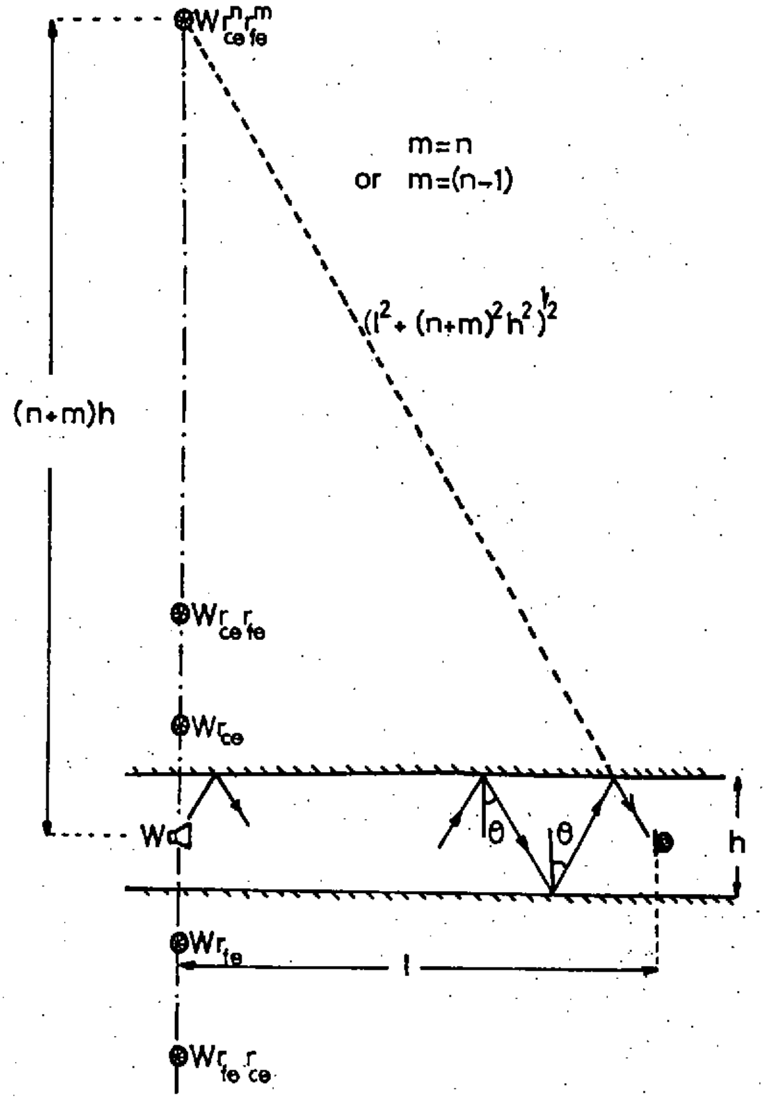

Fig.1. Image array

$$IL = \frac{W}{4\pi l^2} + \sum_{n,m} \frac{W r_{ce}^{n} r_{fe}^{m}}{4\pi (l^2 + (n+m)^2 h^2)}$$

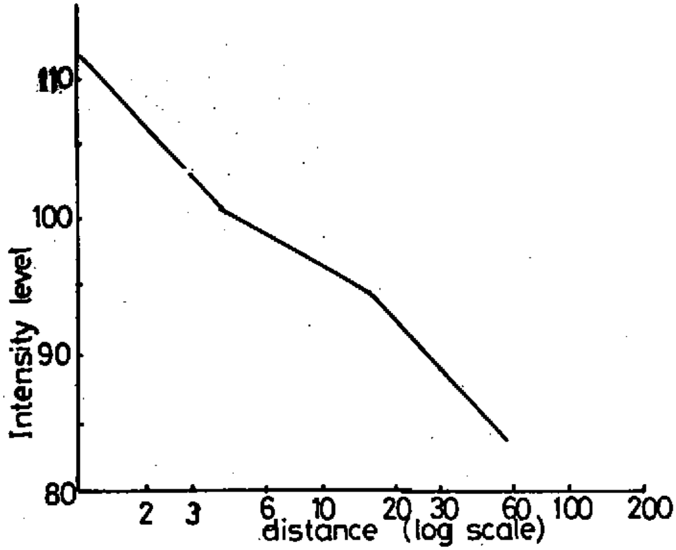

Fig. 2 Intensity level v. distance

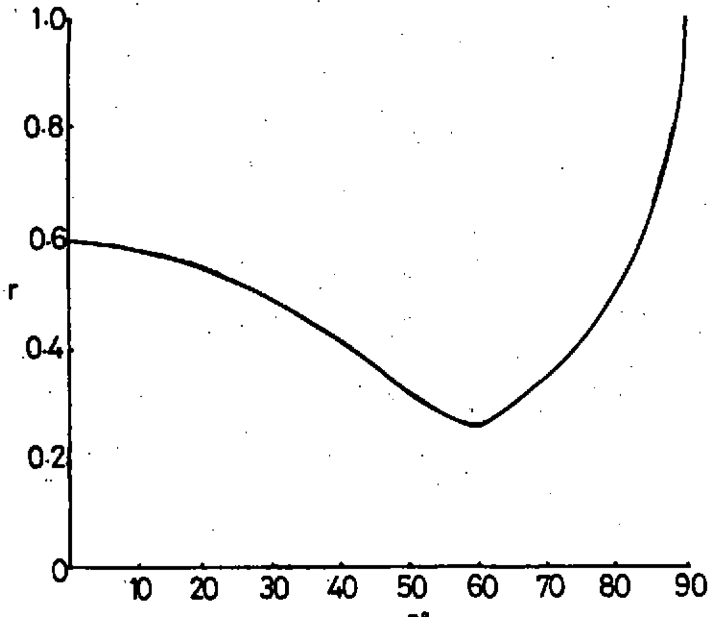

Fig. 3 Reflection coefficient v. angle of incidence