BRITISH ACOUSTICAL SOCIETY: Meeting on Wednesday, 27th September 1972 at the University of Salford.

ACOUSTICS OF THE OPEN PLAN ENVIRONEMNT

Paper No. 72/53.

A THEORETICAL AND PRACTICAL ASSESSMENT OF THE POINT SOURCE SOUND FIELD IN A LANDSCAPED OFFICE

M. WEST

Department of Physics, University of Salford

The point source field can be evaluated either for steady or transient excitation. The steady field may be represented by a curve of band SPL versus logarithm of distance (an attenuation curve) and the transient field in terms of band SPL versus time at a given distance from the source (a decay curve).

1. THEORETICAL PREDICTIONS OF THE STEADY AND TRANSIENT FIELD.

The pure tone point source steady field between two surfaces may be calculated using either an image or a mode method. Calculations using the image method have been reported earlier[1] but these calculations ignored the relative phases of the contributions from each image. If the phases are included the resulting attenuation curve is extremely complicated, the level fluctuating by large amounts over small distances. By ignoring the phase information it was supposed that the rapid fluctuations would be averaged out and the resulting attenuation curve would correspond to that obtained from a source radiating a band of white noise. The fluctuations are certainly averaged out when phase information is ignored but the attenuation curve is different from that calculated with the exact image model, adapted to predict band attenuation.

The pure tone pressure is given by the sum of the n image contributions $R_c^a R_F^b e^{jkr_n}/r_n$ where $R_{c/F}$ is the complex reflection coefficient of the ceiling/floor, a/b is the number of reflections in the ceiling/floor and r_n is the distance of the image from the calculation point. A mineral tile ceiling and a carpeted floor can usually be assumed locally reacting and $R_{c/F}$ may be obtained in terms of the measured small sample normal impedance. If the ceiling consists of a light suspended unit it must be considered as an external reactor. R_c may still be calculated in terms of the measured normal impedance of the suspended unit when rigidly backed[2], but the normal impedance of the ceiling will now vary with angle of incidence. A calculation accuracy of better than ± 0.01 dB can be obtained by including images whose contributions at the calculation point are not more than 40dB less than the direct contribution from the source. The simulated band r.m.s. pressure is given by $\sqrt{(\sum |p|_f^2 + |p|_{f+\Delta}^2 + \cdots |p|_{f+N\Delta}^2 / N+1)}$ where $|p|_{f+N\Delta}$ are the moduli of the pure tone pressures calculated at frequencies $f+N\Delta$, Δ being a small frequency increment. The calculation accuracy of ± 0.01 dB is maintained for $\Delta < 5$Hz.

Caclulation of an attenuation curve using the image model is clearly a lengthy process and it may contain errors in the near field. The mode model is now being used by the author in place of the image model because it cuts down both calculation time and near field errors. The point source field is represented in this model in terms of a series of attenuating modes. Their contributions may be summed at any point to give the pure tone pressure.

Figure 1 shows the predicted attenuation curve for an octave band source in an office with a carpeted floor and a perfectly absorbing ceiling. For each of the three centre frequencies there is a fluctuation about the 6dB line, the fluctuations becoming smaller and closer together the higher the frequency. Figure 2 shows the predicted effect of introducing a suspended ceiling. The curves remain close to the 6dB line but if we regard the area above the line as positive and that below as negative, the approximately zero areas of the curves in figure 1 have been transformed into positive areas in figure 2. Almost identical curves to those in figure 2 are obtained when the ceiling is either changed from an external to a local reactor or raised by 1m.

The decay curve for octave band excitation may easily be obtained using the modal model (the calculation is difficult using the image model). The decay curves usually have a steep early decay region followed by a longer late decay. There is little change in the shape of the curve with frequency or distance from the source.

2. <u>STEADY FIELD MEASUREMENTS ALONG AN UNINTERRUPTED PATH</u>.

Measurements of attenuation have been carried out in the Prototype Landscaped Office at Kew, London. The octave band attenuation curves for a diagonal traverse across the fully furnished office are shown in figure 3. The curves are in fairly good large scale agreement with the theoretical predictions up to about 10-15m from the source, but they do not show the predicted large slope in the 20-30m region. The explanation of the discrepancy lies in the fact that the walls have not been included in the theoretical model. Attenuation measurements were also carried out with zero and half furniture densities but the curves remained very similar to those in figure 3.

3. <u>STEADY FIELD MEASUREMENTS ALONG AN INTERRUPTED PATH</u>.

Screens are extensively used in landscaped offices to improve visual privacy. They also have a significant effect on the acoustic field but only if they interrupt the line of sight to the source. Theoretical predictions of screen behaviour in an open office have been attempted[3] but these are not very accurate owing to the drastic simplifications in ceiling behaviour required in the analysis. Measurements of attenuation with flat screens interrupting the microphone path have been performed in the Kew Office. The screens had dimensions 1.525m high by 1.350m wide. Two types of screen were tested, one consisting of cloth covered blockboard, the other of 50mm thick Cape Insulant (A48). A typical curve is shown in figure 4 for the hard screens at 1000Hz. Screens close to the source are clearly more effective, in terms of their influence on the attenuation curve, than the more distant ones. On the source side of each screen, as we approach it, the level is built up from the original attenuation curve because of reflections from the screen. On the other side of the screen, as we move away from it, the level rises rapidly back towards the original attenuation curve until the reflected field from the next screen causes a levelling-off of the attenuation curve. Similar curves are obtained at higher frequencies, but at lower frequencies the steps in the curve decrease in size becoming insignificant at 250Hz. This frequency limit may be lowered by increasing the screen width or height or both.

Reducing the screen separation can have a remarkable effect on the attenuation curve. For example with a 2m screen separation at 500Hz the 5dB steps obtained with a 5m screen separation are reduced to less than 1dB. For small screen separations (less than 3m) there is a complicated interaction between the screens which is influenced to some extent by the office ceiling.

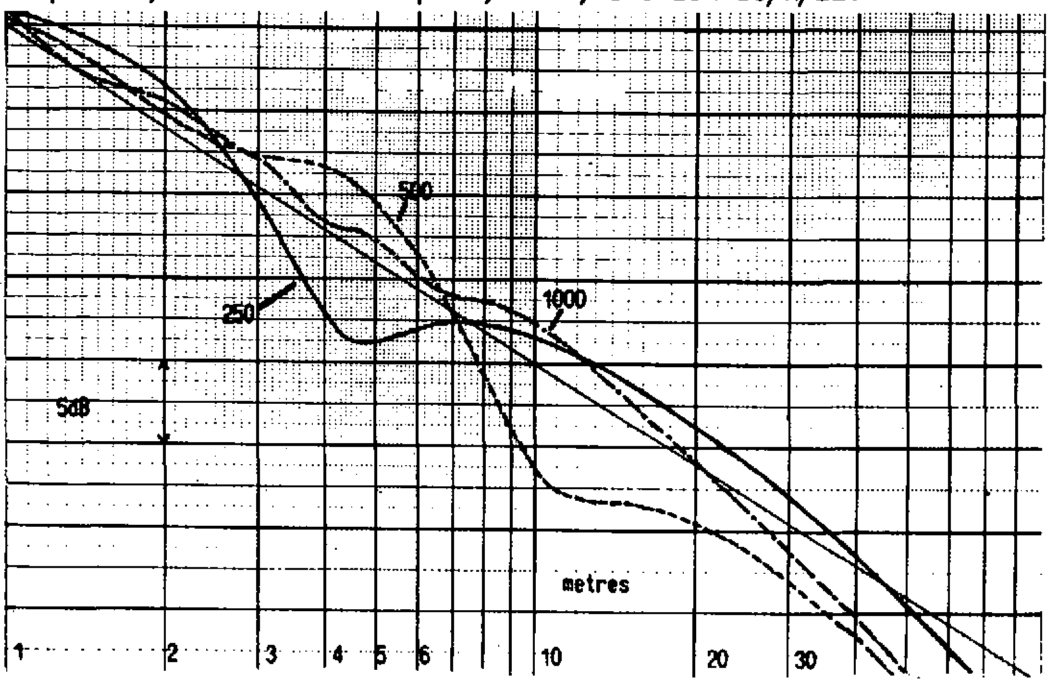
The soft screens, surprisingly, behave almost identically to the hard ones in every respect.

4. TRANSIENT MEASUREMENTS.

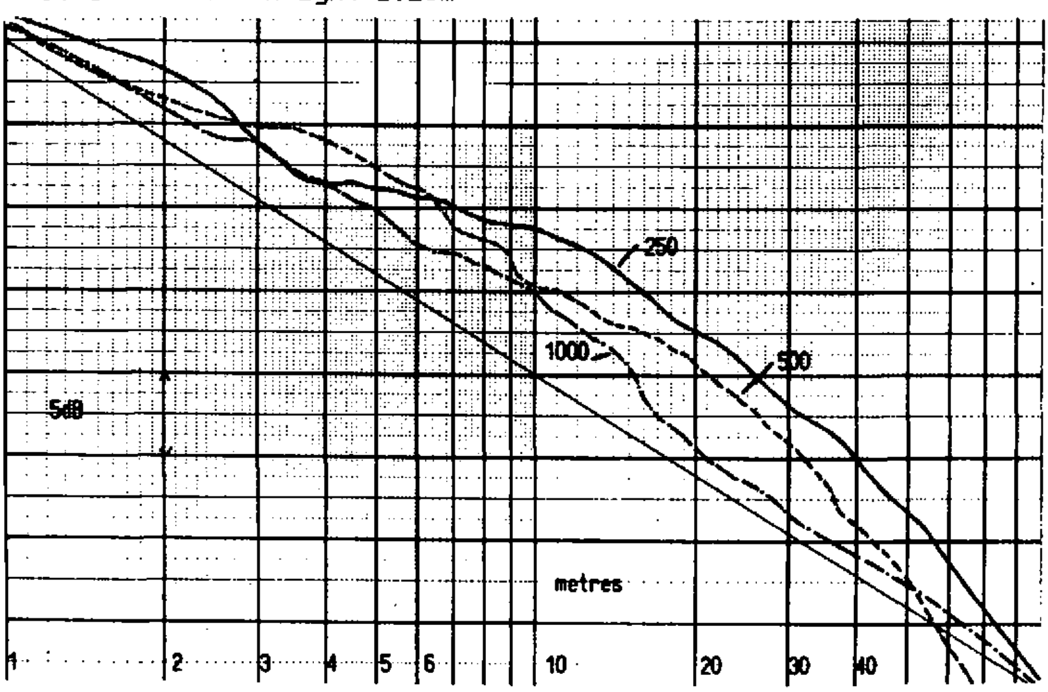
Decay curves have been measured in the Kew office and these were all found to be straight lines. Measurements of the transient behaviour of an acoustic model of the Kew office have shown that the steep early decay predicted by the two surface theoretical model may only be obtained when the walls of the office are highly absorbing.

References

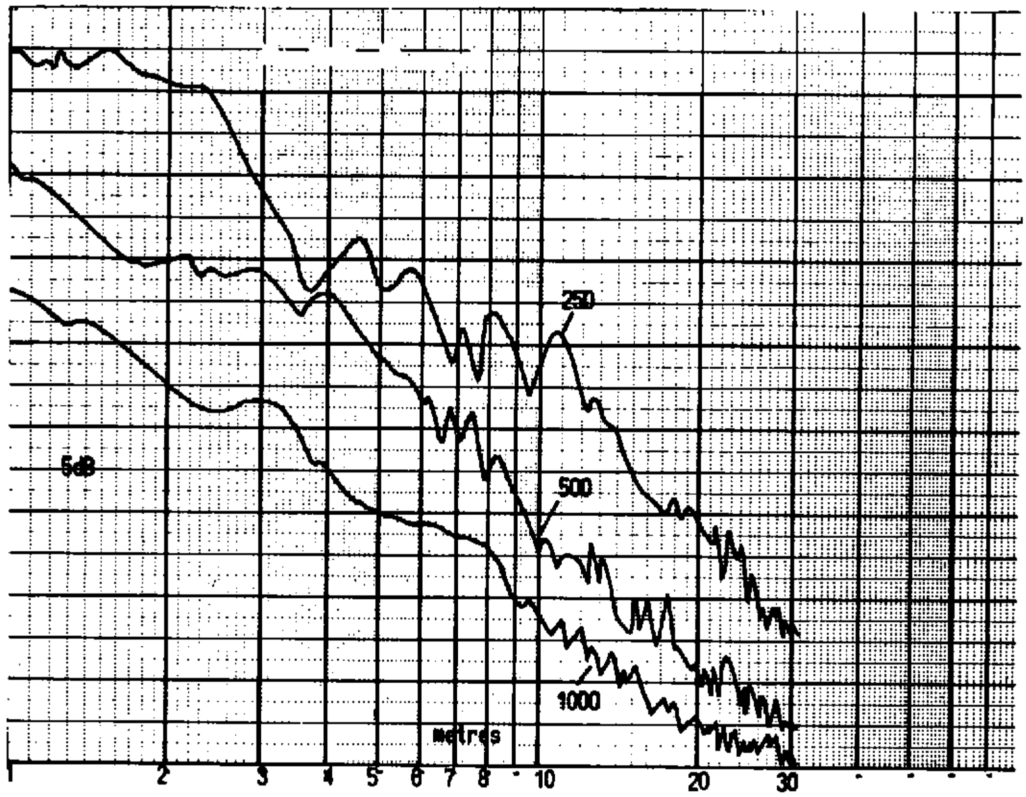
1. Day, B.F., "The Sound Field in Landscaped Offices", British Acoustical Society, Newcastle, April 1970.
2. Beranek, L.L., "Acoustic Impedance of Porous Materials", J. Acoust. Soc. Am. (1942) 13, 248-260.
3. Lyon, R.H., "Diffraction Limits on Sound Isolation in Open-Plan Spaces", 8th I.C.A. Budapest, 1972, section 20/A/11.



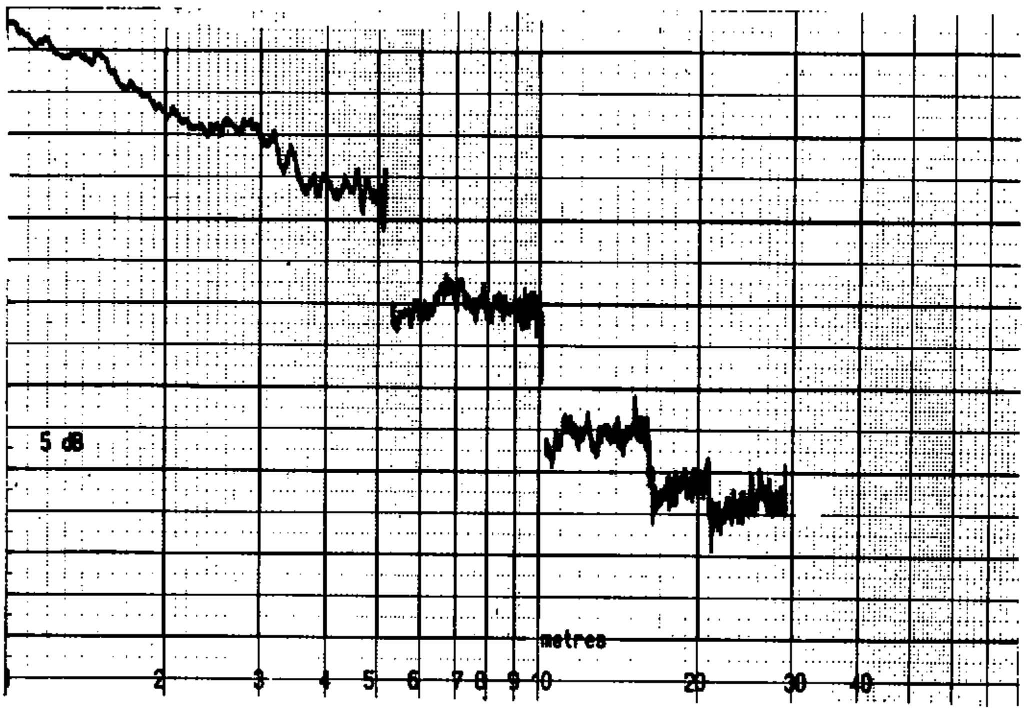
1. Attenuation Curves for an Office with No Ceiling and a Carpeted Floor. Source height 1.16m



2. Attenuation Curves for an Office with an "Acoustimetal Ceiling" (perforated tiles backed with a 25mm layer of Stillite in a polythene bag) on a 1.9m Air Space.



3. Measured Attenuation in the Kew Office. Diagonal traverse. Normal furniture density.



4. Measured Attenuation in the Kew Office with Hard Screens Placed at 5m Intervals. 1000Hz Octave.