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OPTIMUM ABSORPTION IN A REVERBERANT ENCLOSURE

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INTRODUCTION

This paper is concerned with the optimisation of reverberant enclosure absorption. The problem of predicting noise contours in an polygonally shaped enclosure has been completed by McNulty et al [1] by the development of computer software. The present work is a continuation of the prediction method used above where up to tenth order reflection are considered. For a two dimensional rectangular area.

The work initially examines the nature of reflections and provides a table of optimum design values for a rectangular enclosure where the number of reflections is the variable. The theory is based on that for reflections in a rectangular enclosure presented for computer simulation by Allen-Booth and McNulty [2].

THEORY

Consider a rectangular enclosure with dimensions ℓ_1, ℓ_2 and ℓ_3, and absorption coefficients α_1, α_2, α_3, on the faces perpendicular to ℓ_1, ℓ_2 and ℓ_3 respectively.

The co-ordinates of the sound source are S_1, S_2, S_3, whilst those of the receiver are defined as d_1, d_2, d_3.

The i, j, kth image of the source is defined as that image arising from 'i' reflections along the ℓ_1 direction j, reflections along the ℓ_2 direction and k reflections along the ℓ_3 direction and is distant x_{ijk} from the receiver.

The total contribution to the intensity of all such image sources is given by:

$$I = \sum_{\substack{i=o\\j=o\\k=o}}^{\infty} I_o \frac{(1-\alpha_1)^{|i|}(1-\alpha_2)^{|j|}(1-\alpha_3)^{|k|}}{x^2 ijk} \quad \ldots\ldots\ldots (1)$$

where x is calculated from

$$xijk = F_1^2\,(i) + F_2^2\,(j) + F_3^2\,(k)$$

where

$$F_1(i) = (i-1)\ell_1 + S_1 + d_1 \quad (i \text{ odd})$$

$$i\ell_1 + d_1 - S_1 \quad (i \text{ even})$$

$$F_2(j) = (j-1)\ell_2 + S_2 + d_2 \quad (j \text{ odd})$$

$$j\ell_2 + d_2 - S_2 \quad (j \text{ even})$$

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$$F_3(k) = (k - 1)\ell_2 + S_3 + d_3 \quad (k \text{ odd})$$

$$k\ell_3 + d_3 - S_3 \quad (k \text{ even})$$

Hence we obtain equation (2) below

$$\text{Also } \frac{I}{I_d} = \sum_{\substack{i=o\\ j=o\\ k=o}}^{\infty} \frac{z_{ooo}^2 \alpha_1^{|i|} \alpha_2^{|j|} \alpha_3^{|k|}}{z^2 ijk} \quad \ldots\ldots\ldots\ldots \quad (2)$$

Equation (2) may be used to calculate the increase in sound intensity level which will be exactly the same as the increase in sound pressure level, due to sound from the image sources when compared with directly radiated sound only.

The increase in SPL due to image sources = $\text{Log}_{10}\ (I/I_d)$ .... (3)

Equations (2) and (3) above are the basis of optimisation of the number of reflections needed for a particular absorption coefficient. Typical values for a rectangular enclosure are given below.

TABLE 1 ATTENUATION OF SOUND BETWEEN TWO SUCCESSIVE REFLECTION ORDERS FOR VARIOUS ABSORPTION COEFFICIENTS α.

α ↓	1 → 2	2 → 3	3 → 4	4 → 5	5 → 6	6 → 7	7 → 8	8 → 9	9 → 10 (Number of Reflection Orders)
0.9	+0.1								
0.8	+0.2	+0.1							
0.7	+0.3	+0.1							
0.6	+0.4	+0.1							
0.5	+0.6	+0.2	+0.1						
0.4	+0.9	+0.3	+0.1						
0.3	+1.0	+0.4	+0.2	+0.1					
0.2	+1.2	+0.5	+0.3	+0.2	+0.1				
0.1	+1.4	+0.6	+0.4	+0.3	+0.2	+0.1			
0.09	+1.5	+0.6	+0.4	+0.3	+0.2	+0.2	+0.1		
0.08	+1.5	+0.7	+0.4	+0.3	+0.2	+0.2	+0.1		
0.07	+1.5	+0.6	+0.4	+0.3	+0.2	+0.2	+0.2	+0.1	
0.06	+1.5	+0.7	+0.4	+0.3	+0.2	+0.2	+0.2	+0.1	
0.05	+1.6	+0.7	+0.4	+0.3	+0.2	+0.2	+0.2	+0.1	
0.04	+1.6	+0.7	+0.5	+0.3	+0.2	+0.2	+0.2	+0.1	
0.03	+1.6	+0.7	+0.5	+0.3	+0.3	+0.2	+0.2	+0.2	+0.1
0.02	+1.6	+0.7	+0.5	+0.4	+0.3	+0.2	+0.2	+0.2	+0.1
0.01	+1.6	+0.8	+0.5	+0.4	+0.3	+0.2	+0.2	+0.2	+0.1

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With reference to the table we can expect in a very lively room of $\alpha = 0.01$ a difference between two successive reflection of the intensity at any given point to be 1.6 dB. We would have to consider up to ten order of reflection to obtain the same accuracy for one order associated with $\alpha = 0.9$.

Figure I can be used to obtain an understanding of the sound fields that exist in an enclosed area in this case a third order reflection is given.

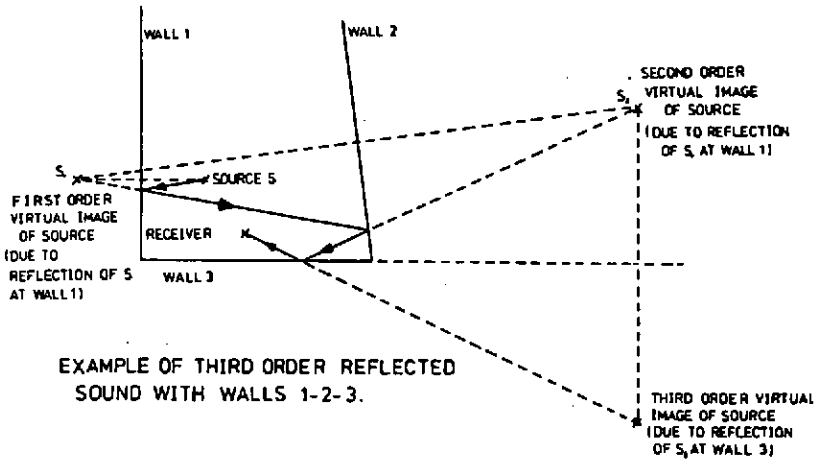

Figure 1

A typical noise contour map from the prediction programme is given in Figure 2. Here we have as data the co-ordinates of the room geometry together with the co-ordinates and sound intensities of the sources. Furthermore we can select the number of reflections required for a given absorption to give optimum accuracy as in Table 1.

CONCLUDING REMARKS

A method has been presented which demonstrates the accuracy of predictions of sound pressure levels in an enclosed area for a given set of absorptions.

REFERENCES

[1] G J McNulty, D Allen-Booth, R Gunson and A Tanchou, 'Computer Simulation of sound in Polygonal Shaped Enclosures'
Proc 10th IMACS, Canada August 1982.

[2] D Allen-Booth and G J McNulty, 'Computer Simulation of Acoustic Intensity in a Rectangular Enclosure'
Proc 10th IMACS, Canada August 1982.

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Noise contours to be drawn - type in 5 values, biggest first

96 93 90 87 84 = SPLA ....SPLE

NB: SPLA > SPLB >....>SPLE

96.0 DB contour is represented with symbol Δ

93.0 DB contour is represented with symbol +

90.0 DB contour is represented with symbol □

87.0 DB contour is represented with symbol *

84.0 DB contour is represented with symbol o

The sound sources are represented with symbol ✱

Number of reflection(s) to take into consideration: 0, 1, 2 or 3?

1 = NR