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ANALYSIS OF METHODS OF PREDICTING SOUND PRESSURES IN ENCLOSED SPACES

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INTRODUCTION

The prediction of sound pressures in a large enclosure is often a difficult problem. Current methods of calculation are not generally sufficiently accurate. For any but ideally proportioned, hard surfaced enclosures, the standard room acoustics equation [1] is unacceptably inaccurate. Errors of as much as 10 decibels for such calculations have been documented [1-5].

Several alternative calculation schemes have been developed to remedy the shortcomings of the room acoustics equation [1,4,5]. This paper presents a comparison of the image source computation method [4,6,7] and the standard room acoustics equation's capabilities to predict sound pressures in several different rooms.

BASIC EQUATIONS

The room acoustics equation is shown below [2]:

$$L_p = L_w + 10 \text{ Log}_{10} \, (Q/4\pi r^2 + 4/RC) \qquad (1)$$

where: L_p is the sound pressure level, L_w is the source sound power level, Q is the source directivity factor, r is the source to receiver distance, and RC is the room constant.

For rectangular shaped enclosures with smooth walls of low absorption, sound energy reaching the receiver after a reflection from a wall can be treated as if it eminated from an image source outside of the room. This image lies on a line extending from the receiver through the point of reflection as shown in Figure 1. Considering multiple reflections, this array of image sources and cells becomes several units deep as shown in Figure 1. Each image cell is designated by three numbers (l,m,n).

The intensity at the receiver point is given by the expression,

$$I = \frac{QW}{4\pi} \sum_{l=0}^{\infty} \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} 1/r^2_{lmn} (1-\alpha_l)^l (1-\alpha_m)^m (1-\alpha_n)^n e^{-mr_{lmn}}, \quad (2)$$

where I is the intensity, W is the source sound power in watts, r_{lmn} is the image source to receiver distance and α is the average absorption coefficient for the surfaces perpendicular to the indicated coordinate directions.

EXPERIMENTAL DATA

To test the validity of these methods for predicting sound pressure levels, comparisons were made to measured data obtained in three different rooms. Comparisons were first made to the data obtained previously by Thompson [1], see Figure 2.

Recently studies were made in Hill Memorial Classroom. As shown in Figure 2, two sets of measurements were conducted in this room for different source positions. Typical results of all these comparisons are presented in Figures 3-6.

CONCLUSIONS

From these four comparisons, the image source method of computation appears to be the more accurate in predicting sound pressure distributions in an enclosure. A major advantage of the image method is that is more closely matches point-to-point variations in the sound pressure level, even when there are errors in the absolute level computed. A major disadvantage of the image method is its computational complexity. Calculation times for this method averaged approximately 40 CPU seconds, while the room acoustics equation required approximately 2 seconds. The computation times for the image method are greater but they are not unreasonable.

REFERENCES

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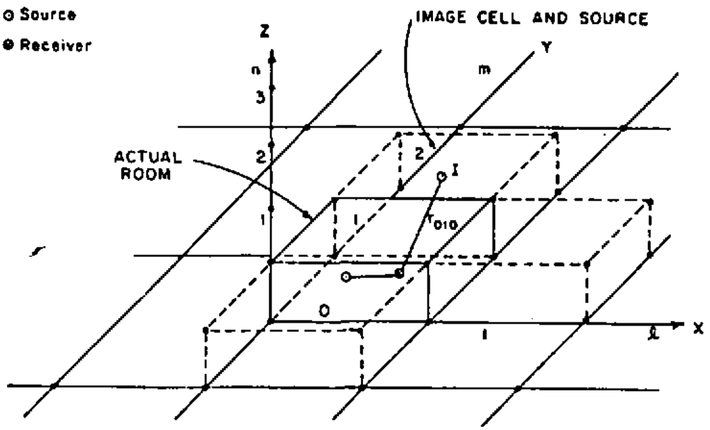

FIGURE 1. IMAGE SOURCE AND IMAGE CELL ARRANGEMENT

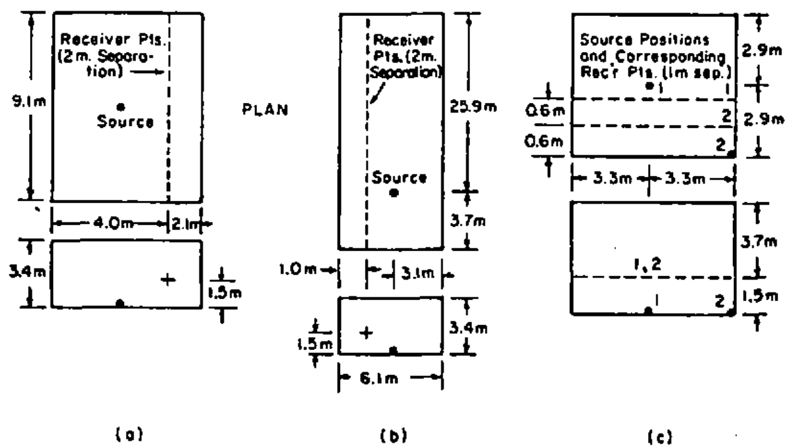

FIGURE 2. SOUND MEASUREMENT ROOMS –
(a) RANDOLPH CLASSROOM, (b) DERRING HALLWAY AND
(c) HILL MEMORIAL CLASSROOM

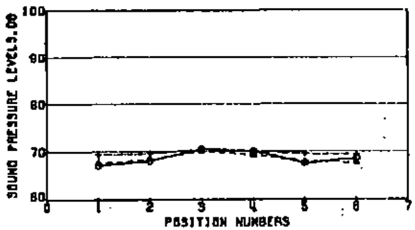

Figure 3 - Randolph Classroom - 1000 Hz. Octave

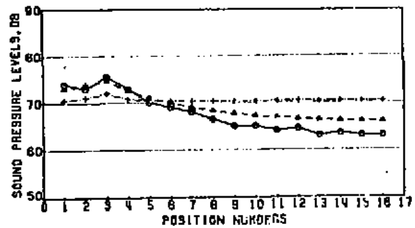

Figure 4 - Derring Hallway - 500 Hz. Octave

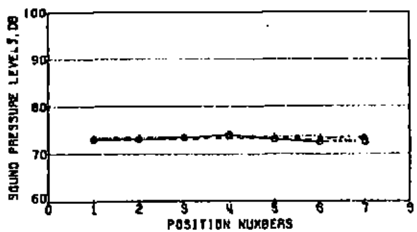

Figure 5 - Hill Memorial Classroom - Center Source - 500 Hz. Octave

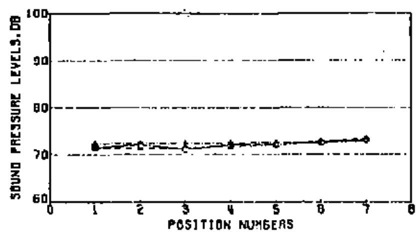

Figure 6 - Hill Memorial Classroom - Corner Source - 2000 Hz. Octave

⊙ Measured Values Δ Image Source Method + Room Acoustics Equation