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REVERBERATION REINFORCEMENT BY MEANS OF ELECTRO-ACOUSTIC COUPLING.

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Introduction

Although many other factors are now known to be important in determining the acoustics of an auditorium the reverberation time is still generally believed to be the most significant. It has long been recognised that rooms for speech benefit from having a shorter reverberation time than similar rooms intended for music. As a result of this it is impossible to design a single hall with excellent acoustics for both speech and music.

A number of attempts have been made to design multipurpose halls incorporating variable reverberation characteristics. Techniques employed include the use of variable acoustic treatments on the walls and electro-acoustic systems. Jones and Fowweather (1) have described an electro-acoustic system utilising the properties of a space acoustically coupled to the main auditorium. This paper describes an investigation of the properties of such a system.

Theory

An initial attempt at developing a theoretical model of the Jones-Fowweather system was made using classical reverberant field theory. A schematic diagram of the electro-acoustic system is shown in Fig.1. Assuming totally diffuse sound fields in both primary and secondary enclosures the following "power balance" equations can be obtained.

$$w = A_1 \mathcal{E}_1 c/4 + s(\mathcal{E}_1 - \mathcal{E}_2)c/4 + V_1 \partial\mathcal{E}_1/\partial t \qquad (1)$$

$$\mathcal{E}_2 = \mathcal{E}_1 s/(A_2 + s) \qquad (2)$$

where w = the acoustic power of the source, A = the total absorption in a space, $\mathcal{E}$ = the reverberant field energy density, s = the area of the coupling aperture, c = the velocity of sound in air, k = a constant determined by the properties of the electro-acoustic feedback loop and the subscripts 1 and 2 refer to the primary and secondary spaces respectively.

These equations can be solved using standard numerical techniques. Figures 2 and 3 show examples of computer simulated logarithmic decay curves for a 2,000 m^3 hall having an average absorption coefficient of 0.2 coupled to a 500 m^3 space having an average absorption coefficient of 0.05 via a number of different sized apertures and for a number of different values of the feedback constant k.

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Experimental Validation of Theoretical Predictions

Equations 1 and 2 were derived assuming totally diffuse reverberant fields in both enclosures. With increasing amounts of absorption in each space the validity of this assumption becomes questionable. A series of experimental measurements were performed on a scale model incorporating an electro-acoustic feed-back loop (see Fig.4). The decay times obtained were compared with theoretical predictions. The agreement between the two was found to be good when both spaces were "live" (i.e. having average coefficients of absorption less than 0.25).

The traces obtained had the double slope characteristics typical of coupled spaces (see Fig.5). An effective reverberation time was measured from each trace in the manner described by Jones and Fowweather (1), i.e. by simply laying a protractor along the curves and visually averaging the slope over a 40 dB range. A comparison between the reverberation times measured in this way and the theoretical predictions obtained for two experimental configurations are shown in Figures 6 and 7.

Conclusion

A simple classical reverberation approach has been shown to predict the effect of an electro-acoustic feedback loop utilising the properties of a naturally coupled space. The limitations of the work are a) measurements were made of the decay of an established steady sound field b) no attempt has been made to obtain a subjective assessment as to the acceptability of the resultant "double slope" decay curves.

Whilst it can be argued that since reverberation times are usually measured from the decay of an established steady sound field it is interesting to note that Jones and Fowweather (1) used different microphone positions in the ceiling void to control their reverberation time. This suggests that an approach based upon classical reverberant field theory may not be valid for non-steady sound sources such as speech and music.

With regard to the subjective acceptability of the double slope decay curve this perhaps presents a serious argument against the widespread use of this system of reverberation reinforcement. Work by Atal et al (2) has demonstrated that the subjective assessment of reverberation in a room is determined largely by the initial decay rate. The feedback system described in this paper only significantly affects the secondary slope of the decay curves.

References

(1) M. H. JONES and F. FOWWEATHER 1972 Acustica 27, 357-363. Reverberation reinforcement - an electro-acoustical system for increasing the reverberation time of an auditorium.

(2) B. S. ATAL, M. R. SCHROEDER and G. M. SESSLER 1965 Proc.5th. ICA Liege. Subjective reverberation time and its relation to sound decay.

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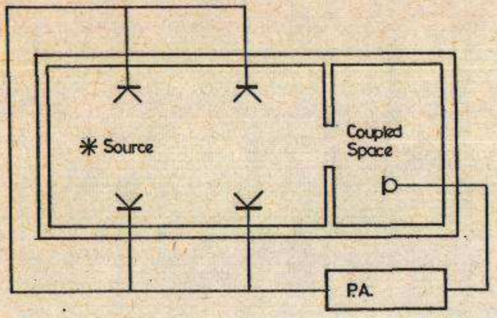


Figure 1

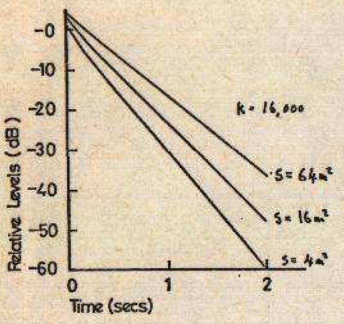
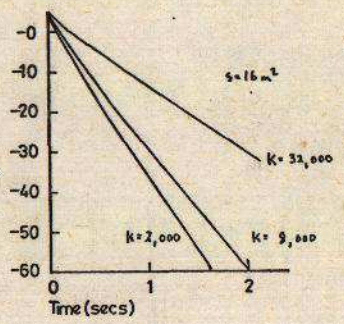


Figure 2



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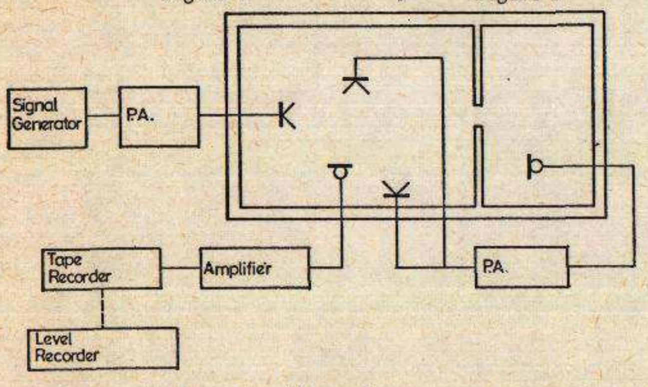

Figure 4

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Figure 5

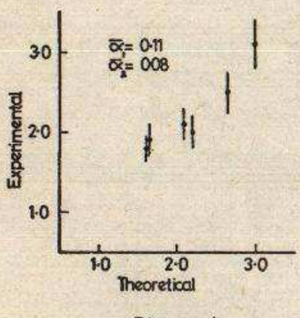

Figure 6

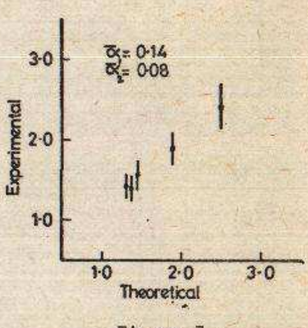

Figure 7