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ACTIVE ATTENUATION IN SMALL ENCLOSURES

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INTRODUCTION

Active attenuation models have been developed for the prediction of attenuation in a duct, for example (1), and the application of active noise control in 3-dimensions has been investigated (2,3). In this paper a theoretical model is described which is intended to model the operation of a simple Tight-Coupled attenuator operated in an audiometric enclosure, an enclosed volume of internal dimensions approximately 6ft x 3ft x 2.5ft.

EXPERIMENTAL SYSTEM

A simple Tight-Coupled monopole systen was set up with a single microphone and loudspeaker. The microphone was positioned 20cm vertically below the loudspeaker, on the axis of the drive unit, the whole system being inside the audiometric enclosure. The microphone was positioned so that it corresponded reasonably well with the position of a subject's head when inside the booth. The system set up is shown schematically in Figure 1.

As can be seen, the feedback loop includes a signal processing device which would be programmed to achieve maximum attenuation at the microphone. The signal processor characteristic was determined by measuring the transfer function of the loop and inverting it to obtain the required filter characteristic, this is essentially the same as the process described in (2) by Berge.

The coefficients of the digital filter to implement the transfer function were them determined via an optimisation process calculated in the frequency domain, with the filter arranged as a cascade of biquadratic sections. Constraints were imposed on the coefficients to ensure that a stable design would result. Comparing the predicted response with that required for perfect cancellation enables the attenuation coefficient Δ, as defined below, to be calculated. This was calculated as a function of frequency and is shown in Figure 2.

$$\Delta = 10 \log_{10} (P^2/R^2)$$

P : primary noise amplitude (without ANC)
R : resultant noise amplitude (with ANC)

MODEL OF LOUDSPEAKER SOURCE RADIATING INTO ENCLOSURE

The model was founded on considering the cancelling loudspeaker as an array of point sources of equal strength, frequency and phase. The array elements were arranged to best represent the drive unit of a KEF B139 loudspeaker, and by using a separation of 2cm between the source centres 75 elements were produced.

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To calculate the spatial variation of the attenuation in the region surrounding the microphone it was first necessary to calculate the sound field at some arbitrary neighbouring point due to the direct field, and also reflected waves from the enclosure walls. The direct field is thus given by:

$$Pd = \sum_{i=1}^{75} (1/r_i) \exp(-ikr_i)$$

where r_i is the distance of the ith element from the point being considered. The indirect field was calculated by working out the effective path length, via a reflection, to the point taking into account also a reflection coefficient for the surface, giving an appropriate amplitude and phase shift. It may be noted here that because it was wished finally to calculate variations in attenuation rather than absolute sound pressure field values it was not critical that these figures truly represented the walls of the structure, as each point including the reference point (microphone position) would be equally affected.

PREDICTED VARIATION OF ATTENUATION

Using a mathematical model as outlined above, programmed on a computer the sound field could be calculated over the region of interest. This enabled the variation with respect to the reference point to be calculated and hence the attenuation predicted. Two of the attenuation contours produced are shown in Figures 3 and 4.

DISCUSSION AND SUMMARY

The contour plots, Figures 3 and 4, are over a quarter plane horizontal region, the distance D representing the distance from the loudspeaker. Figure 4 is a typical result showing a relatively small variation, which is to be expected since the match at the reference point is only moderately good. Figure 3 is a rather rare condition where circumstances combine to produce positions of almost perfect cancellation. These points are clearly defined and there is a very rapid fall off in attenuation in their neighbourhood. A drop of 15dB (40 to 25) in attenuation occurs inside $\lambda/100$, which for a higher frequency, say 330 Hz, is approximately 1cm. It is also possible to see the overall symmetry of the system being shown up.

1. Hong, W.K.W., Eghtesadi, Kh., Levethall, H.G., "The tight coupled monopole and tight coupled tandem attenuators in a duct". Proceedings Internoise 1983, Edinburgh.

2. Berge, T.S., "A feasibility study of active noise cancellation of low frequency noise in vehicle cabs". ELAB (Norway) Report No. JTF44 A82033 1982.

3. Mazzanti, S., Piraux, J., "An experiment of active attenuation in 3-dimensional space". Proceedings Internoise 1983.

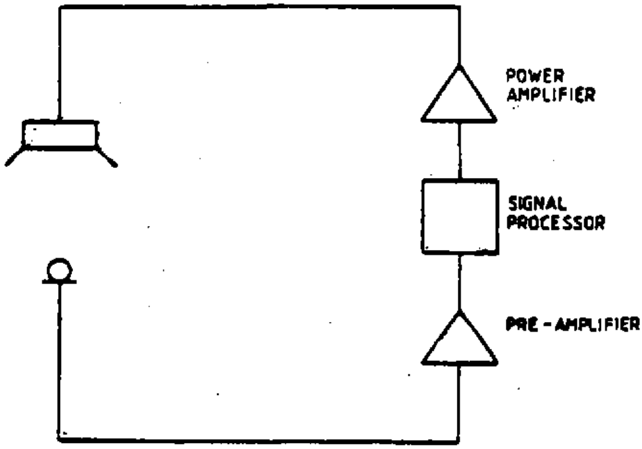


FIG 1 SYSTEM SET-UP

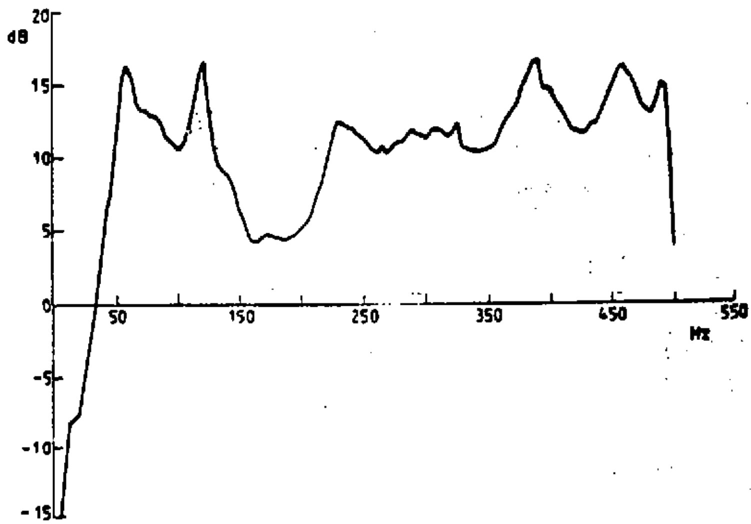
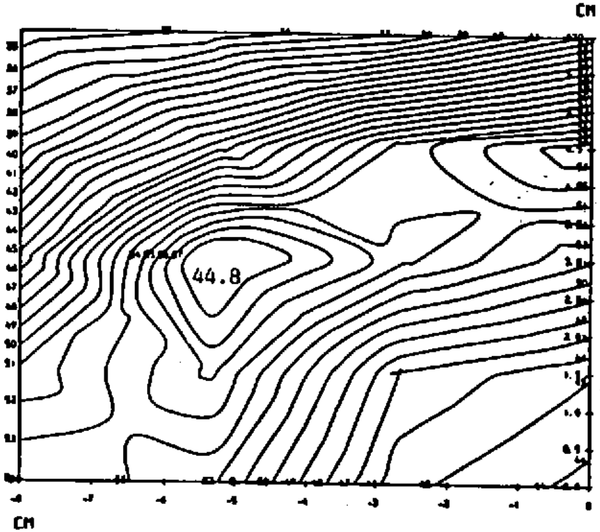


FIG 2 ATTENUATION COEFFICIENT



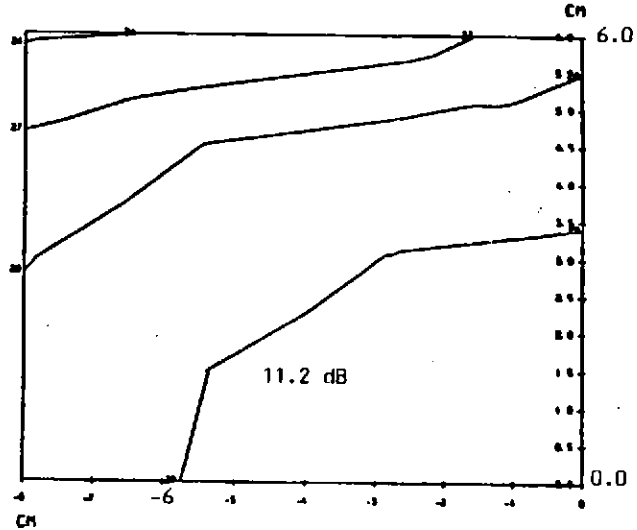
Attenuation Contours

F = 64 Hz D = 25cm

Interval = 0.8 dB

Max = 44.8 dB

FIG 3



Attenuation Contours

F = 248 Hz D = 20cm

Interval = 0.4 dB

Max = 11.2 dB

FIG 4