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THE TIGHT-COUPLED MONOPOLE(TCM) AND TANDEM(TCT) ATTENUATORS IN A DUCT

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INTRODUCTION - A common feature of active attenuators[1-5] is that the sound radiation in the duct has been assumed to be one-dimensional. This approximation is true for systems with large microphone-loudspeaker spacing and small duct cross-section. However it is inadequate for the description of the noise cancellation in front of the loudspeaker as well as for locating the microphone in Tight-Coupled systems, where the microphone and loudspeaker are in close proximity.

Tight-Coupled Monopole Attenuator[6] - Fig.1 is the feedback diagram where M is the microphone, S the loudspeaker, H the transfer function of electrical system(microphone, amplifier, loudspeaker). The G term represents the transfer function between the positions shown.

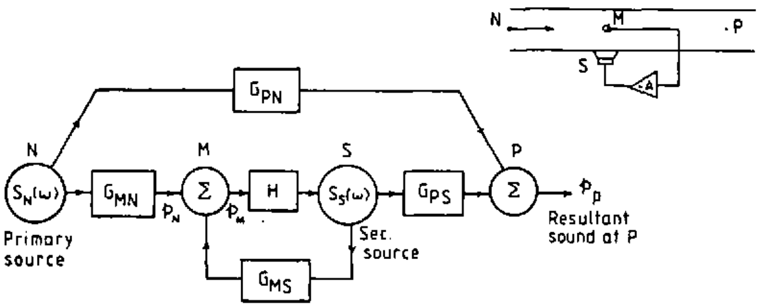

Figure 1. Feedback diagram of TCM Attenuator.

By summing the term for p_P, it can be shown that

$$\frac{p_P}{p_N} = [\ i\ 2\pi\ k\ G_{PM}\ ] - [\ \frac{-H\ G_{PS}}{1 - H\ G_{MS}}\ ] \qquad (1)$$

gives the noise output(p_P) of the system compared with the primary noise(p_N) at the microphone and $G_{PN} = i\ 2\pi k\ G_{PM}\ G_{MN}$.

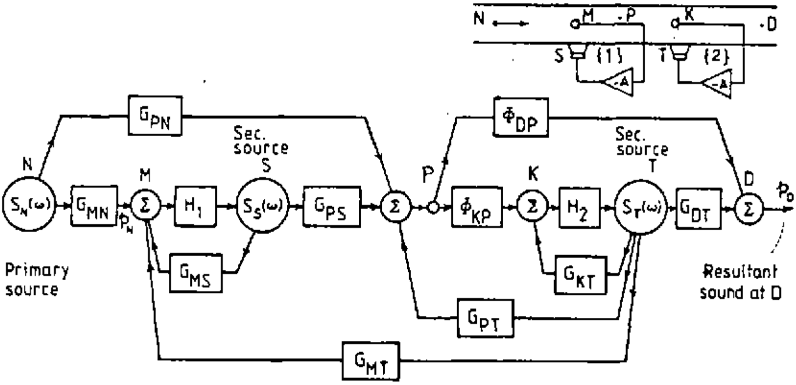

Figure 2. Feedback diagram of TCT Attenuator.

Tight-Coupled Tandem Attenuator[7] - Cancellation of the primary noise by the secondary source occurs predominantly within a small region upstream and downstream of the attenuator loudspeaker . This suggests that, beyond this region, attenuation is complete and the residual sound can be treated as a primary noise by a second TCM cascaded to the first. Fig.2 is the feedback diagram where M & K are the microphones, S & T the loudspeakers, H_1 & H_2 the transfer functions of electrical systems. P is a field point downstream of the second TCM. The term Φ represents the transfer function for plane waves between the positions shown. It can be shown that

$$\frac{p_D}{p_N} = \frac{\left[i\ 2\pi k \frac{G_{PM}}{G_{PS}} + \frac{H_1}{1 - H_1 G_{MS}} \right] \left[\frac{1 - H_2 G_{KT}}{H_2\ \Phi_{KP}} \Phi_{DP} + G_{DT} \right]}{\left[- \frac{H_1 G_{MT}}{1 - H_1 G_{MS}} - \frac{G_{PT}}{G_{PS}} + \frac{1 - H_2 G_{KT}}{H_2\ \Phi_{KP}\ G_{PS}} \right]} \qquad (2)$$

Experimental Measurement and Results - An experiment was carried out to measure the performance of the TCM and the TCT systems on a plane as defined by the central axes of the duct and the attenuator loudspeaker (2). The duct was made of sheet metal, having dimensions of 10 metres long, 450 mm wide and 600 mm high. Absorbent lining was used in the attenuator to reduce the effects due to the presence of higher order modes. A constant pure tone was used as the primary noise. The measurement results at 155 Hz are plotted in three-dimensional graphs, with attenuation as height of the graph. They are shown in Fig.3&4 for the TCM and TCT together with the computed results using equations (1) and (2) . From these figures, it can be

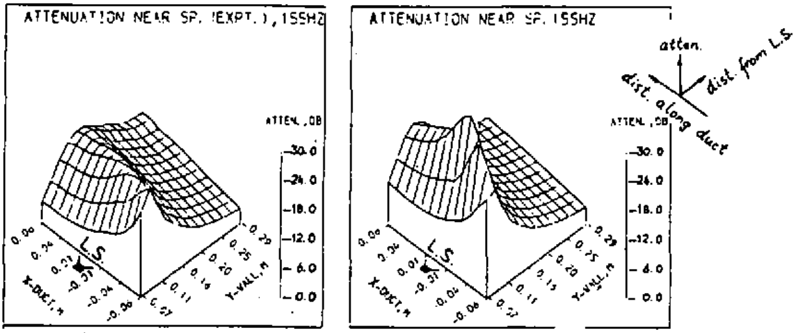

Figure 3. Active attenuation of TCM, (a) measured (b) calculated.

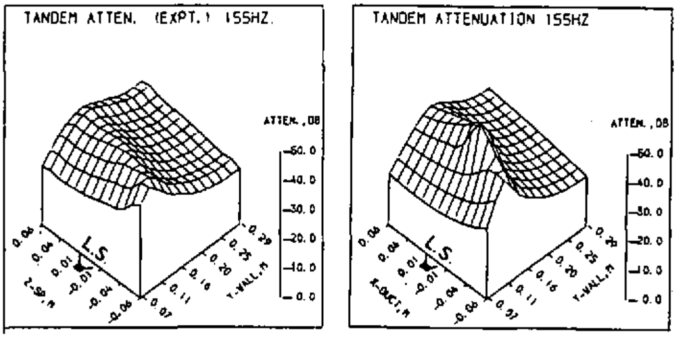

Figure 4. Active attenuation of TCT, (a) measured (b) calculated.

seen that the attenuation does not occur immediately downstream of the loudspeaker. Instead, it is a continuous and gradual process taking place from slightly upstream. Its profile can be shown to change significantly with frequency . The presence of this region with higher attenuation indicates that the amplitude and phase of the secondary sound can match that of the primary sound particularly well at some distance from the secondary speaker source. The performance of the TCM(1), (2) and of the TCT Attenuators are shown in Fig.5. The TCT Attenuator could provide a minimum of 20 dB for more than three-and-a-half octaves from 30 Hz to 330 Hz .

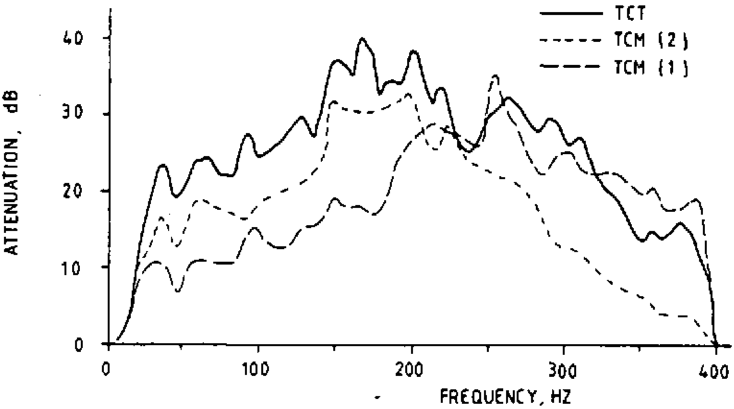

Figure 5. Performance of the TCM(1), TCM(2) and TCT Attenuators.

Discussion and Conclusion - The computer program for the theoretical model calculates the sound attenuation at a field point using the exact location of the attenuation microphone in the duct, the cross-section dimensions of the duct and the thickness as well as the location of the absorptive lining present in the TCM Attenuator. For a given duct and lining configuration, the parameter for the microphone location can be varied and the computer program gives the corresponding attenuation profile across the duct section downstream of the attenuator loudspeaker. Hence, the preferred location for the microphone can be found by optimising the attenuation across the duct section. The agreement between the computed and experimental results shows that the theory is a valid description of the cancellation of sound in a duct. The physical size of the duct is important in the performance of the Tight-Coupled system and this parameter should be included in the control theory .

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