Directional Microphone Arrays for Measurement in an Anechoic Wind Tunnel

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Abstract: This study investigates a number of microphone arrays that can be used in an anechoic wind tunnel for measuring out-of-flow aerodynamic noise generated by automotive vehicles. It concludes that a 20 microphone weighted linear array produces worthwhile results with the arced array superior at the higher frequencies and the straight line array performing better at the lower frequencies.

INTRODUCTION

The working section, Figure 1, of the aero-acoustical wind tunnel at this university has a cross-sectional area of 15m x 5m. Immediately upstream of this area, is an adjustable section which can produce free jets at speeds of up to about 60 m s⁻¹.

FIGURE 1. Cross Section through Wind-Tunnel showing Microphone Array and Jet Flow

Detailed attention has been given to the acoustic and aerodynamic design of the wind tunnel. This includes the use of quite fans, splitters downstream of the fans, and acoustical treatment to the jet collector and all turning vanes. The result is that the aerodynamic noise generated by full sized vehicles is clearly distinguishable above the background noise level of the tunnel. Further, the test section configuration allows for out-of-flow acoustical measurements to be made. Thus the ambiguity with normal in-flow measurements - ie the difficulty of distinguishing between pressure fluctuations that travel at the speed of the flow and those that travel at the speed of sound - has been eliminated. A consequence however is the need to develop directional microphone arrays so that the noise associated with particular localised areas on the vehicles, such as the rear vision mirror, can be easily identified and simply measured, preferably in real time.

MICROPHONE ARRAYS

Attention has centred on developing microphone arrays having regard to work already reported (1) - (3). One, two and three dimensional arrays have been examined but the present results refer to line arrays since these were found, in the present context, to be optimal in terms of cost, signal processing and analysing requirements, and suitability for use in the wind tunnel. If needed, the linear array could be rotated through 90° to obtain directionality in that new plane. Similarly, it could be moved parallel to the side of the vehicle if details of the noise sources over the full length or height of the vehicle were required. The directivity results from summing the various phase differing signals, weighted if desired, as discussed in standard texts.

RESULTS AND DISCUSSION

The overall intention was to produce a central narrowly focussed beam with any side lobes decreasing rapidly and smoothly in amplitude. Numerous line arrays were investigated and took the form of a straight line or of an arc. For practical purposes the number of microphones was limited to 20 and the length of the array was limited to 2m. Arc radii extended from 2m to 4m and the distance between the array and the noise source typically was taken as 3m. The spacing between the microphones and the weighting factors applied to each microphone were varied. For practical purposes these were fixed for any particular configuration although it was recognised that there was merit in allowing them to vary with frequency. Such variations however would require very complicated mechanical and data analysis facilities which at this stage seem not to be justified.

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Uniformly spaced microphones were found, on balance, to be the most appropriate as were weighting factors which varied smoothly from smaller values at the outside microphones to larger values at the central microphones. The variation was typically from about 0.2 to 1.0.

Some representative results for the straight line array and the arced array are given in Figures 2 and 3 below.

\begin{figure}[h]
    \centering
    \includegraphics[width=0.5\textwidth]{fig2}
    \caption{Directivity pattern of a Weighted Line Array of Microphones.}
    \end{figure}

In both cases the array was 2m in length while for the arced array the radius was set at 3m.

\begin{figure}[h]
    \centering
    \includegraphics[width=0.5\textwidth]{fig3}
    \caption{Directivity pattern of a Weighted Arced Array of Microphones.}
    \end{figure}

It is noted that for both configurations the general objectives have been broadly achieved. The arced array performs better than the straight line array does at the higher frequencies in that the central lobe is narrower and the side lobes are smoother and smaller. The straight line array however performs better at the lowest frequency although neither array is particularly discriminatory here. It remains to be established if this limitation is finally of practical significance for the aero-acoustic work on automobiles. Clearly increasing the length of the microphone array will improve the low frequency performance although the spatial constraints of the wind tunnel will limit this approach.

REFERENCES