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JET NOISE SOURCE IDENTIFICATION WITH FAR FIELD MICROPHONE ARRANGEMENTS

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Introduction

Jet noise source identification and location is still an important issue since no really conclusive or generally accepted description of the noise generation processes in turbulent jets has been achieved to date. While there is a definite need for a better understanding of jet mixing noise, one may question if far field approaches via acoustic mirror, telescope, or polar correlation techniques can provide the missing information. There are not only limitations in the spatial resolution which restrict these techniques to jet noise at the higher Strouhal and Mach numbers but also more fundamental difficulties in the interpretation of measured "equivalent source strength density distributions". In particular, if large-scale coherent turbulence structures participate in jet noise generation the assumption of a uniform amplitude and phase of the pressure field radiated from compact elements of this distribution is questionable. It may be shown that various acoustic interference mechanisms due to mere source coherence and specific source structure effects may cause "mislocation" of sources in a jet. Some of these objections are less valid at the lower Helmholtz numbers but for these, unfortunately, the spatial resolution of all three techniques becomes poor.

Since interpretation of source location results depends on a specific model of the jet noise sources it appears to be very difficult to gain from these a new insight into the problem for the relevant jet flow parameters. This view was substantiated in Reference (1) of which the present paper is an abridged version .

Experimental source location techniques

Various far-field microphone arrangements are increasingly used for studying aeroacoustic sound sources like jets and high-speed trains. The techniques which are superior to conventional directional microphones differ in the way the pressure signals are monitored and processed. In Figure 1 the acoustic mirror is schematically compared to two correlation methods employing either N = 14 or 2 microphones simultaneously. All three techniques have in common that their resolution capability, as characterized by the "window" 2 b of the image characteristics for a point source on the jet axis, is limited by the acoustic wave length to be resolved,

for the acoustic mirror: $$\frac{b}{\lambda} = 1.22\,\frac{r}{c} \qquad (1)$$

for the acoustic telescope: $$\frac{b}{\lambda} = \frac{N-1}{N}\sqrt{\left(\frac{r}{c}\right)^2 + \frac{1}{4}} \qquad (2)$$

for the polar correlations: $$\frac{b}{\lambda} = \frac{1}{2}\,\frac{1}{\sin\alpha_m} \qquad (3)$$

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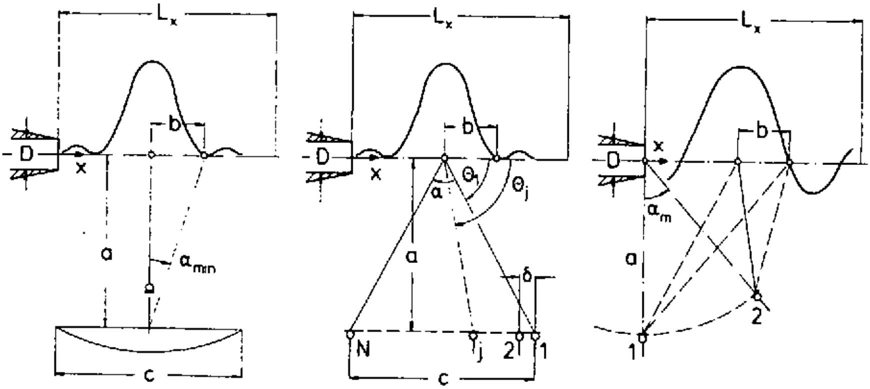

Figure 1. Three jet noise source location techniques

Application to the sources of jet mixing noise

All three measuring techniques produce plausible results if a very special source distribution is anticipated, namely that of a large number of uniformly radiating, statistically uncorrelated point sources located on the jet axis. Each source element would thus provoke a sound intensity per slice of the jet which could be determined by focusing the directional microphone system along the jet axis. Such a procedure would not be very sensible if, as we are now convinced, the jet radiates coherently over the full axial extent L_x of its sound producing volume,

$$L_x/D = 5 - 10 \qquad (4)$$

Which of the two conflicting models of the jet noise sources is correct, has become a crucial question since large-scale turbulence structures were identified as potential noise generators. For a coherently radiating jet the intensities of different source elements do not simply add in the far field and we then face the following complications:

- aggravated far-field condition.

For wave lengths of the order of the axial or radial jet dimensions L_x, L_r certain quasi-deterministic wave interference mechanisms occur which bring in the Helmholtz parameter $He = D/\lambda$ in addition to Mach and Strouhal number. In the relevant range of parameters,

$$0.5 < Ma < 2;\ 0.1 < St < 1;\ 0.05 < He < 2 \qquad (5)$$

a proper geometric far field condition would require

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$$r/D \gg \frac{1}{2}(L_x/D)^2 \; D/\lambda = 0.6 \; - \; 100 \qquad (6)$$

replacing $$r/D \gg 1 \qquad (7)$$

for the acoustic far field.

- limited resolution capability

Even if r = 100 D were assumed sufficient and if huge mirrors and arrays ($c \cong r$) with large N and $\alpha_m = 90°$ were employed, a half-way satisfactory resolution could be achieved at relatively high He only,

for the acoustic mirror: $$b/D \cong 1.22/He = 0.61 - 25 \qquad (8)$$

for the acoustic telescope: $$b/D \cong 1.12/He = 0.56 - 22 \qquad (9)$$

for the polar correlations: $$b/D \cong 0.5/He = 0.25 - 10 \qquad (10)$$

For moderate or small He, apparently none of these far-field approaches is capable of resolving for the source strength distribution along the axis.

Conclusions

We thus find ourselves in a dilemma where we may choose between violating far-field condition (6) at higher He or loosing resolution power at lower He. It is in this peculiar situation that the assumption of only locally correlated source fluctuations would enable an interpretation of the far-field data by subsequent deconvolution procedures. The latter, however, cannot produce correct results when coherent sources are involved unless their detailed space-time structure were known a priori.

We may thus conclude that far-field microphone arrangements like those in figure 1 cannot possibly solve the current controversy about the character of the turbulent sources generating jet noise. Apart from turbulence measurements in and close to the jet, more sophisticated two-point correlations in the far-field like those discussed in another paper on this conference (2) may eventually settle this question provided that jet noise researchers will ever agree on a uniform interpretation of experimental space correlations or cross spectra (3,4).

References

(1) H.V. FUCHS 1978 J. Sound Vib. 58, 117-126. On the application of acoustic "mirror", "telescope", and "polar correlation" techniques to jet noise source location.

(2) U. MICHEL and H.V. FUCHS 1978 IOA Spring Conf., Cambridge University, April 6-7.The azimuthal structure of jet pressure near and far fields.

(3) H.S. RIBNER 1978 Journal of Sound and Vibration 56, 1-19. Two point correlations of jet noise.

(4) H.V. Fuchs 1978 J. Sound Vib. (Letter to the editor). Two point correlations of jet noise and their interpretation.