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VISUALIZING ACOUSTIC FIELDS BY MEANS OF INTENSITY VECTORS

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1. INTRODUCTION

The acoustic intensity vector is a well suited quantity to visualize acoustic energy flow. With the objective that such visualization is of value, both in the teaching of students and in research work, we have over the last few years tried to make use of relatively simple experimental and theoretical techniques to obtain such vectors and to present some examples where the energy flow information gives better physical insight than mere pressure measurements. Most of our work has been concerned with pure tone sound in reactive surroundings, for instance a sound source close to a barrier or the near acoustic field of a vibrating structure.

2. EXPERIMENTAL PART

The approximate acoustic intensity expression

$$\bar{I}_r \approx \frac{1}{2\rho\Delta r} \int_{-\infty}^{\infty} \frac{I_m\{C_{12}(\omega)\}}{\omega} \, d\omega , \qquad (1)$$

where C_{12} denotes the imaginary part of the cross spectral density function between two pressures $\hat{p}_1$ and $\hat{p}_2$ [1], reduces to

$$\bar{I}_r \approx \frac{1}{2\rho\Delta r\omega} |\hat{p}_1||\hat{p}_2| \sin(\phi_1 - \phi_2) \qquad (2)$$

in the case of pure tone sound. $\phi_1 - \phi_2$ is the phase difference between the two pressures. The acoustic fields of interest have been sampled for pressure amplitudes and phases at close enough positions so that the intensity vectors might be calculated according to (2). Normally, only one microphone has been used in the sampling to avoid the sources of error introduced by two microphone channels. The phase difference is most easily obtained from $\phi_1 - \phi_2 = \phi_1 - \phi_{ref} - (\phi_2 - \phi_{ref})$, where the reference phase might be taken from a stationary microphone or from a set of loudspeaker leads.

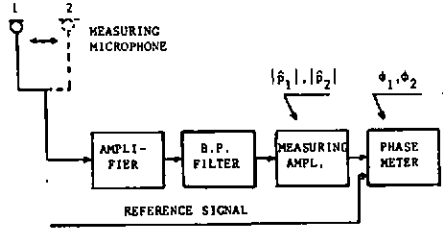

Figure 1.

Instrumentation for measuring pure tone intensity using 1 microphone.

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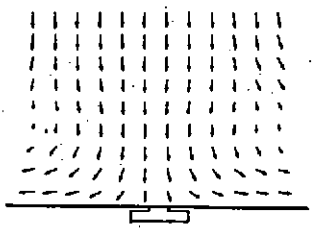

Figure 2. Sound wave incident on a Helmholtz resonator.

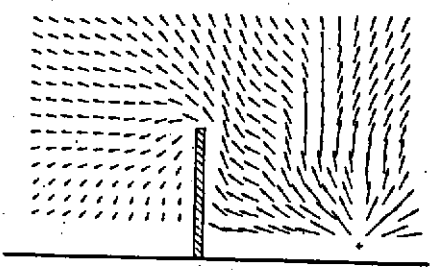

Figure 3. The intensity field across a thin hard barrier. Sound source is about one wavelength from the barrier.

3. THEORETICAL PART

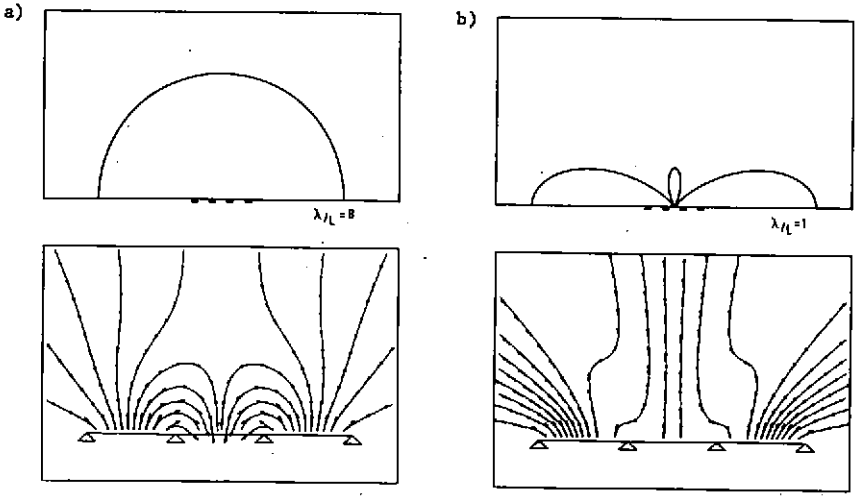

Figure 4. A three span simply supported beam in its fundamental mode. Figures show near field power flow by means of intensity vectors along acoustic streamlines as well as the far field directivity. a) $\lambda/L = 8$, b) $\lambda/L = 1$.

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Our theoretical work has primarely been corncerned with power flow in the near field of resonantly vibrating structures. Details of the near field power flow and the connection between this and far field parameters like directivity and radiation efficiency have been studied.
The starting point has also here been to evaluate the quantities of equation 2. For a baffled structure, a simple integral expression gives the complex pressure as

$$p(x,y) = \frac{j\omega\rho}{2\pi} \int_S \frac{v(S)e^{-jkr}}{r}\, ds, \qquad (3)$$

where v(S) is the velocity distribution, and r the distance from a field point x,y to an element on the surface.

At low frequencies it is often found that a part of the acoustic energy will flow back into the structure. Hence, negative intensity might be measured. A power calculation based on intensity measurements might therefore require a relatively large number of measuring points.

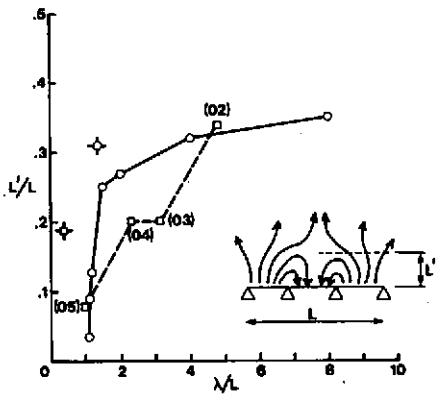

Figure 5 is a collection of data on the maximum distance away from a structure at which such inflow occurs.

—o— Fundamental mode of baffled threespan beam (theoretical)

–□– Axisymetric modes of a baffled circular (L = diameter) membrane (theoretical, ref. 2).

◇ 4.2 mode of unbaffled rectangular panel (experimental, ref. 5)

◈ Unbaffled panel with a rib (experimental, ref. 5).

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4. REFERENCES

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