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ACOUSTIC CHARACTERISTICS OF A FACE-TO-FACE MICROPHONE ARRANGEMENT FOR SOUND INTENSITY MEASUREMENT

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1. Introduction

With recent advances in electronic devices and signal processing techniques pertaining to both analogue and digital methods, acoustic intensity measurement by the two-microphone method is becoming widely used. One of the most important aspects is the choice and configuration of transducers, particularly for measurements at the extremes of the frequency scale. One microphone arrangement which is currently used consists of half-inch microphones placed face-to-face, which sense the pressure field through slots around the circumference of a cylinder comprising the microphones and coaxial mountings.

This report presents the results of an investigation of some of the acoustic characteristics of a face-to-face microphone arrangement, and the consequences of these characteristics on the accuracy of measurement of sound intensity. It is primarily concerned with amplitude response.

2. Directional Response

The directional response of a face-to-face microphone configuration was determined for various frequency bands of plane waves travelling normal to the axis of the mounting stems. The measurements were made in an anechoic environment, the source being a loudspeaker producing white noise. The 1/3-octave filtered electrical signal produced by one of the pair of microphones was recorded as they were rotated by a turntable.

Figure 1 shows the directional response for the 12.5 kHz 1/3 octave band. This plot shows the nature and relative magnitude of the directional response, the datum being the response at 0°, the direction of maximum response, when the sensing microphone is facing the source. This response shows characteristic lobes due to diffraction: a total of eight lobes for the 20 kHz and 16 kHz bands, six for the 12.5 kHz and 10 kHz bands, four for the 8 kHz and 6.3 kHz bands, and only the two principal lobes (common to all frequencies) discernible for the 5 kHz and 4 kHz bands.

The function governing this behaviour is:

$$f = \frac{2j}{\pi k_s a H_1^{(2)}(k_s a)} + \sum_{m=1}^{\infty} \frac{8j^{m+1}}{k_s a\left[H_{m-1}^{(2)}(k_s a) - H_{m+1}^{(2)}(k_s a)\right]}$$

where a = radius of cylinder

$k_s = k \sin\phi$

k = wavenumber

ϕ = angle between microphone axis and field direction

$H^{(2)}$ = Hankel function.

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As the microphone is rotated from 0° incidence then k_s increases from 0 to a maximum value of k. As k increases the number of significant terms increases which interfere to produce the characteristic responses.

3. Frequency Response

To relate the directional responses, the frequency response of the basic microphone element is required.

The field was calibrated for 1/3-octave filtered bands of noise from 4 kHz to 20 kHz centre frequencies using a Brüel and Kjaer 4133 free field microphone, of which the free field response is known, facing towards the source. The face-to-face microphones were then placed in this calibrated field position at a specified orientation to the field (0° in the first instance) and the 1/3-octave responses of one microphone noted. The diaphragm of the microphone forms one end wall of a cylindrical cavity, the other end wall being an aluminium cap fitted to the face of the protection grid. Approximate dimensions of this cavity are a radius of 6.6 mm and a length of 1 mm.

At low frequency, the distribution of the magnitude and phase of the pressure oscillations will be essentially uniform within this cavity; at higher frequencies the first radial acoustic resonance is approached. The microphone electrical output will be a weighted average of the pressure distribution within the cavity, the weighting being due to the variation of sensitivity across the microphone diaphragm.

To infer the "diaphragm averaged" pressure in the cavity, the actuator response of the microphone is subtracted from the readings and to normalise, the field correction (as measured by the 4133) is also subtracted. An adjustment must also be made to compensate for sensitivity differences. This gives (in dB) the diaphragm averaged pressure in the cavity relative to the excitation pressure of the incident field. This procedure was followed for three microphones which are all one half-inch in diameter but with different sensitivities and actuator responses. The cavity pressure gains show that the range of dynamic diaphragm characteristics represented here have a small effect compared to the overall effect of the radial resonance, and that this resonance follows closely to $20 \log 1/J_0$ except at high frequency near the resonance, where damping will determine the characteristic.

4. Discussion

A way of exploiting the non-uniform directional and frequency response characteristics is to choose a separation distance for the microphones which produces a finite separation error in intensity measurement which compensates for the radial resonance gain. For the case of half-inch microphones this distance is approximately 12 mm. This will also produce a partial compensation at angles other than 0° to the incident field and thus increases the directional range for a given limit of accuracy. For this compensation to work, the actuator response of the microphone must be flat to the highest desired frequency, that is to say pressure microphones are more suitable than free-field microphones.

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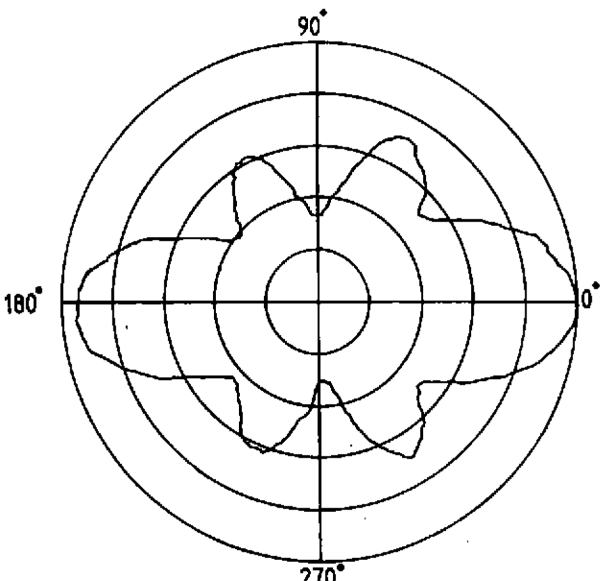

Figure 1. 12.5 kHz Directional Response.

Frequency (Hz)	F.S.E. (dB) (12 mm, 0^o)	Microphone Response (0^o) (dB) (12 mm, 0^o)	
12500	-8.9	+7.9	±2.0
10000	-4.4	+4.7	±0.8
8000	-2.6	+2.4	±0.4
6300	-1.5	+1.7	±0.2
5000	-0.9	+1.3	±0.1
4000	-0.6	+0.5	±0.1

Figure 2. Table of 12 mm Finite Separation Error and a 0^o incidence microphone frequency response.