Proceedings of The Institute of Acoustics

THE ACOUSTIC FIELD OF A SOLID DIELECTRIC TRANSDUCER WITH A METALLIC DIAPHRAGM

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INTRODUCTION

A sensitive and stable transducer has been designed and constructed for use in the 100 kHz region at elevated temperatures and in certain hostile environments.

Measurements reported here of the far field produced by the device can be accounted for on the assumption that it behaves as a uniformly radiating piston source: near field measurements suggest a source in which the radiation efficiency varies over its surface in a manner which is not completely axially symmetrical.

THE TRANSDUCER

In its usual practical form a Sell-type transducer consists of a thin metallised film stretched over, and in contact with, a roughened metallic counter-electrode. An ac voltage in series with a dc potential applied between the conductors causes the foil to vibrate utilising the voids behind the foil created by the surface irregularities.

The present device has instead a thin metallic foil as its radiating surface and the anodised surface of a roughened aluminium counter-electrode provides the dielectric. When used with a 6.1 μm aluminium foil the device operates satisfactorily, at least at moderately elevated temperatures. The counter-electrode is 0.040m in diameter, the device capacitance is in the region of 300pF and it withstands the application of 350v dc for long periods without breakdown.

MEASUREMENT METHODS

Experiments have been performed in air at room temperature (a) to measure the far field sensitivity of the device (b) to explore spacial variations of pressure and phase in the near and far fields (c) to examine the pulse response and resonance frequency of the diaphragm.

For this purpose a microcomputer-based data acquisition system has been designed and constructed to control the movement of a probe microphone throughout a plane parallel to the transducer foil at various axial distances from the foil and to analyse the results.

Source signals used were bursts of sine waves of 100kHz synthesised from the output of a 10MHz crystal oscillator. The length of the burst was selectable in integral numbers of cycles from one upwards; usually a 16 cycle burst of 8v rms was satisfactory in conjunction with a 250v bias voltage. This form of excitation removed the effects of unwanted reflections.

The acoustic signal was detected using B&K types 4138 ⅛" microphone, 2619 pre-amplifier and 2607 measurement amplifier incorporating special low-Q filters for minimising transient disturbance. A Datalab type DL920 8-bit fast capture device sampled and digitised the 2607 output at a rate of 0.1 μs and returned the data to the microcomputer for processing and storage: machine code routines were used throughout to achieve the necessary speed.

Acoustic pressure was computed as the rms value of 10¼ cycles at the centre of the burst. Relative phase changes across the measurement plane were estimated digitally by detection of the time delay, reckoned as a number of 10MHz pulses, from the initiation of the burst to the detection of a particular zero-crossing point in the captured pulse. This allows a theoretical resolution of 3.6 degrees of phase. The ⅛" microphone is approximately one wavelength in diameter and this implies the phase estimate was necessarily a form of average of the values for the immediate locality of the measurement points.

RESULTS

Far field sensitivity

This was obtained by direct system comparison with a B&K type 4220 Pistonphone and includes allowance for the manufacturer's estimate of an 8dB increment (electrostatically determined) in the free field response of the microphone at 100kHz. For three different foils taken from a sample of 6.1 μ m aluminium the sensitivities evaluated for an axial distance of 0.30m and corrected for air absorption averaged 110dB re 20 μPa per volt with a range of 0.7dB.

Damping and resonance frequency

A 23v,80 μs, square voltage pulse was imposed on the 250v bias voltage. The resulting acoustic signal was detected at an axial range of 0.30m and reformed as an analogue signal from the capture device. The applied pulse and the acoustic response are shown in fig.1. Manufacturer's information [1] indicates the observed transients are mainly or entirely produced by the new transducer; the observed transient are substantially unaltered when the low-Q filters are removed.

From this it appears the resonance frequency is approximately 87kHz, a figure which is confirmed by separate measurements using continuous waves. This implies that when excited at 100kHz, the device is operating in its mass-controlled region with the benefit that the unavoidable second and higher order harmonic distortion is correspondingly suppressed.

The Q factor of the radiating device is estimated to be approximately 2.

Pressure and phase variations

Pressure and phase data were taken at various axial distances, z, between z = 0.30m which is in the far field $(z = 2.55a^2/\lambda)$ and z = 0.04m which is clearly within the near field $(z = 0.34\ a^2/\lambda)$.

Selected results are presented in figures 2 to 4 for z = 0.30m, 0.04m and 0.12m respectively. From the rectangular measurement grid at each separation points lying along four equally spaced diameters have been extracted for clarity and plotted with identifying symbols. The data presented refer to one particular 6.1 m foil using 8v rms ac on top of 250v dc voltage.

In figures 2a and 2b the solid lines represent the expected spatial pressure and phase variations based on the assumption of a simple circular piston in an infinite baffle. The rms displacement under these operating conditions is calculated to be approximately 0.16 μm. Any variations in radiating efficiency which may occur across the surface of the transducer would not be expected to affect the quality of fit of the experimental data to the theoretical curves.

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In figures 3a and 3b which are in the near field the solid curves are calculated from the predictions of Seki, Granato and Truell [2] . These curves have been evaluated by assuming a uniformly radiating piston of 0.034m diameter. The fit to the experimental data is markedly better when this reduced apperture size is assumed instead of the full geometrical apperture (0.040m) of the counter-electrode. It is clear that the detailed field pattern is less than perfectly accounted for in this manner. The implication would appear to be that the radiating surface suffers spatial variations of radiative efficiency across its surface and that these variations have an axially symmetrical component.

The intermediate case of z = 0.12m is presented in figures 4a and 4b. The solid lines represent the predictions of [2] assuming the same (0.034m) effective piston diameter.

Additional measurements made with two, nominally identical, foils produce, as may be expected, identical behaviour in the far field region to that shown in figures 2a and 2b. In the near field, the assumption of a reduced piston diameter still holds but there are significant variations among the detailed patterns.

REFERENCES

[1] Condenser Microphones and Microphone Preamplifiers, Messrs. Bruel & Kjær p,64 December 1976.

[2] "Diffraction effects in the ultrasonic field of a piston source and their importance in the accurate measurement of attenuation", Seki H., Granato A., Truell R., J. Acoust Soc. Am., 28, 2, 230 - 238, 1956.

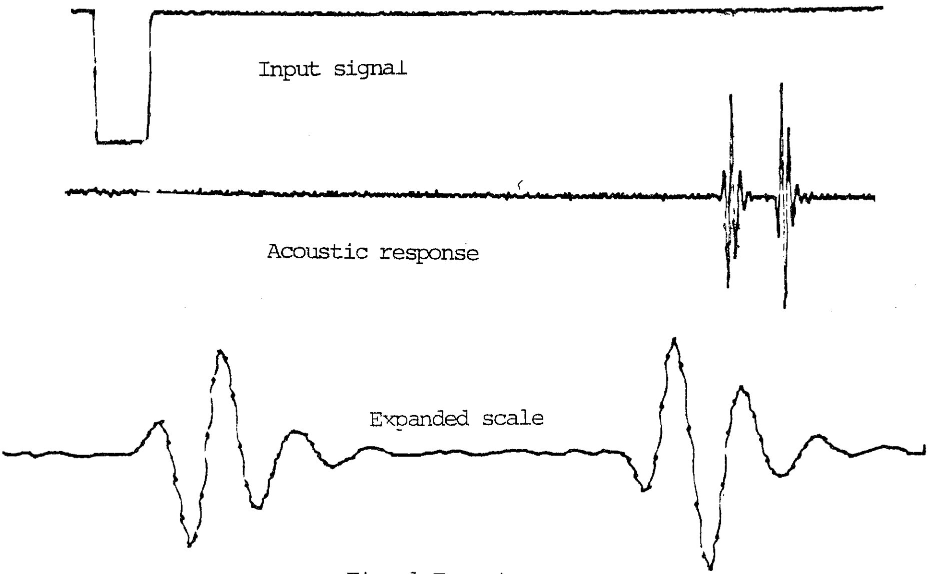

Fig. 1 Transient response

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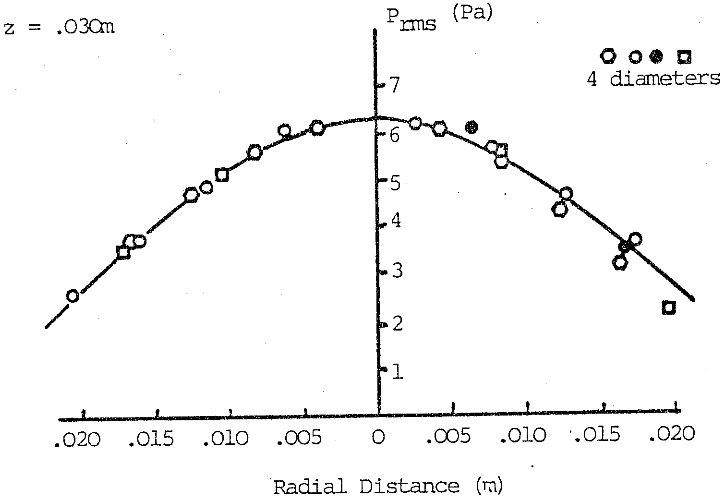

Fig. 2a

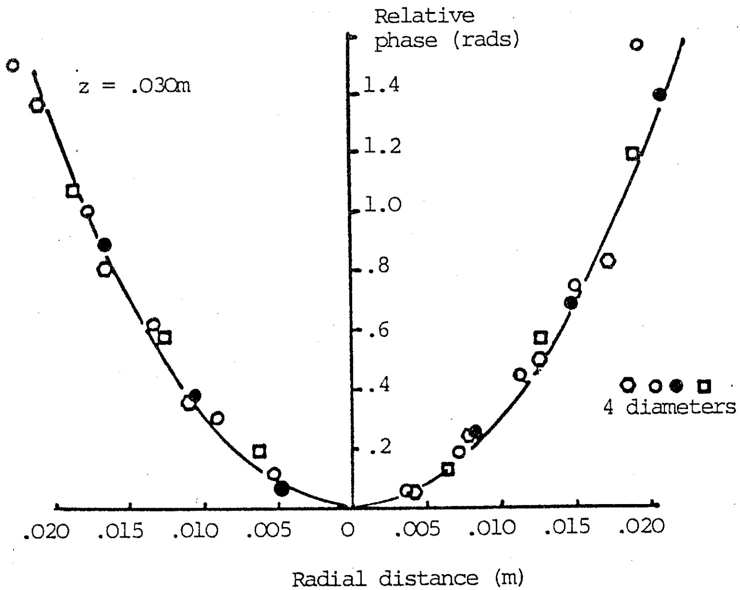

Fig. 2b

A SOLID DIELECTRIC TRANSDUCER WITH A METALLIC DIAPHRAGM

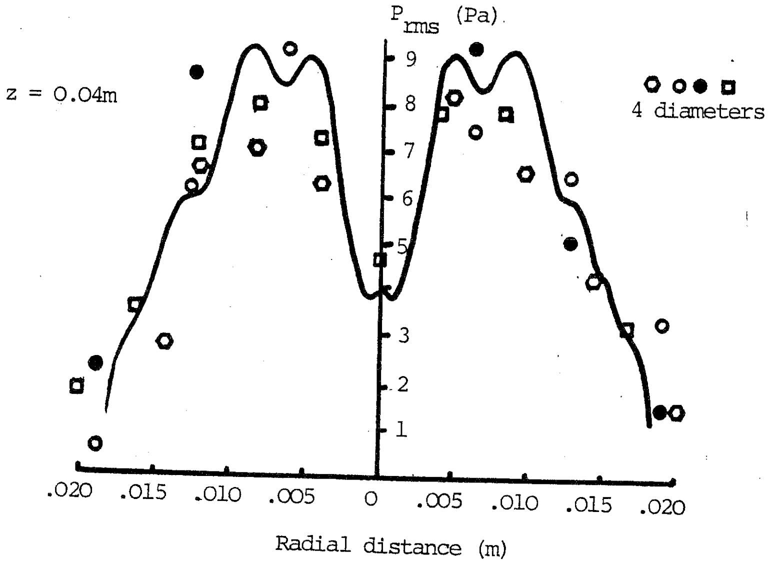

Fig. 3a

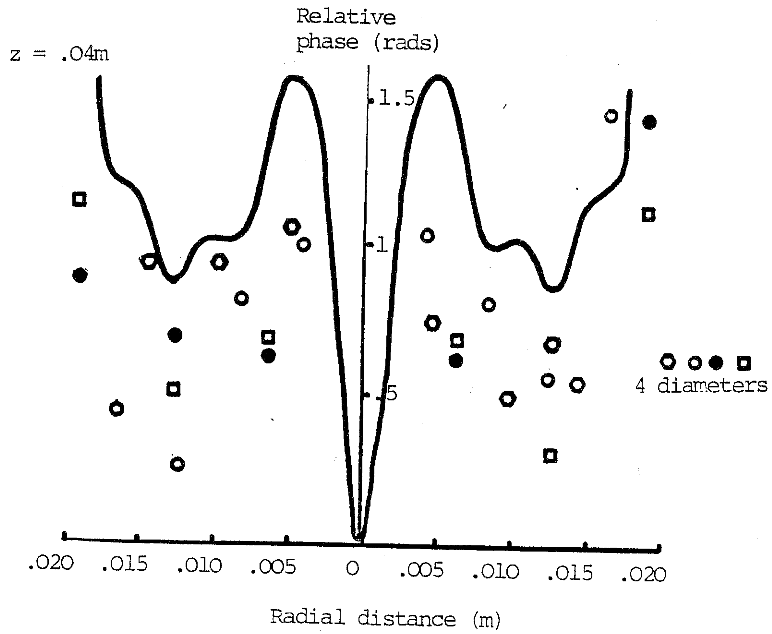

Fig. 3b

A SOLID DIELECTRIC TRANSDUCER WITH A METALLIC DIAPHRAGM

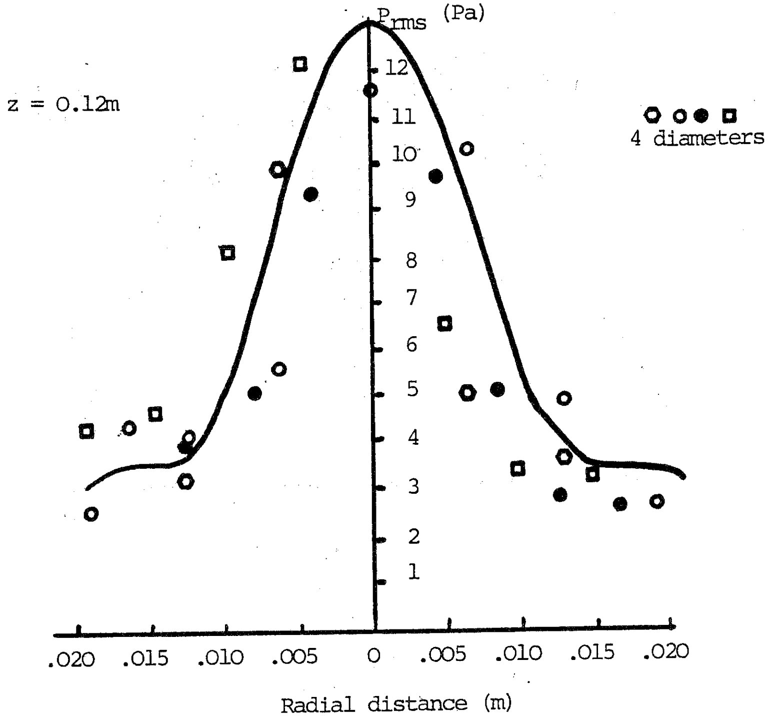

Fig. 4a

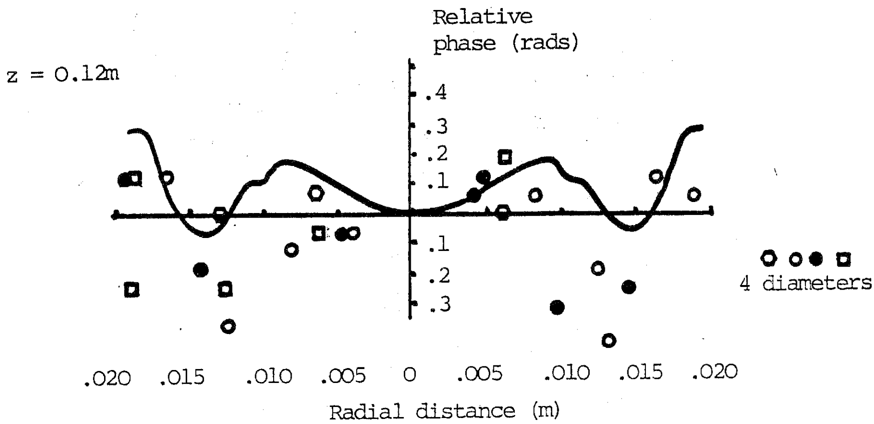

Fig. 4b