Computational acoustics and some applications to electromechanical and electroacoustic transducer design

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With the advent of digital computers computational approach is now well-accepted and increasingly practiced in many branches of engineering. The acoustical engineering is the field to which the computational approach could effectively be utilized, as it belongs to the classical physics in which mathematical models or governing equations are well-established. The acoustics deals with sound waves and vibrations in fluid or elastic media, for which wave equation or Helmholtz equation of scalar- or vector- type is to be solved under proper prescribed initial and boundary conditions. This is generally a difficult task but now numerical solution is possible, and finite element and boundary element methods are most promising for computer implementation.

During the last decade, we have been applying these techniques to various acoustical problems; namely the bounded or unbounded field, the coupled fluid-structural problem in which the acoustic field couples to the elastic vibration and the coupled electro-mechanical problem in which the electric field couples to the elastic vibration.

We will first discuss acoustic field problems demonstrating the frequency characteristics of a vocal tract. Then we will discuss the coupled fluid-structural problem demonstrating the responses of a cochlea model, a loudspeaker and a condenser microphone. Lastly, we will consider piezoelectric or electrostructive device problems, demonstrating piezoelectric or electrostructive resonator, filter and sonar design.

In this digest, we present only two examples. The loudspeaker (Fig.1) is a device in which sound production is made by a vibratory diaphragm that is electrodynamically driven. The electrical current is converted to the force which drives the conical shell. The cone is axisymmetric and the finite elements are used for modelling the shells and the concave field (Fig.2). The outer region is considered for radiation by the eigenfunction expansion approach. The coupling condition is established so that the volume displacement is compatible between the shell-medium interface boundaries.

Fig.4 illustrates the cross-section of a condenser microphone with removable nose cone. Capacitance is formed between the stretched diaphragm and the backplate. The vibration is excited in the diaphragm due to the arriving sound and changes the air gap allowing the displacement current through the condenser electrically biased. The boundary element method is used throughout. The configuration and the element division in the diaphragm region is shown in Fig.5. The damping in the air gap is also taken into account. The measured results are also shown in the figures for both cases.

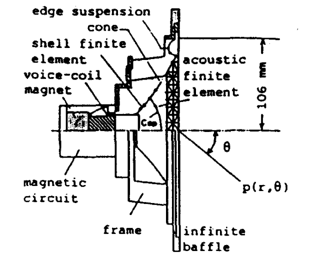


Fig.1 Cross-sectional view of the direct-radiator type loudspeaker model

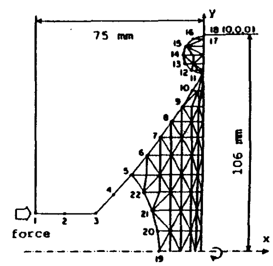


Fig.2 Finite element division for the calculated model

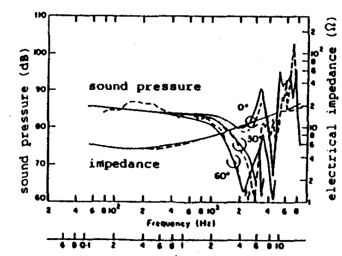


Fig.3 Calculated and measured(---) far field sound pressure and electrical impedance

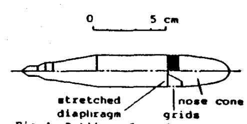


Fig.4 Outline of condenser microphone with nose cone

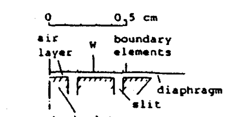


Fig.5 Boundary element on thin layer. The thickness of air layer is enlarged.

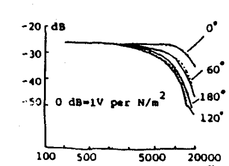
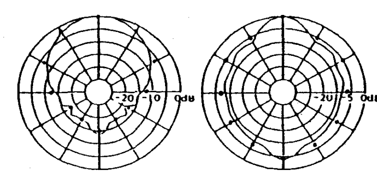


Fig.6 Frequency response of microphone with priamplifier in free field. ——— computed, ······· measured by B&K.



(a) without nose cone (b) with nose cone

Fig.7 Directivities of microphone in free field (frequency=15000Hz)
—— computed, • measured by B&K