Wave Propagation in an Infinite Elastic Plate in Contact with an Inviscid Liquid Layer

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velocity steps and CW pulses. Neither the wave-harmonic series, which converges poorly at early times, nor geometric acoustics, which predicts zero pressure on passive elements, is applicable. A technique successfully used for CW impedance calculations was adapted to transient situations. On passive elements, the pressure is computed from Watson's "creeping-wave" formulation, which fails on the active element; there, the pressure is approximated by ignoring baffle curvature. The required Laplace integrals are available in the literature. Numerical results are presented. [Sponsored by Naval Ship Systems Command, under Computer Applications, Inc. subcontract.]

9:45

4B2. Numerical Calculation of Farfield of Transducer Array near Critical Frequency. George Chertock, *Naval Ship Research and Development Center, Washington, D. C. 20007.*—For the case of a simple box-shaped transducer array, operating near a frequency at which the *interior* space of the box has a standing-wave solution with $p=0$ at the surface, one method of calculating the external radiation field has been developed and demonstrated by Schenck [J. Acoust. Soc. Amer. **44**, 41–58 (1968)]. An alternative method of solution to this same problem is demonstrated, based on an approximation to the sound pressure at the surface of the array.

10:00

4B3. Some Solutions to a Mixed-Boundary-Value Problem. L. P. Solomon, *Department of Mechanical Engineering, University of Michigan, Ann Arbor, Michigan 48105* and N. Schryer, *Mathematics Department, University of Michigan, Ann Arbor, Michigan 48105.*—Most problems in wave propagation are characterized by boundary conditions of only one type, e.g., vanishing normal-velocity components in the case of a resonant cavity. The problem investigated by D. L. Lansing, C. E. Watkins, and G. T. Kantarges, "Oscillating Pressures within a Cylindrical Chamber that Has a Circular Piston in One End Wall" [J. Acoust. Soc. Amer. **36**, 2222–2232 (1964)] is also of that type. A problem in the same vein, but with a pressure-release surface somewhere on the cylinder surface appears to be a logical and simple extension, but this is not the case, since the boundary conditions become mixed. Numerical techniques have been employed to obtain solutions to the problem of a cylinder with a piston of smaller radius than the cylinder radius at one end, with the shoulder having either a vanishing velocity condition or pressure-release condition imposed. Cases where the piston is inserted in the cylinder are also presented. Comparisons are made to the analytical solutions attained by Lansing *et al.*

10:15

4B4. New Method for Acoustical Radiation Problems with Mixed-Boundary Values. John L. Butler, *Parke Mathematical Laboratories, Inc., Carlisle, Massachusetts 01741.*—A series-expansion method for the solution of acoustical-radiation problems with mixed-boundary values is presented. The condition of a given velocity on a transducer face and a given pressure or impedance on the surrounding boundary is of interest in underwater acoustics. With this mixed-boundary condition, solutions are difficult to obtain using the usual methods in even the simplest cases. In the method presented here, a wavefunction expansion is truncated to include only the number of terms equal to the number of specified boundary values. The solution improves as this number increases, and coefficients may be evaluated through a matrix inversion as in a nearfield-to-farfield prediction method presented previously [J. Acoust. Soc. Amer. **44**, 351(A) (1968)]. The particular case of a radiator on a sphere is treated and results are presented that show that the sound beam is more directive if the remaining portion of the sphere is soft. [Work sponsored by the Office of Naval Research (Acoustics Programs Branch).]

10:30

4B5. Computer Display of Array Characteristics. G. W. Byram and G. V. Olds, *Acoustics Division, Naval Research Laboratory, Washington, D. C. 20390.*—The calculated response of a linear array of isotropic point sensors to a plane wavefront has been displayed in three-dimensional computer plots. These plots display beamformer output as a function of signal angle and a third variable selected from frequency, beam angle, and array shading. Sidelobes appear as sharp ridges that curve across the baseplane of the plot. Changes and shifts in sidelobe structure as a function of the third variable are readily visible. General equations for contours of constant amplitude in the signal-angle, beam-angle, and signal-angle frequency planes are derived. Plots of these equations can be used to extrapolate one known beam pattern to other beam angles and frequencies.

10:45

4B6. Analysis of Array with Nonlinear Amplifier/Transducer Modules. R. F. DeLaCroix, *General Dynamics Electronics Division, Rochester, New York 14601.*—Procedures for modeling the performance of a transmitting array require either an explicit or implicit definition of the velocity of each radiating element as a function of the electrical input signal and the acoustic pressure on the radiating surface. To date, most array modeling work has been restricted to linear systems where the velocities are computed from the electrical input signal and the linear equivalent circuit for each element in the array. When an array contains nonlinear amplifiers or transducers, this equivalent circuit, in general, will be a function both of the input signal and the pressure on the radiating surface, and the linear analysis techniques cannot be used. Two methods, repeated matrix inversion and iterative lookup, have been developed and applied to the hydroacoustic amplifier/transducer module. In both methods, the nonlinear operating profile characteristics of the coupled amplifier/transducer module are known, either by prediction using a simulation program for nonlinear devices or by measurement. The operating profile is defined by several equivalent Thevenin circuits in the former method and by tabular data in the latter. Several examples show that for larger arrays the latter method requires much less computer time and storage than the matrix method.

11:00

4B7. Wave Propagation in an Infinite Elastic Plate in Contact with an Inviscid Liquid Layer. W. W. Walter and G. L. Anderson, *Watervliet Arsenal, Watervliet, New York 12189.*—The dispersion relation for straight-crested waves in an isotropic plate in a state of plane strain that is covered by a layer of an incompressible liquid is derived and investigated in the limits of very long wavelengths (thickness–stretch vibrations of the plate–liquid system) and of very short wavelengths (surface waves and the solid–liquid interface). In the case of surface waves, there are two dispersive modes, one predominantly elastic (analogous to Rayleigh waves) and the other essentially fluid, and in the thickness–stretch case, there are an infinite number of essentially elastic modes and one fluid mode. An approximate version of the dispersion relation valid for arbitrary wavelength is obtained by using two nonclassical plate theories to account for the extensional and flexural deformations of the plate. This relation gives rise to five modes on the real branch, which are identified as being thickness–stretch, thickness–shear, flexural, extensional, and fluid in character, and three modes on the imaginary branch, namely, flexure, thickness–shear, and thickness–stretch. Two of the five cutoff frequencies are modified by the presence of the liquid layer. A variety of numerical results are presented in graphical form.

11:15

4B8. Acoustic Radiation from Fluid-Loaded Rectangular Plates. HUW G. DAVIES, *Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*—The acoustic radiation into a fluid-filled infinite half-space from a randomly excited, thin rectangular plate inserted in an infinite baffle is discussed. The analysis is based on the *in vacuo* modes of the plate. The modal coupling coefficients are evaluated approximately at both low and high (but below acoustic critical) frequencies. An approximate solution of the resulting infinite set of linear simultaneous equations for the plate modal velocity amplitudes is obtained in terms of modal admittances of the plate–fluid system. These admittances describe the important modal coupling due to both fluid inertia and radiation damping effects. The effective amount of coupling, and hence the effective radiation damping acting on a mode, depends on the relative magnitudes of the structural damping—i.e., on the widths of the modal resonance peaks and on the frequency spacing of the resonances. Expressions are obtained for the spectral density of the radiated acoustic power for the particular case of excitation by a turbulent boundary layer. [Work supported by the Office of Naval Research.]

11:30

4B9. Sound Radiated by Beam-Stiffened Plate. D. FEIT AND H. SAURENMAN, *Cambridge Acoustical Associates, Inc., Cambridge, Massachusetts 02139.*—A common structural element in aerospace and marine vehicle design consists of a relatively thin skin supported by a framework of attached beams. The present study treats this configuration as a thin elastic plate with one or more parallel beams attached. In order to find the sound pressure radiated by such a plate, the dynamic response of the plate beam system is first computed following the procedure of Lamb [J. Acoust. Soc. Amer. **33**, 628–633 (1961)]. The two-dimensional Fourier transform of the response thus obtained is used to calculate the radiated sound pressure. The resulting pressure field is then used as an indirect means of finding the significant interframe resonances. [The work presented here was supported by the Office of Naval Research Structural Mechanics Branch.]

11:45

4B10. Comparison between Theory and Experiment for a Mechanical Luneberg Lens. G. A. BRIGHAM, *Autonetics Division of North American Rockwell Corporation, Anaheim, California 92803.*—The first mechanical Luneberg lens was built and tested by Toulis in the latter half of the previous decade. Using the wave theory [C. A. Boyles, J. Acoust. Soc. Amer. **43**, 709 (1968); G. E. Lord, J. Acoust. Soc. Amer. **43**, 1177(L) (1968); G. A. Brigham, Int. Congr. Acoust., 6th, Tokyo (August 1968)] for a Luneberg lens with a monopole feed close to the nearfield, we have computed, for Toulis' test conditions, the polar response of an ideal lens. The comparison is within 4 dB throughout the 180° scanning pattern. Visual observation of Toulis' compliant-tube lens reveals that the actual fabrication would produce some cylindrical effects in the lens. When allowances are made for this, the theory and experiment are observed to be within 2 dB of each other in the full pattern over the 2 oct test bandwidth.

12:00

4B11. Sinusoidal Horns. B. N. NAGARKAR, T. D. MATHIS, A. P. RIPPER, AND R. D. FINCH, *Department of Mechanical Engineering, University of Houston, Houston, Texas 77004.*—It is pointed out that a sinusoid satisfies Salmon's criterion for a good horn shape. Calculations have been made of the throat impedance of sinusoidal horns of various dimensions, including the case of a single globe terminating in a cusp. Depending on the relative dimensions of the mouth and throat, the device may be used as an impedance transformer. Experimental determinations of directivity of an underwater horn have been made and found to compare favorably with conical horns. Finally, it is demonstrated that several musical instruments employ sinusoidal cavities, the bell of the English horn being discussed in particular.

TUESDAY, 4 NOVEMBER 1969 — DON ROOM, 9:30 A.M.

Session 4C. Interaction of Light with Sound Waves I

O. K. MAWARDI, *Chairman*

Invited Papers (40 minutes)

9:30

4C1. Birth and Growth of Brillouin Scattering. LEON BRILLOUIN, *New York.*

(Abstract not received)

10:15

4C2. Quantitative Investigations of Stimulated Brillouin Scattering. W. KAISER, *Physics Department, Technische Hochschule, Munich, Germany.*

(Abstract not received)

11:00

4C3. Resonance-Enhanced Brillouin Scattering in Crystals. R. ITO, E. BURSTEIN, A. PINCZUK, AND M. L. SHAND, *Department of Physics, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*—The Brillouin scattering intensity exhibits resonance enhancement as the frequency of the incident