Use of the complex intensity vector for sound radiation and sound field studies

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Citation: The Journal of the Acoustical Society of America **78**, S24 (1985); doi: 10.1121/1.2022712
View online: https://doi.org/10.1121/1.2022712
View Table of Contents: https://asa.scitation.org/toc/jas/78/S1
Published by the Acoustical Society of America

boundaries. In this study, we add to random structural effects those of a lossy bottom interface consisting of large-scale random facets with curvature, on which may be superimposed small-scale roughness. Each facet is assumed to possess small random slope, depth deviation, and curvature. Initially, we take acoustic rays to be specularly reflected from a large-scale facet bottom, and derive formulas for the mean and variance of incoherent intensity at a point receiver for a transmitted cw signal. The results are sufficiently general to permit their use with different bottom-acoustic models. Relative effects of structure and topography are compared. Subsequently, small-scale roughness is added to the facets, and the consequences of scattering are considered. [Work supported by ONR.]

4:35

K13. The stabilization of stepwise coupled modes. Richard B. Evans (Naval Ocean Research and Development Activity, NSTL, MS 39529)

A decoupling algorithm is derived to stabilize the calculation of the stepwise coupled modes. The stepwise coupled mode method reduces the elliptic wave equation in a discretely range-dependent environment to the solution of a matrix two-point boundary value problem. The solution of such boundary value problems can be unstable in the presence of modes whose amplitudes both grow and decay rapidly with range. This stability problem affects the accuracy of the stepwise coupled mode solution as range and frequency increase. The decoupling algorithm described here solves this stability problem. The algorithm makes it possible to decouple the growing solution from the decaying solution. Then each solution can be computed accurately by integrating in a direction in which the solution decays. The stabilized stepwise coupled mode method is more accurate at longer ranges and higher frequencies than the original method. [Work supported by NORDA.]

4:50

K14. Acoustical effects of ocean current shear in the parabolic approximation. J. S. Robertson (U. S. Military Academy, West Point, NY 10996-1786), M. J. Jacobson, and W. L. Siegmann (Rensselaer Polytechnic Institute, Troy, NY 12180-3590)

In a previous study [J. S. Robertson, W. L. Siegmann, and M. J. Jacobson, J. Acoust. Soc. Am. 77, 1768–1780 (1985)], the authors developed a family of parabolic equations which include effects due to the presence of a steady, depth-dependent current. Three of these equations contained a new term which explicitly depended on current gradient. In this work, we study the effects of this new term. By appropriately transforming and simplifying, the equations are transformed into parabolic equations which can be integrated numerically with existing implementations. Presence of ocean current fine structure is one mechanism which can require new terms. Propagation is examined in a shallow isospeed channel with a lossy bottom and a variety of shear flows, some of which model actual ocean flows. Current fine structure can induce variations in intensity which are substantial and which depend on shear structure, source and receiver locations, and frequency. Finally, intensity differences are examined in reciprocal sound transmissions. [Work supported by ONR.]

TUESDAY AFTERNOON, 5 NOVEMBER 1985 — SUITE 4, 1:30 TO 4:45 P.M.

Session L. Shock and Vibration I: Acoustic Intensity: Experiments and Computations

Richard V. Waterhouse, Chairman

David W. Taylor Naval Ship Research & Development Center, Bethesda, Maryland 20084

Chairman's Introduction—1:30

Invited Papers

1:35

L1. Recent developments in acoustic intensity. Gunnar Rasmussen (Brüel & Kjær, 18 Nærum Hovedgade, 2850 Nærum, Denmark)

The development of intensity measurement techniques has increased the demand for knowledge about the transducers used and for improved calibration techniques. The phase response of transducers is very important. Knowledge about the behavior of transducers at higher frequencies is especially significant for the determination of the effective acoustical spacing between transducers. The use of two, four, or six transducer probes is required in order to obtain the total energy density at a point. The estimation of the active intensity and the reactive intensity of a wave field depends on proper use of instrumentation and calibration technique and proper use of the transducers in a wave field. The configuration in which the transducers is mounted plays an important role in obtaining good data. Development in instrumentation enables the use of gating techniques, which improves the signal enhancement. By combining information in frequency and time domain a better understanding of source behavior is achieved.

2:00

L2. Use of the complex intensity vector for sound radiation and sound field studies. Jiri Tichy and Adin Mann (Graduate Program in Acoustics, The Pennsylvania State University, State College, PA 16804)

The traditional intensity technique to determine the sound power radiated by sources or propagating through a sound field uses the real part of the complex intensity only. More information on the sound field and sound radiation can be obtained if both real and imaginary components of the intensity vector are considered. This paper presents the results of studies of the fundamental relationships between sound pressure, particle velocity, complex intensity, and both potential and kinetic energy. As shown before, the real part of the intensity vector is rotational (curl $I_r \neq 0$, div $I_r = 0$), while the imaginary (reactive) component of the complex intensity vector is irrotational (curl $I_i = 0$, div $I_i \neq 0$). The conditions of the vortex formation were studied as a function of the source distribution. The relation between the extremes of the intensity curl and the energy in the sound field have been formulated. The applications of the sound intensity field structure on the sound radiation from complex radiators is shown using specific examples. New graphical methods of presenting the intensity field are shown. The paper also presents experimental results obtained by an automatic computer controlled system for intensity measurements.

2:25

L3. Measurement of the acoustic intensity in the nearfield of a fluid-loaded, point-driven cylinder using nonplanar nearfield acoustical holography. Earl G. Williams (Naval Research Laboratory, Code 5133, Washington, DC 20375-5000)

Nearfield acoustical holography (NAH) is confined to the reconstruction of acoustic fields in parallel planes with a hologram consisting of a measurement of the acoustic pressure over a plane boundary. Although ideal for planar sources, such as vibrating plates, NAH encounters problems in dealing with nonplanar sources. Therefore, we have modified the technique to apply specifically to a cylindrical geometry with a hologram comprising a cylindrical contour. The cylindrical hologram consists of the measurement of the amplitude and phase of the pressure field at 4096 points on this cylindrical contour. This contour is located close, and concentric with, a radiating cylindrical source (in this case a finite, point-driven cylindrical shell submerged in our underwater tank facility). We show how this hologram is processed in a rigorous manner to map the pressure, vector velocity, and vector intensity (real and reactive components) from the surface of the source into the farfield. The vector intensity maps are shown to be helpful, in many cases, in identifying the location of the point driver attached inside the shell. Both the active and reactive intensity fields will be shown. Since the vector velocity is also obtained from the cylindrical hologram, we can identify the radial mode shape of vibration from the radial velocity component at the shell surface, and along with the reconstructed surface pressure (which provides the fluid loading) we can also map the surface intensity. This latter quantity is used to compute the total power radiated by this mode shape. This new technique provides a comprehensive method to study radiation from cylinders.

2:50

L4. Energy streamlines for sound sources. R. V. Waterhouse and D. Feit (David Taylor Naval Ship Research & Development Center, Bethesda, MD 20084-5000)

These streamlines are constructed so that at each point on one, the sound intensity vector is tangential to the streamline. They thus show the direction of flow of the sound energy in an acoustic field. Energy streamlines are formally analogous to the velocity streamlines familiar in fluid mechanics, and for axially symmetric sources represent contours of the Stokes stream function. The latter function can be computed from the intensity function, as the two are analytically related in a skew differential manner. Examples of the streamlines are given for the circular piston source in an infinite rigid baffle and the water-loaded plate driven by a line or a point source. The streamlines are chosen so that equal energy flows between each adjacent pair of streamlines. The sound pressure field is irrotational, but the sound intensity field is rotational, and interesting patterns of circulating energy, including vortices, occur for some source configurations.

Contributed Papers

3:15

L5. Some problems associated with making sound intensity measurements in the presence of reverberant fields and/or background sources. A. F. Seybert and J. A. Holt (Department of Mechanical Engineering, University of Kentucky, Lexington, KY 40506-0046)

This paper is concerned with potential problems that one may encounter when attempting to use the two-microphone method to determine the sound intensity and sound power of a source when background and reverberant fields are present. Under such conditions, the primary variables controlling the accuracy of the sound intensity estimate are shown to be the ratio of the unknown intensity to the mean-square pressure of the background/reverberant field and the accuracy of the estimate of the phase angle between the two microphones. Proceeding from a few simple concepts we illustrate the abovementioned measurement problem with results obtained from a controlled experiment. [Work supported by International Business Machines Corporation.]

3:30

L6. A nonlinear coherence function and its application to machine diagnostics. Tom Coffin and Jen Yi Jong (Wyle Laboratories, P. O. Box 1008, 7800 Governors Drive West, Huntsville, AL 35807-5101)

The harmonic content in dynamic measurements from rotating machinery contains much subtle information concerning equipment operational condition and component degradation. For this reason, the power density spectrum (PSD) has long been employed to assess the relative magnitude of fault-related spectral contributions. Measurements on high-performance rocket engine turbomachinery suffer from severe noise contamination from numerous extraneous sources, which impedes rotating element diagnostic evaluation. It is thus difficult to determine whether an apparent high-level harmonic contribution is indeed related to the fundamental rotational frequency, f_1, or possibly due to an independent source. The ordinary PSD, being an absolute value, is of no assistance to this problem. In an effort to relate synchronous speed characteristics with an