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Previous investigators have recognized that an approximation may be made to the eigenfunctions and eigenvalues for a Pekeris waveguide such that the eigenfunctions end in a node at an effective pressure release bottom below the actual bottom. A simple graphical derivation of the approximation is presented and the accuracy of the approximation for the marine sediments found to be typical of bottoms along the continental shelf is investigated. For a water column capable of supporting up to 74 modes, the approximation results in errors in the vertical wave number of less than 0.25% for all modes for all bottom types. This modest error indicates that the approximation should be useful in modeling various problems.

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...sion technique for the solution of a normal mode ... model. M. F. Werby and Joe Soileau (NOARL, Numerical ... Div., Stennis Space Ctr., MS 39529)

It is sometimes desirable to obtain a normal mode solution of a waveguide problem in a closed mathematical form. In particular, here, the vertical part of the solution in terms of a sine series for a variable velocity profile where the sine functions are eigenvalues for a suitable isovelocity case is desired. This problem has been done within the context of conventional perturbation theory and was found to be too limiting, particularly for the lower-order modes. It is possible, however, to exploit Sturm–Liouville theory and closure to obtain a coupled system of equations that leads to an adequate sine expansion as well as the appropriate eigenvalues. A new perturbation method is also derived from the results that is less limiting than the conventional perturbation approach and should be of general value to other classes of problems. Calculations are performed and compared with other numerical techniques.

3UW4. Modeling air-to-water sound transmission using standard numerical codes of underwater acoustics. David M. F. Chapman, Dale D. Ellis (Defence Res. Establishment Atlantic, P.O. Box 1012, Dartmouth, Nova Scotia B2Y 3Z7, Canada), and David J. Thomson (Defence Res. Establishment Pacific, FMO Victoria, BC V0S 1B0, Canada)

In a recent paper [D. M. F. Chapman and P. D. Ward, J. Acoust. Soc. Am. **87**, 601–618 (1990)], it was shown that a normal mode underwater acoustic propagation code can be modified to model air-to-water sound transmission simply by altering the mode excitation coefficients. These new coefficients are the exact wave-theoretic expressions for the air-to-water transmission problem. Herein, it is shown that if the height of the source above the surface is sufficiently small, then the air-to-water transmission problem can be approximated accurately by replacing the source in air with a source in water at a depth $d \ll \lambda$ below the surface, where λ is the acoustic wavelength in water. For a distant receiver in water, both the true source in air and the effective source in water exhibit nearly identical dipole radiation patterns. Although the effective directivity of the two sources is the same, the source strength is not. The correct transmission loss due to a source in air can be recovered from the transmission loss computed for a shallow source in water by adding the quantity $20 \times \log_{10}(k_a d)$, where k_a is the wave number in air. Using this approach, numerical results for three standard underwater acoustic models (normal mode, multipath expansion, parabolic equation) will be compared to benchmark results provided by the SAFARI model for a generic air-to-water transmission example.

3UW5. Accuracy of the pressure release bottom approximation for normal modes in shallow water. Grayson H. Rayborn, Barry I. Barker (Dept. of Physics and Astronomy, Univ. of Southern Mississippi, Hattiesburg, MS 39406), George E. Ioup, and Juliette W. Ioup (Univ. of New Orleans, New Orleans, LA 70148)

Previous investigators have recognized that an approximation may be made to the eigenfunctions and eigenvalues for a Pekeris waveguide such that the eigenfunctions end in a node at an effective pressure release bottom below the actual bottom. A simple graphical derivation of the approximation is presented and the accuracy of the approximation for the marine sediments found to be typical of bottoms along the continental shelf is investigated. For a water column capable of supporting up to 74 modes, the approximation results in errors in the vertical wave number of less than 0.25% for all modes for all bottom types. This modest error indicates that the approximation should be useful in modeling various problems. [Work supported by NOARL and the Navy/ASEE Summer Faculty Fellowship Program.]

3UW6. A two-dimensional downslope propagation model based on coupled wedge modes. Harel Primack and Kenneth E. Gilbert (Natl. Ctr. for Phys. Acoust., University, MS 38677)

A "wedge-mode" representation of the acoustic field [M. J. Buckingham, J. Acoust. Soc. Am. **82**, 198–210 (1987)] has been implemented in a 2-D propagation model that can treat realistic sound-speed profiles. Wedge-mode calculations are compared to parabolic equation (PE) calculations for an isospeed profile and profiles typical of the Mediterranean sea in summer and winter. For an isospeed profile over a penetrable bottom, the wedge modes are almost uncoupled. For a realistic depth-dependent profile, however, the modes are significantly coupled. Moreover, at the beginning of the downslope region, mode-continuum-mode coupling (tunneling) occurs. When only the wedge-mode coupling is accounted for, fair agreement is obtained with the parabolic equation results. When, in addition, the tunneling effect is accounted for with a hybrid mode-PE model, excellent agreement is obtained with the full parabolic equation calculation.

3UW7. Appropriate starting fields for different PE approximations. Finn B. Jensen and Michael B. Porter (SACLANT Undersea Res. Ctr., 19026 La Spezia, Italy)

The suite of parabolic wave equations available today for solving range-dependent propagation problems in ocean acoustics encompasses forms ranging from the standard narrow-angle PE originally introduced by Tappert to very wide-angle PEs based on Padé series expansions. Each PE form has inherent phase errors that increase with increasing angle away from the main propagation direction (horizontal). These phase errors also affect the angular energy distribution in space so that a given initial field leads to different farfield radiation patterns in different PE's. This is explicitly illustrated by solving the classical Lloyd mirror problem for a point source near the free surface in a homogeneous half-space. The results clearly show the importance of selecting a starting field compatible with the particular PE being solved. Thus it is seen that the use of a wide-angle source with a narrow-angle PE may result in an amplitude overshoot of 3–4 dB for propagation directions around 30° off the main propagation direction.

3UW8. An accurate and stable elastic parabolic equation with application to interface wave propagation. Michael D. Collins (Naval Res. Lab., Code 5160, Washington, DC 20375-5000)

The parabolic equation (PE) method has recently been extended to handle sound propagation in an ocean overlying an elastic bottom. Of the two original elastic PE implementations, however, one has stability limitations [Collins, J. Acoust. Soc. Am. **86**, 1459–1464 (1989)], and the other has accuracy limitations [Wetton and Brooke, J. Acoust. Soc. Am. **87**, 624–632 (1990)]. An elastic PE that is very accurate and completely stable and is based on a new higher-order Padé approximation has been derived by combining and generalizing the original models. Accuracy is achieved by placing several constraints on the derivatives of the Pade series at the point corresponding to the reference wave number. By requiring that the Padé series map part of the lower left quadrant of the complex plane into the upper half of the complex plane, an instability associated with nonpropagating modes can be eliminated. The complex coefficients of the desired Padé series are determined by solving a system of nonlinear equations with Newton's method. The new elastic PE is accurate and efficient for problems involving compressional, shear, and interface waves, very wide propagation angles, and large depth and weak range dependence in the geoacoustic parameters. With this upgrade, the elastic PE is suitable for general use.