A theoretical investigation of sound propagation in shallow water at low frequencies using a 3-D benchmark model of the fluid wedge over an elastic bottom

Piotr Borejko
Institute of Structural Engineering, TU Wien,
Vienna, A-1190, Austria
piotr.borejko@tuwien.ac.at

In shallow-water environments long-range propagation proceeds by repeated reflections from the surface and the bottom of the channel, as is the case for an underwater sound of a wide spectral range, whose very low frequencies may propagate over large (several tens of kilometers) distances, without significant losses.

In this paper, a 3-D benchmark model of the fluid wedge over an elastic bottom is applied to investigate low-frequency long-range propagation from an acoustic source submerged in shallow water overlaying a sloping elastic-type seabed, such as a marine sediment possessing enough rigidity (elasticity in shear) allowing hydroacoustic-to-seismic conversion at a water-sediment interface.

Inside the wedge, acoustical propagation (proceeding by repeated reflections of the acoustic wave emitted from a point source) may be analyzed into a series of its basic constituents, the so-called "generalized ray integrals," each term of the series is identified as a Laplace-transformed wave motion traveling along a specific path in the wedge, the first being the wave from the source directly to the receiver, the second being reflected once, etc.

The inverse Laplace transforms of the ray integrals, found by applying the method of Cagniard, are in the form of integrals along a complex contour. Using a standard Gauss-Legendre quadrature (DGQRUL routine of the ISML Fortran Numerical Library), the CPU intensive numerical evaluation of each integral can then be accomplished along a new (the analytical equivalent of the original) contour to avoid the branch points of the refracted waves, the stationary point of the regularly reflected wave, and the poles of the pseudo-Rayleigh and Scholte interface waves. These singular points might cause great difficulty in numerical integration if performed along an original contour.

Hence, this approach provides a complete signal recorded by a remote receiver, comprised of contributions from all of the wave motions typical for the model (not only from the source signal and the regularly reflected waves but also from the refracted waves and the pseudo-Rayleigh and Scholte interface waves) received in order of their arrivals at a large distance from the source.

When a source emits acoustic signals of a low-frequency content, the contribution from the Scholte waves becomes dominant at large distances. Therefore, low-frequency long-range propagation in a shallow water wedge (coastal wedge) over an elastic seabed may indeed be governed by the Scholte waves.

With the recent advent of a novel high order Gauss-Legendre quadrature and benefits offered by High-Performance Computing (HPC) environments, like modern multiprocessor systems where high precision calculations can be executed parallelly at greatly enhanced speeds, it can be possible in a reasonable time to achieve desired accuracy in the calculations, even at

larger propagation ranges than those reported in the paper, by increasing the number of Gaussian points in numerical integration.

Keywords: penetrable wedge, hydroacoustic-to-seismic conversion, Scholte waves, HPC