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Efficient numerical models for the prediction of acoustic wave propagation in the vicinity of a wedge coastal region

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ABSTRACT

In this paper, numerical frequency domain formulations are developed to simulate the 2D acoustic wave propagation in the vicinity of an underwater configuration which combines two sub-regions: the first one consists of a wedge with rigid seabed and free surface, and the second one is assumed to have a rigid flat bottom and a free flat surface.

The problem is solved using two different numerical methods: the Boundary Element Method (BEM) and the Method of Fundamental Solutions (MFS). Two models are developed by using a sub-region technique, where only the vertical interface between sub-regions of different geometries has to be discretized. These formulations incorporate Green's functions that take into account the presence of flat rigid and free surfaces and of a wedge. Green's functions are defined using two approaches: the image source method is used to model the rigid flat bottom and free flat interface, whereas the response provided by the wedge sub-region is based on a normal mode solution. Additionally, a MFS and a BEM model are also implemented which require the discretization of the sloping rigid seabed of the wedge, therefore making use of Green's functions for a rigid flat bottom and a free surface (using the image source method).

A detailed discussion on the performance of these formulations is performed, with the aim of finding an efficient formulation to solve the problem. It is found that the model based on the MFS and on the sub-region technique has a significantly lower computational cost and is stable, therefore being the most suitable for the analysis of acoustic wave propagation in the studied configurations.

1. Introduction

Computational methods for determining the sound field in an acoustic medium have evolved over the past decades. In the specific field of underwater acoustics, many methods have been applied with great success, as documented in the excellent reference work [1], all of them with specific limitations. Some of the most well-known and broadly applied methods are based on acoustic ray theory, normal mode analysis (pioneered by the works of Pekeris [2]), simplified parabolic equations (initially introduced in this field by Hardin and Tappert [3]) or Green's functions for layered media (as defined, for example, in the works of Schmidt and Tango [4] or Tadeu et al. [5,6]).

The more exact wave theory, together with modern high-speed computing infrastructures and the advances in numerical physics, allowed the development of different and more accurate approaches for some specific problems in underwater acoustics, including models based on the well-established finite difference, finite element and boundary element numerical methods.

An important early work on acoustic scattering in the open ocean using the Boundary Element Method, by Dawson and Fawcett [7], takes the waveguide surfaces to be flat, except for a compact area of deformation where the acoustic scattering takes place. An application of the Boundary Element Method (BEM) using a hybrid model which combines the standard method in an inner region with varying bathymetry and an eigenfunction expansion in the outer region of constant depth was subsequently presented by Grilli et al. [8].

Santiago and Wrobel [9,10] implemented the sub-region technique in boundary element formulation for the analysis of two-dimensional acoustic wave propagation in a shallow water region with irregular seabed topography. In their approach the bottom and surface boundaries of the regions are modeled using Neumann and Dirichlet conditions, allowing for the use of Green's functions that satisfy either the free surface boundary condition or both the boundary conditions on the free surface and rigid bottom.

In a number of acoustic environments, the geometry of the propagation domain can be assumed to be constant in one

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