FDTD Modeling of Scattered Electromagnetic Waves at Ultra Low-Frequencies from Objects in Ocean Water

Dallin Smith*[(1)], Sean Burns[(1)], Stephen Potashnik[(2)], and Jamesina Simpson[(1)]
(1) ECE Dept., University of Utah, Salt Lake City, UT 84112, USA
(2) Office of Naval Research, Arlington, VA 22203, USA

The skin depth of electromagnetic waves in ocean water is on the order of 160 meters at 3 Hz and just 50 meters at 30 Hz. Detection of objects much below the surface of the ocean using electromagnetic waves is thus very challenging due to the expected attenuation of the waves. Detection at relatively large depths at ultra low frequencies (ULF: < 3 Hz), however, may be a viable option due to the larger skin depths (1.5 km at 0.03 Hz) at those frequencies.

Using the finite-difference time-domain (FDTD) method, ULF scatterings from an object submerged in the ocean are obtained. This is achieved by running the FDTD model in the scattered-field only regime, in which a single or group of electromagnetic field components in a three-dimensional (3-D) FDTD grid is excited by a "hard" source, i.e. the electric field component(s) are set to a sinusoid at ULF. Running the FDTD model in this regime assumes that the ULF waves have already been generated elsewhere and have propagated to the location of the object in the ocean. Only the scatterings from the object are simulated.

The propagation attenuation versus distance from the source (object) is recorded and compared to the propagation attenuation as predicted by plane wave theory. A total round trip propagation attenuation is also estimated for ULF sources originating in the air region above the ocean (from the air region down to the object and then back up to the air region). Frequencies ranging from 0.01 Hz to 1 Hz are tested. The 3-D FDTD simulations are run on supercomputer access provided by the U.S. Department of Defense High Performance Computing Modernization Program (HPCMP). Approved for Public Release, Distribution Unlimited.