Characterization of extremely low-frequency electromagnetic sources in conducting media

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Abstract

Physical fields whose sources exist within maritime vessels are of concern to ship-designers and military planners. Among the fields of most significance which have been studied intensively, are those of magnetic, acoustic and pressure sources. New technological developments now require analyses of the underwater electric and magnetic fields of onboard, extremely low-frequency electromagnetic sources.

This study investigated methods by which the electromagnetic sources of maritime vessels may be characterised during normal operations in typical coastal environments. It focused on situations where both the sources and field measurement points were located in a common seawater volume. At the electromagnetic frequencies of interest such a medium acts as a thin conducting layer with significant levels of wave reflection and refraction at the media boundaries.

To enhance propagation models of the electromagnetic fields over short ranges, the initial investigations aimed to characterise key parameters of the conducting media in shallow-water conditions. Conductivity values of seawater can be readily established by conventional methods. However, in the case of the seabed media, direct conductivity measurements are usually highly variable along horizontal and vertical sections due to aeons of land erosion, and the long-term effects of inshore waves and currents. Procedures are described which show how electromagnetic theory and indirect measurement techniques may be used to infer the characteristic values of key seabed parameters in shallow-water areas. This element of the study utilised both analytical and numerical electromagnetic models, and the efficacy of each in this context was examined.

Subsequent phases of the study analysed the nature of the electromagnetic sources. In some situations the sources were regarded as point dipoles, and in others they were assumed to have a finite length. Techniques were developed to characterise the dipole moment, length and the location of a typical ship-like source, when each is treated as an electric current dipole. This information was used in turn to demonstrate the likely accuracy in ranging operations on extremely low-frequency, electromagnetic sources over short ranges, and in shallow-water conditions.

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Table of contents

List of figures