The Influence of the Seawater and Seabed Interface on the Underwater Low Frequency Electromagnetic Field Signatures

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Introduction

The shallow sea consists of air, seawater and seabed; and, the seawater and seabed interface is the basic electric property interface. The conductivity discontinuity of the interface has a direct influence on the propagation and attenuation of the underwater low frequency electromagnetic field. It is necessary to analyze the influence of the electric property interface on the electromagnetic field in order to improve the measurement accuracy of marine underwater electromagnetic field tests, and the performance of underwater electromagnetic communication.

The influence of the seawater and seabed interface on the underwater electromagnetic field has been investigated by some scholars. Inan carried out research on the propagation property of the extremely low frequency electromagnetic field excited by the vertical magnetic dipole and the horizontal electric dipole, which is present at the seawater and seabed interface. It is found that the underwater electromagnetic field is affected largely by the seabed conductivity, and the vertical component of the electric field is more sensitive to the variation of the seabed conductivity. The influence of the seabed on the spatial distribution of the underwater electric field produced by the horizontal electric dipole was researched by Lu, who found that the influence should not be neglected in the area near the dipole.

In this paper, the influences of the interface on the electromagnetic signatures are analyzed quantitatively. The research conclusions have wide application prospects in the interface influence correction on the vessel’s underwater electromagnetic field measurement and the long distance measurement of the underwater electromagnetic field in the sea environment.

Methods

In this paper, the physical mechanics of the interface influence is analyzed and interpreted by use of the interface influence factor on basis of the image method principle. The shallow sea is simplified as the air, seawater and seabed three layers homogeneous and isotropic conducting media model; and, the equation formula of electromagnetic field excited by the harmonic horizontal electric dipole in the seawater is presented. Through numerical testing, the spatial distribution and attenuation characters of the electromagnetic field excited by the harmonic horizontal electric dipole are investigated, and the influences of the interface on the electromagnetic signatures are analyzed quantitatively.

Fig.1. The schematic diagram of image method
Fig.2. The sketch map of the air, seawater and seabed three layers homogeneous model

Results

(a) Electric field longitudinal component
(b) Electric field vertical component

Fig.3. The contrast curves of the electric field excited by the horizontal dipole (15Hz) between the seawater and seabed interface and no interface

(a) Electric field
(b) Magnetic field

Fig.4. The attenuation curves of the electromagnetic field excited by the horizontal dipole (10Hz) between the seawater and seabed interface and no interface

The influence model of the seawater and seabed interface is as follows:

\[ E_x = -0.49\eta^3 + 1.45\eta^2 - 1.99\eta + 2.0 \]

\[ E_z = 0.45\eta^3 - 1.36\eta^2 + 1.91\eta \]

Where \( \eta \) is the ratio of the seabed conductivity \( \sigma_2 \) and seawater conductivity \( \sigma_1 \).

Discussion and Conclusions

In this paper, the influence of the seawater and seabed interface on the underwater electromagnetic field is investigated by use of theoretical analysis and numerical test. The conclusions are as follows:

(1) The seawater and seabed interface has a great influence on the underwater electromagnetic field due to the conductivity discontinuity in the interface. The horizontal component amplitude of the underwater electric field increases and vertical component amplitude decreases, apparently because of the high resistance property of the seabed. The transverse component amplitude of the underwater magnetic field is reduced and the vertical component amplitude is unchanged. The interface influence decreases with the increment of the vertical distance between the measurement line and interface. Because the marine underwater electromagnetic field measurement sensors are located in the seabed, the interface influence cannot be neglected in the process of the measurement data analysis. It is necessary to correct the interface influence by use of the corresponding method.

(2) The attenuation rate of the underwater electromagnetic field decreases, apparently due to the existence of the seawater and seabed interface. The phenomenon indicates that it is impossible to achieve long range detection of the underwater electromagnetic field signature by use of the sensors located in the seawater and seabed interface.