FREQUENCY DOMAIN ELECTROMAGNETIC SOURCE POLARIZATION INVESTIGATION IN CASE OF A 2-D SEAFLOOR TRENCH

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Introduction

In the course of seafloor EM survey the topographical changes of the seafloor can have influence on the EM components. These topographical inhomogeneities are 3-D ones. However, they are frequently elongated in one direction and can be treated as 2-D inhomogeneities. The aim of this model study is to present a numerical method for frequency domain marine controlled-source electromagnetic measurements using horizontal electric dipole sources on the seafloor and illustrate how the EM responses are affected by a 2-D trench. The horizontal electric dipole source is parallel and perpendicular to the structural strike and the EM field components are computed along an in-line horizontal seafloor profile perpendicular to the axis of the trench at two frequencies.

Numerical procedure and results

The chosen numerical procedure was a finite-difference method after a Fourier transform of Maxwell's equations from the space domain (x,y,z) to the along-strike wavenumber domain (k_x,y,z) . In this way the original 3-D problem can be derived to a set of 2-D ones. The coupled partial differential equations for the two electric source polarizations in the wavenumber domain are very similar to those of two coupled transmission sheets and this analogy made it possible to fulfil the interior boundary conditions, because each gridpoint could be considered as a branch point of circuit. Along the grid edges terminal-impedance type boundary condition was used, i.e. the edge of the mesh was grounded. The block tridiagonal structure of the coefficient matrix of the finite difference linear set of equations was taken into account during the solution. After the

Fig. 1. Normalized amplitudes of the horizontal electric field components along the horizontal sea bottom line over the 2-D seafloor trench at $f=1$ Hz. E_x has been computed for dipole equatorial, E_y for dipole axial arrays.

solution of the linear systems belonging to different k_x values EM components are determined numerically by an inverse Fourier transform. Choosing logarithmically equidistant sampling in the spatial wavenumber domain after $k_x = 0 \text{ m}^{-1}$ additional 14 spatial wavenumbers were needed to get EM responses for transmitter-receiver range of $14,5 \text{ km} \leq R \leq 19,5 \text{ km}$ at both frequencies. A course grid with 120 columns and 43 rows was applied to $f = 0.1 \text{ Hz}$, and a finer grid of 148 columns and 45 rows was used at $f = 1 \text{ Hz}$. In order to enhance the EM response of the 2-D seafloor trench normalized amplitudes and relative phases were taken along the profile. The reference model was defined as a homogeneous horizontally stratified model with the sea water ($\rho_{sea} = 0,3 \text{ ohm}$, $h_{sea} = 3 \text{ km}$), the upper layer of the crust ($\rho_u = 10^4 \text{ ohmm}$, $h_u = 5 \text{ km}$) and the lower "infinite" one ($\rho_l = 10^3 \text{ ohmm}$). The edge of the trench was 15 km far from the source, it has a rectangular cross-section with 1 km width and 600 m depth. In the figures x denotes the structural strike, E_x and H_x can be computed at dipole equatorial, E_y and H_y at dipole axial arrays.

Fig. 2. Normalized amplitudes of the horizontal electric field components over the 2-D seafloor trench at $f=0.1$ Hz

Fig. 3. Normalized $|H_x|$ components over the 2-D seafloor trench at $f=0.1$ Hz and $f=1$ Hz

Fig. 4. Normalized $|E_z|$ components over the 2-D seafloor trench at $f=0,1$ Hz and $f=1$ Hz

Conclusion

Frequency domain EM measurements using artificial sources can be carried out approaching the far zone in the transition zone. Due to the horizontal skin effect in case of marine FEM measurements the far zone features can be observed at relatively smaller transmitter-receiver distances to compare with on-land EM frequency soundings. The normalized EM field responses of a 2-D trench to dipole equatorial and to dipole axial arrays were presented along a horizontal in-line profile on the sea-bottom at two frequencies (Fig. 1.-4.). The electric field responses of the dipole axial arrays have better resolution than those of the dipole equatorial ones, similarly HPOL and EPOL modes in MT due to the electric charge accumulation along the boundaries. E_z and H_z responses are particularly sensitive to these topographic changes, H_z is induced by the current flow in strike direction within the trench. The topographical effects have to be taken into consideration to avoid the misinterpretation of FEM seafloor responses.

Reference

PETHŐ, G., P. KAIKKONEN and L.L. VANYAN, 1995: Numerical modeling for the effect of a 2-D seafloor trench on sea-bottom EM measurements using horizontal electric dipole sources. *Geophysica*, 31, 1-21.