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Spectral method for processing hydromagnetic survey data at shallow depths

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Magnetic surveys are commonly used for solving variety of geotechnical and geological challenges in offshore areas, jointly with a set of other geophysical methods. The most popular technique employed is hydromagnetic surveying with towed magnetometers. One of the most significant challenges encountered during processing of the magnetic data is related to temporal variations of the Earth's magnetic field. Accounting for diurnal magnetic field variations is often done by carrying out differential hydromagnetic surveys, a technique developed in the 1980-s. It is based on simultaneous measurements of the magnetic field using two sensors towed behind the vessel with a given separation. This technique allows to calculate along-course gradient which is free of magnetic field temporal variations. This measurement system resembles a gradiometer, with the distance between two sensors being referred to as the base of the gradiometer. It is possible to calculate anomalous magnetic field by integrating obtained magnetic field gradient. Studies have shown that accuracy of its reconstruction decreases with increasing base of the gradiometer. This becomes most significant when distance between the sensors and sources of magnetic field anomalies is small. This situation occur when the survey area is located in shallow water (i.e. for shallow marine, river or lake surveys).

An approach for deriving magnetic anomalies and accounting for diurnal variations in differential hydromagnetic surveys based on the frequency (spectral) representation of the measurements was proposed in 1987 [Melikhov, 1987]. This approach utilizes the fact that it is possible to reconstruct the spectrum of magnetic field anomalies along the vessel course from the spectra of measured signals from the first $S_1(\omega)$ and second $S_2(\omega)$ sensors. Assuming that the sensors are located at the same depth, it can be achieved via the following transform:

$$T(\omega) = \frac{S_1(\omega) - S_2(\omega)}{1 - e^{-i\omega l}},$$

where ω - spatial frequency, *l* - base of the gradiometer, and *i* - imaginary unit. Assuming that at a single moment in time magnetic field variations equally affect both sensors, resulting Fourier spectrum T(ω) will correspond the spectrum of anomalous magnetic field, free of the magnetic variations. It should be noted that, similar to the along-course gradient integration approach, anomalous magnetic field is restored to a certain accuracy level.

Estimates made on model examples showed that accuracy of the field reconstruction using this method is comparable to the accuracy levels of modern marine magnetic surveys (±1-3 nT). It could be noted that for gradiometer bases comparable or larger than depths to magnetic anomaly sources, errors of the field reconstruction are significantly lower for the spectral transformation-based approach compared to along-course gradient integration.

References:

Melikhov V.R., Bulychev A.A., Shamaro A.M. Spectral method for solving the problem of separating the stationary and variable components of the geomagnetic field in hydromagnetic gradiometric surveys // Electromagnetic research. - Moscow. IZMIRAN, 1987. - P. 97-109. (in Russian)