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On the Use of UAVS in Electrical Prospecting; Influence of Local Objects on the Magnetic Field of Current Line AB

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Abstract

The integration of unmanned aerial vehicles (UAVs) in geophysical exploration has gained significant attention due to their ability to enhance survey efficiency and data accuracy. This study presents a mathematical modeling approach to analyze the influence of local objects on the magnetic field generated by an electric current line in geophysical surveys. The model considers a grounded current line AB positioned at the boundary between two half-spaces, with five local spherical objects possessing increased magnetic permeability. The calculations focus on the Cartesian components of the magnetic field at a given height above the boundary. Results indicate that the anomalous magnetic field generated by local objects is significantly weaker compared to the primary field from the current line, making its detection challenging. However, specific field components demonstrate higher sensitivity to local object influence, offering potential for refined data interpretation. The findings contribute to the ongoing development of UAV-based geophysical techniques, emphasizing the importance of precise field measurements for improved subsurface characterization.

Keywords: UAV; Electrical Prospecting; Magnetic Field; Mathematical Modeling; Geophysical Exploration

Introduction

In recent years, many studies have been conducted on the use of unmanned aerial vehicles (UAVs) in electrical and magnetic exploration. Some of the results of such studies have been published, for example, in the works [2-4,8]. This paper presents the results of mathematical modeling for the following conditions. The line AB of electric current I (with grounded current electrodes A, B) lies on the boundary S of the homogeneous lower conducting half-space V2 and the upper half-space V1 (air). The current I in the line AB and the emission currents of the electrodes A, B are the exciters of the normal magnetic field $\vec{H}^{\text{HopM}}$. In the half-space V2 at small depths from the surface S there are five local spherical objects with increased magnetic permeability μ. These objects are the exciters of the anomalous magnetic field $\vec{H}^{\text{aHoM}}$. Total magnetic field $\vec{H}^{\text{cyMM}} = \vec{H}^{\text{HopM}} + \vec{H}^{\text{aHoM}}$.

We will assume that the center of the current line AB is located at the origin of the Cartesian coordinates, and the current I is directed along the X axis. The Z axis is orthogonal to the plane S and is directed into the half-space V2 (downward). In the mathematical modeling, the Cartesian components of the fields were calculated in the half-space V1 $\vec{H}^{\text{HopM}}$, $\vec{H}^{\text{cyMM}}$ and $\vec{H}^{\text{aHoM}} = \vec{H}^{\text{cyMM}}$- $\vec{H}^{\text{HopM}}$ at a height h above the boundary S. Expressions for the field $\vec{H}^{\text{HopM}}$ is in the electronic version of the textbook [1] (pp. 88 - 90), and the method for calculating the influence of local objects on a constant and variable field is in the works [5-7].

Note also that (at this stage) the calculation results given below are obtained for direct current I and a constant magnetic field. But it is obvious that these results will remain valid for the components of the low-frequency harmonically changing field when measuring the reactive components of the magnetic field changing in phase or in antiphase with the current I. Unlike the similar model for the magnetic field of alternating current I, the expressions for the constant magnetic field are elementary functions, and not improper integrals in the sense of the principal value.

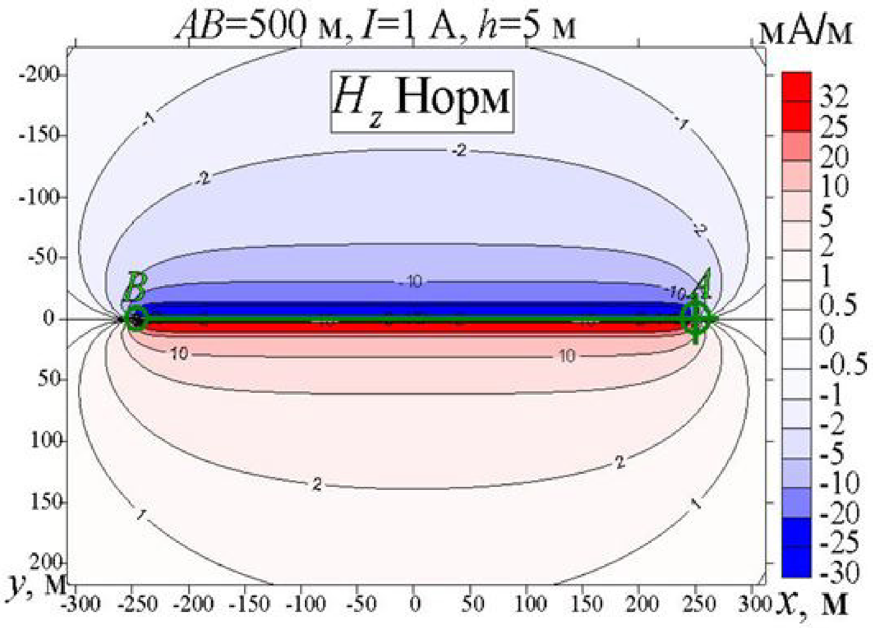


Figure 1: Component Map H_z^{HopM}

Figure 1 shows the $MapH_z^{HopM}$ (at height h=5 m) and the position of the current line AB in the plane S. It is clear that above the X axis, on which the line AB lies, the component H_z^{HopM} changes sign, and the magnitude $\left|H_z^{HopM}\right|$ decreases with distance from line AB.

In Figure 2, where the map is shown H_z^{cyMM}, the limits of change of coordinates x, y are less than in Figure 1. The green circles show the position in the plan of five local magnetized objects located in the lower half-space. In this figure we see that for the given parameters of the model, the influence of local objects on the $mapH_z^{cyMM}$ is practically unnoticeable. This is obviously due to the fact that when the field is excited current line AB absolute value $\left|H_z^{HOpM}\right| >> \left|H_z^{aHOM}\right|$

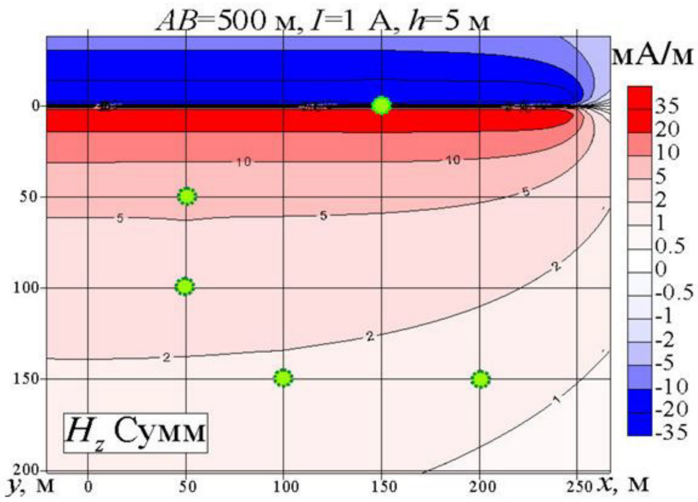


Figure 2: Component Map H_z^{cyMM}

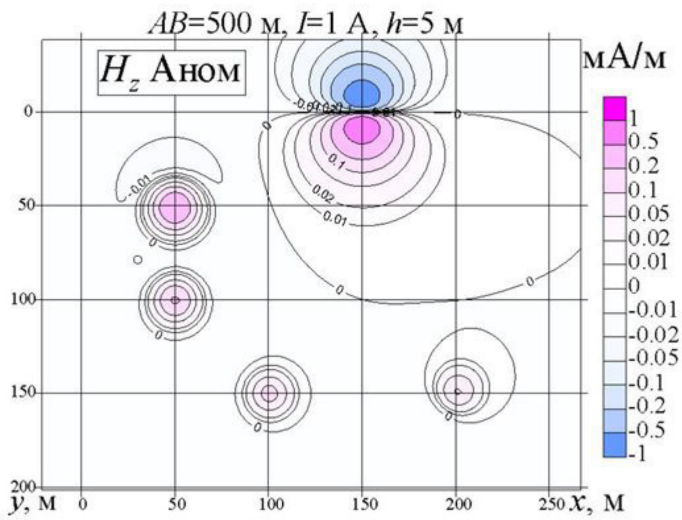
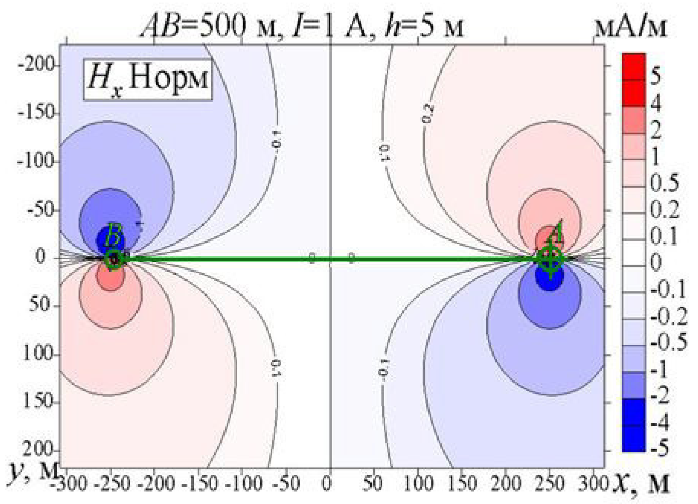


Figure 3: Component Map H_z^{aHOM}



$I_z^{aHOM}|$

Figure 4: Component Map H_x^{HopM}

Figure 3 shows the component $map.H_z^{aHOM} = H_z^{cyMM} - H_z^{HopM}$. Of course, on this map we see anomalies caused by the influence of all local objects. But when comparing the values H_z^{aHOM} and H_z^{HopM} in figures 1, 3 we see that indeed, as already noted, $\left|H_z^{aHOM}\right| << \left|H_z^{HopM}\right|$. Of course, in mathematical modeling of the value H_z^{aHOM} could be calculated with very high accuracy. And the question of whether it is possible in practice to determine H_z^{aHOM} ensure high measurement accuracy H_z^{cyMM}, calculations H_z^{HopM} and subsequent calculation of the difference $H_z^{aHOM} = H_z^{cyMM} - H_z^{HopM}$ raises doubts.

Figure 4 shows the component map. H_x^{HopM}. In this figure we see that the main contribution to the component H_x^{HopM} introduces the magnetic field of the emission currents of the electrodes A, B, and not the magnetic field of the current I in the line AB. In the central part of the map, at a distance from the electrodes A, B, the inequality is valid $\left|H_x^{HopM}\right| << \left|H_z^{HopM}\right|$ (see Figure 1). At the same time, the magnetization of local objects and the values H_x^{aHOM} depend, of course, on all components of the total field $\vec{H}^{\text{cyMM}}$, including from components H_z^{cyMM}. Therefore, the influence of local objects on the component H_x^{cyMM} (oriented in the direction of the line AB of current I) is much more "noticeable" than such an influence on the component H_z^{cyMM}.

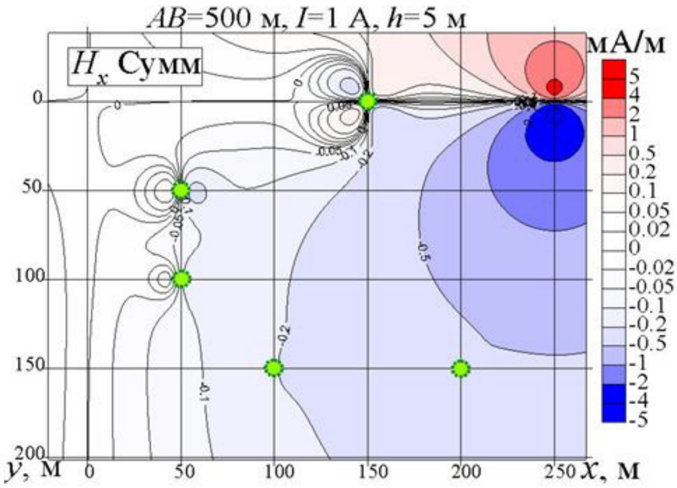


Figure 5: Component Map H_x^{cyMM}

We see this in Figure 5, which shows the map H_x^{cyMM}. Three anomalies caused by magnetized local objects are clearly visible on this map. That is, when a normal magnetic field is excited by the current line AB, compared to H_z^{cyMM} component H_x^{cyMM} more "sensitive" to the influence of local magnetized objects.

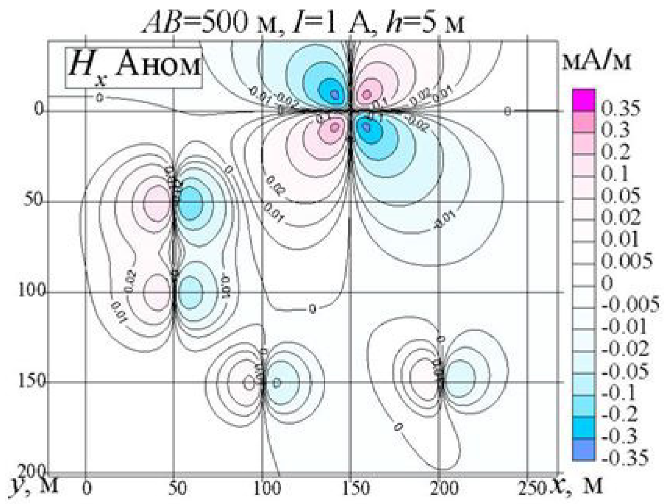


Figure 6: Component Map H_x^{aHOM}

Figure 6 shows the map $H_x^{aHOM} = H_x^{cyMM} - H_x^{HOpM}$. Note that for the given model parameters, the values $\left|H_x^{aHOM}\right|$ reach tenths of mA/m, which is comparable with the values $\left|H_x^{HOpM}\right|$ in the central part of the map in Figure 4.

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