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On the use of UAVs in Electrical Exploration; The Influence of Local Objects on the Magnetic Field of an Ungrounded Loop

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Annotation

It is increasingly being used in electrical and magnetic exploration unmanned aerial vehicles. In this case, the measuring devices are not located on the surface of the earth, but at a significant height above this surface. Below are the results of mathematical modeling for the case when the exciter of the normal magnetic field is a closed loop of electric current lying on the surface of the earth, and the sources of the anomalous field are local magnetized objects located under this surface. The results of the modeling showed what effect these objects have on different components of the magnetic field.

Keywords: Electrical Exploration; Ungrounded Loop; Mathematical Modeling; Magnetic Exploration

Theory

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 [1,2,6]. This paper presents the results of mathematical modeling for the following conditions. A rectangular line l of electric current I ("rectangular loop") lies on the boundary S of a homogeneous lower conducting half-space V2 and an upper half-space V1 (air). Current I is the exciter of a normal magnetic field $\vec{H}^{\text{НОрМ}}$. 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 $\vec{H}^{\text{аНОМ}}$. Total magnetic field $\vec{H}^{\text{суММ}} = \vec{H}^{\text{НОрМ}} + \vec{H}^{\text{аНОМ}}$.

In the mathematical modeling, the Cartesian components of the fields were calculated in the half-space V1 $\vec{H}^{\text{НОрМ}}, \vec{H}^{\text{суММ}} and \vec{H}^{\text{аНОМ}} = \vec{H}^{\text{суММ}} - \vec{H}^{\text{НОрМ}}$ at a height h above the boundary S. The method for calculating the influence of local objects on a constant and variable field is given in the works [3-5].

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 1a shows the map H_z^{HOpM} (at height h=5 m) and the position of the rectangular loop in the plane S. It is clear that above the line l of the current I component H_z^{HOpM} changes sign, and the magnitude $\left|H_z^{HOpM}\right|$ decreases with distance from line l.

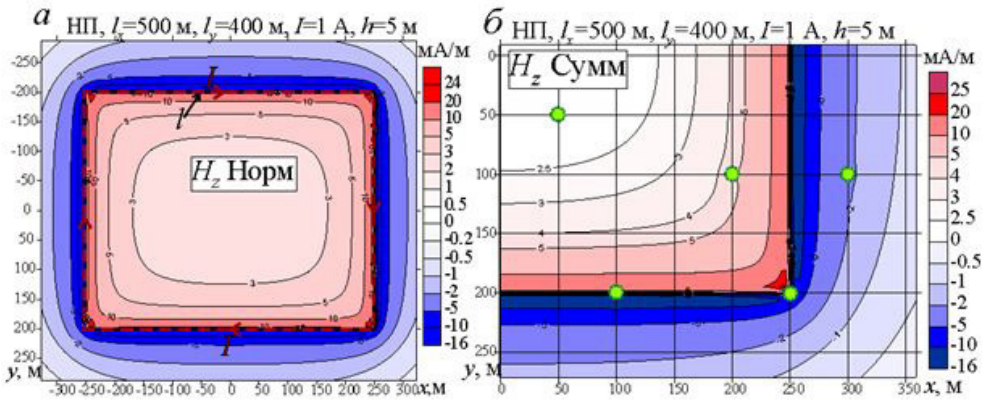

Figure 1: Component maps $H_z^{HOpM} and H_z^{cyMM}$

In Figure 1, b, where the map is shown H_z^{cyMM}, the limits of change of coordinates x, y are less than in Figure 1, a. 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 map H_z^{cyMM} is practically unnoticeable. This is obviously due to the fact that when the field is excited $\vec{H}^{\text{НОрМ}}$ rectangular line l current I absolute value $\left|H_z^{HOpM}\right| >> \left|H_z^{aHOM}\right|$.

Figure 2 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, a, 2 we see that indeed, as already noted, $\left|H_z^{aHOM}\right| << \left|H_z^{HOpM}\right|$. Of course, in mathematical modeling the values H_z^{aHOM} could be calculated with very high accuracy. And to clarify 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 $H_z^{aHOM} = H_z^{cyMM} - H_z^{HOpM}$. Experimental studies are needed.

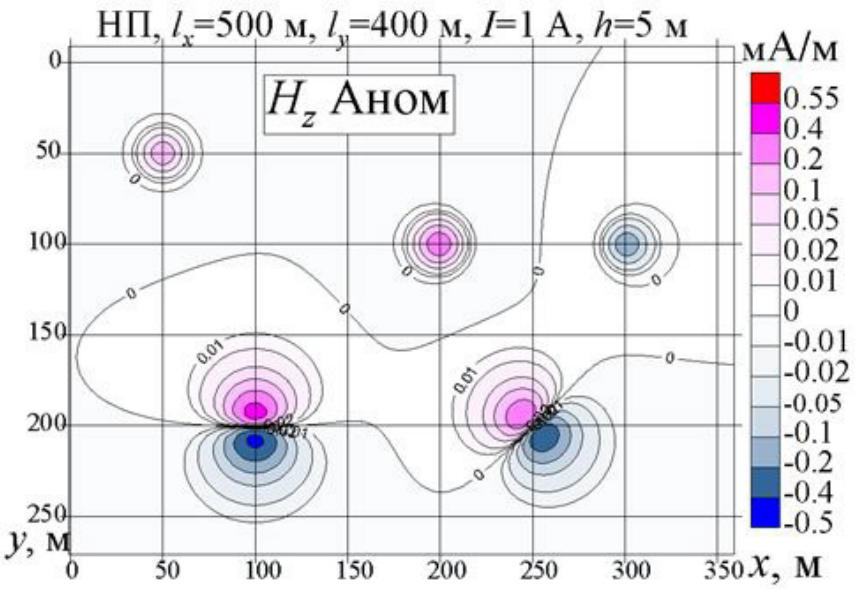

Figure 2: Component map H_z^{aHOM}

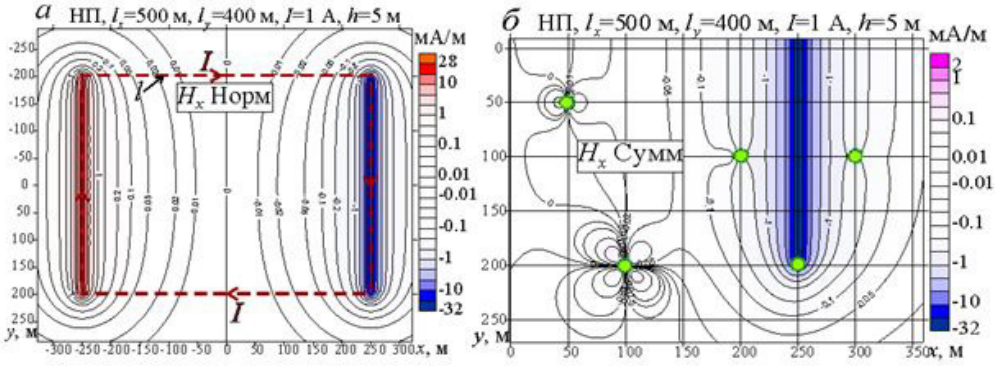

Figure 3: Component maps H_x^{HOpM} $And H_x^{cyMM}$

Figure 3a shows a map of the horizontal component H_x^{HOpM}. According to the Biot-Savart-Laplace law, the maximum values $\left|H_x^{HOpM}\right|$ we observe those sections of the contour l, the current I along which is collinear to the direction of the Y axis. In the central part of the map, the inequality $\left|H_x^{HOpM}\right| << \left|H_z^{HOpM}\right|$ (see Figure 1, a). At the same time, it is very important that the magnetization of local objects and the values H_x^{aHOM}. It depends, of course, not only on the component H_x^{cyMM}, and from 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} manifests itself much more "noticeably" than such an influence on the component H_z^{cyMM}.

We see this in Figure 3, b, which shows the map H_x^{cyMM}. This map clearly shows two anomalies caused by magnetized local objects. These are the objects whose centers have coordinates x=50 m, y=50 m and x=100 m, y=200 m. That is, when a normal magnetic field is excited by a rectangular current loop I, compared to H_z^{cyMM} component H_x^{cyMM} more "sensitive" to the influence of local magnetized objects. In addition, some influence on the component H_x^{cyMM} provide local objects with coordinates of centers x=200 m, y=100 m and x=300 m, y=100 m.

Similar results were, of course, obtained for the other horizontal y - component of the magnetic field. Only the maximum values $\left|H_y^{HOpM}\right|$ in this case we observe those sections of the contour l, the current I along which is collinear with the direction of the X axis.

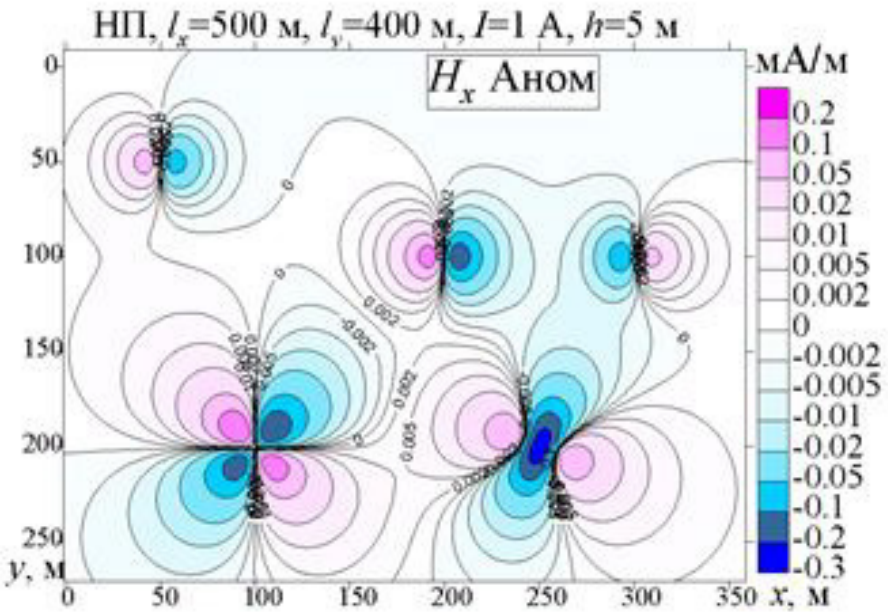

Figure 4: Component map H_x^{aHOM}

Figure 4 shows the component 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 greater than the values $\left|H_x^{HOpM}\right|$ in the central part of the map in Figure 3, a.

Conclusions

The simulation results showed that when a magnetic field is excited by an ungrounded loop and measurements are made using a UAV when searching for local magnetic objects, the horizontal components of the magnetic field are more "sensitive" to the influence of these objects.

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