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Detection of Temperature Anomalies Arising from Foreign Bodies Buried in the Ground

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Abstract—Based on solutions to the heat conductance equation, the paper presents the data concerning the impact of thermophysical properties of a foreign body buried in undersurface ground and of parameters of natural heat exchange process on the ground surface temperature. Estimation of probabilities of detection of local temperature anomalies is performed with the use of airborne scanning IR equipment.

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INTRODUCTION

Recording of infrared (IR) images permits to detect sources of intrinsic thermal radiation, to reveal underground communications and cavities, the objects buried in the ground, and to detect disturbed and restored soil segments [1, 2]. In recent years there is an aroused interest in remote detection of buried explosive devices, mines in particular, judging by temperature anomalies of ground surface heated by the sun [3]. It is well known that burying a foreign body in the ground makes an impact on the process of heat exchange of the upper (above the body) layer of soil with lower layers, thus resulting in emergence of a local temperature abnormality. Successful resolution of the problem of remote detection of buried foreign objects is associated with usage of many-spectrum devices having good temperature sensitivity in IR range. To substantiate the requirements to temperature sensitivity of IR channel of this type of optic-electron equipment, it would be interesting to consider temperature anomalies depending on buried objects and watched under various conditions of natural heat exchange.

In [4] we performed theoretical analysis of behavior of these temperature anomalies in conditions of stationary solar heating. We also obtained data in concern with possibility of their remote detection via IR channel of an airborne small-size optic-electron scanning device [5]. In the course of analysis we used the models of three-layer and single-layer thermoactive surface on an isothermal substrate [6, 7]. These models correspond, respectively, to fragments of a background with a buried foreign object and without it. The overall thickness, dictated by deepness of terrain surface warm-up, was set about 30–50 cm [6]. Based on solution of the stationary equation of heat conductance, we deduced analytical expressions, which defined behavior of the single-dimensional (in depth) temperature field for the single- and three-layer surface depending on natural heat-exchange conditions and thermophysical properties of the ground and a buried foreign object. The derived dependencies were used for assessment of temperature anomalies and of probability of their detection by IR equipment. However, the stationary model, used in [4], has some limitations, which demands for further research in the revealed properties.

In this work we present results of the inquiries extending those reported in [4] and devoted to accounting the transient process of natural heat exchange and to elaboration of the thermophysical model used. To obtain the necessary data about the dynamics of temperature anomalies, we use numerical solutions to the nonstationary equation of heat conductance for a three- and a single-layer model, corresponding to a fragment of land surface with a buried foreign object and without it. As in [4], in the course of analysis with the three-layer model we consider two limit cases of the intermediate foreign layer: with high heat conductance inherent in metals, and with low heat conductance peculiar to insulators, such as plastics. Calculation of the single-dimensional (in the depth direction) temperature field is carried out with the use of difference equations set up by the explicit finite-difference scheme [8]. The depth of penetration of solar warm-up is determined directly in the course of equation treatment. We also perform comparable analysis of results obtained from solution of the stationary and nonstationary equations of heat transfer.