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Determination of Forest Environment Density by Georadar "OKO-2"

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Abstract: *A radar method for surveying forests based on GPR technology is proposed, which allows measuring the density of the forest environment with an error of ±5%. The forest is irradiated by a georadar installed on a car. Counting the number of reflections from tree trunks (hyperbolas) in a given area allows you to quickly and reliably determine the number of trees per unit area (ar) and recalculate into forest density. A clearer radargram of reflections from tree trunks was obtained with vertical polarization, i.e. the signal reflected from the tree trunk is higher when the polarization of the probing electromagnetic pulse is parallel to the trunk.*

Keywords: *georadar method, forest environment, ground penetrating radar, forest density.*

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1. Introduction

An important and not yet fully resolved issue in the physics of wave processes is to take into account the influence of vegetation cover on the propagation of electromagnetic waves. Coniferous, deciduous, mixed and tropical forests [1] occupy over 40% of the Earth's land mass. At the same time, the steppe regions are 70% covered with cereal crops, orchards, cotton, coffee and tea plantations. Therefore, the development of models that allow qualitatively assessing and quantitatively predicting the parameters of the electromagnetic field in the Earth-ionosphere waveguide channel in the presence of vegetation is a very urgent task

[2]. Accounting for the influence of vegetation cover is of independent importance for predicting electromagnetic fields during the operation of various radio-electronic systems in order to improve the reliability of information transmission by radio communications, improve the accuracy of both stationary and, especially, mobile radio navigation systems, as well as to improve the accuracy of location of thunderstorm activity centers. and other sources of electromagnetic radiation for multipoint measurements. The review of the literature presented in [2] provides a fairly detailed analysis of the few experimental data and methods for calculating electromagnetic fields in the presence of vegetation in the ranges of medium, long, and superlong waves. The main element of the vegetation cover is a separate tree of the forest [2]. At the same time, trees have different geometric characteristics depending on the type (coniferous: spruce, pine, cedar, larch, etc., deciduous: birch, aspen, oak, alder, etc.). Depending on the age of the trees, their height and diameter change, as well as the height of the crown from the ground and the diameter of the tree crown. At the same time, the wood of tree trunks has a certain specific electrical conductivity, which depends on the ambient (air) temperature in accordance with the change in the nature of the life of trees. Therefore, the representation of an individual tree and a forest area as a whole in a certain model that takes into account the above geometric and electrical characteristics is a very urgent task. The theoretical analysis and the results of experimental studies of electromagnetic field distortions in the presence of a separate tree, which is the main element of the vegetation cover, made it possible to represent the tree in the model of a vertical electric reradiator with a capacitive load. In this case, the complex resistance of an individual tree in the model of a vertical electric re-emitter with a capacitive load is completely determined by the geometric characteristics of the trunk and crown of the tree, taking into account the specific electrical conductivity of the wood of the tree trunk, which gives good agreement between theory and experiment [2]. The effective complex resistance can be determined using well-known formulas that are valid for a leaky capacitor, which include the geometric dimensions of the tree, and take into account the dependence of the specific electrical conductivity of the wood of the tree trunk on the ambient temperature.

The purpose of the work is to propose and substantiate experimentally a georadar method for measuring the density of the forest environment, which makes it possible to quickly and reliably survey forest areas.

2. Equipment and experimental technique

On the territory of Russia [1], forests cover an area of more than 7 million km^2, of which in the Baikal and Transbaikal regions – 960 thousand km^2 (60% of the territory). The main role in Siberia is played by coniferous forests – pine, larch, spruce, cedar. Of the hardwoods, birch and aspen are the most widespread. The pine forests that prevail in the Siberian region usually grow on dry sandy soils and on the southern slopes of the mountains. The height of the trees varies from 5 to 30 m, on average 10–20 m; trunk diameter – from 0.1 to 0.8 m, on average 0.15–0.35 m. In open places, the height of trees is lower than in dense forest. To predict the propagation of radio waves along the earth's surface covered with forest, it is necessary to know both the electrical parameters of forest vegetation ($\sigma_л$ и $\varepsilon_л$) and the density of the forest environment. There is a limited amount of experimental data in the literature [3, 4] obtained under various physical and geographical conditions (subtropics, the European part of Russia, North America). Georadar (ground penetrating radar) method is based on the phenomenon of reflection of electromagnetic waves from media and surfaces on which the electrical properties change [1]. The main parameter of the medium in the range of meter and decimeter radio waves is its dielectric constant ε. The OKO-2 georadar used in the measurements includes emitting (field source) and receiving (receiver) antennas. The source emits an electromagnetic wave of a given frequency in the form of a finite one and a half period pulse. The forest is irradiated by a GPR mounted on a vehicle, which moves along the profile during GPR survey, usually along a forest road. Counting the number of reflections from trunks in a given area allows you to quickly determine the density of the forest. An electromagnetic wave in the study medium is reflected from the boundaries of the layers and various inhomogeneities with different dielectric properties. At each point of the profile, a radar trace is recorded – the dependence of the signal amplitude on the time of arrival of the reflected signal. A set of traces along the entire profile makes up a radarogram. The first reflection on the radarogram is called the direct signal (direct signal). The direct wave is in most cases the same for all profile traces. It is determined by the design of the antenna and the profile surface. When the georadar moves along the profile, reflection from local objects or boundaries of media with different dielectric constants occurs. A set of reflections can form a straight line, in the case of a boundary, or a hyperbola (hyperbolic curve) in the case of reflections from a local object, while the object itself is at the top of this hyperbola (Fig. 1) [2]. A diffracted wave from a local object is described by the following equation:

$$t(x) = \frac{2L}{V} = \frac{2\sqrt{x^2 + h^2}}{V},$$

[1] Radio technical device for subsurface sounding (ground penetrating radar) "Oko-2". Technical description. User manual. Moscow, LLC "Logic Systems," 2006.

[2] GeoScan32. Illustrated user manual. Ramenskoye. Moscow region: LOGIS, 2013.

where x is the distance from the projection point of the object on the surface to the point on the profile, t(x) is the time of passage of the electromagnetic pulse in the medium along the “emitter-object-receiver” path, L is the distance from the georadar to the object at depth h, V is the speed radio pulse propagation in the medium: 0.3 m/ns in air.

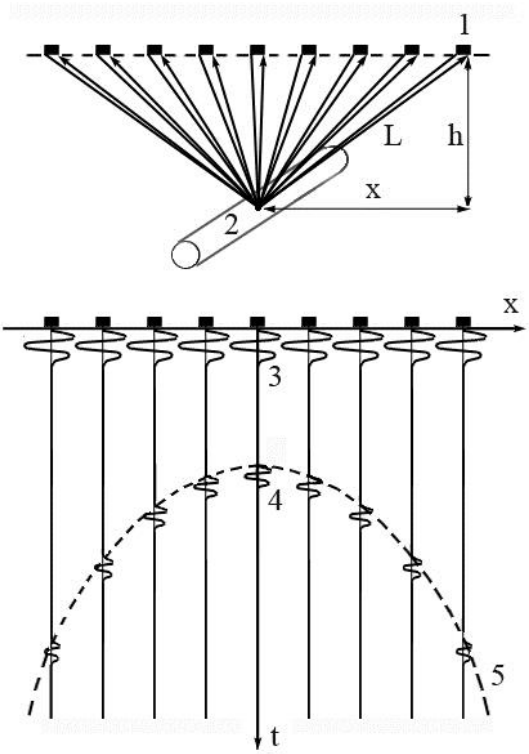

Fig. 1. Display of a local object – a tree trunk and a temporal picture of the GPR signal reflected from it. 1 – ground penetrating radar; 2 – local object; 3, 4 – direct and reflected wave, 5 – hyperbolic curve (dotted line)

3. Discussion of the results

Let us consider the results of studying the characteristics of the forest environment (coniferous forest) using the OKO-2 georadar with the AB-400 antenna unit. The forest is irradiated by a georadar installed on a car moving along the forest road (Fig. 2).

The tree trunk is a vertical cylindrical re-radiator with electrodynamic parameters that are significantly different from the ground air: specific electrical conductivity $\sigma_л = 10^{-2} - 10^{-3}$ S/m and dielectric constant $\varepsilon_л = 4 - 30$ [2]. On the radarogram (Fig. 2), reflections from tree trunks in the form of hyperbolas are clearly and contrastingly distinguished.

Fig. 2. Test plot of the forest. The arrow shows the trajectory of the car
with the OKO-2 georadar with the AB-400 antenna unit

The measurements were carried out for horizontal and vertical polarizations of the electromagnetic field. A clearer radarogram of reflections from tree trunks was obtained with vertical polarization of the electromagnetic field. This

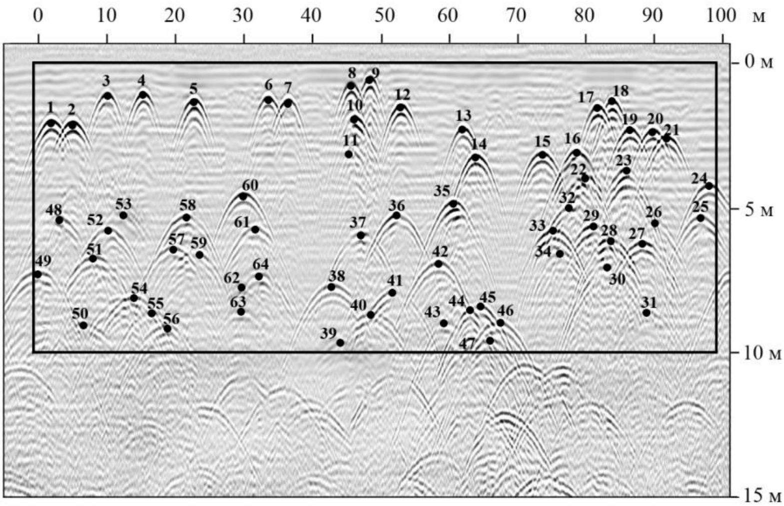

Fig. 3. Radarogram of the forest. GPR “OKO-2” with antenna unit AB-400. Vertical polarization.
The location of tree trunks is indicated by dots with numbers.
A test area 10 m × 100 m (10 ar) is marked with a rectangle

effect is due to the fact that when the polarization of the probing electromagnetic pulsed field (E-component) is parallel to the tree trunk, the effective scattering area of the tree will be higher. Counting the number of hyperbolas in a given area makes it possible to quickly and efficiently determine the density of the forest (Fig. 2). In the experiment performed by the OKO-2 georadar with the AB-400 antenna unit (central frequency 400 MHz, wavelength λ = 75 cm) on a test forest area with dimensions of 10 m × 100 m (10 ar), 64 hyperbolas of the reflected signal from coniferous trunks were identified (pine) trees (Fig. 3). Comparison with the actual number of trees showed 3 gaps due to the shading effect of close trunks, which is 95.5% of the true number of trees.

4. Conclusion

A radar method for surveying forests based on GPR technology is proposed, which makes it possible to measure the density of the forest environment with an error of ±5%. Counting the number of reflections from tree trunks (hyperbolas) in a given area allows you to quickly and reliably determine the number of trees and recalculate to the density of the forest. A clearer radarogram of reflections from tree trunks was obtained with vertical polarization, i.e. the signal reflected from the tree trunk is higher when the polarization of the probing electromagnetic pulse is parallel to the trunk. Theoretical studies presented in [2] show that the presence of vegetation significantly affects the electromagnetic field, which at some distances from the radiating device can be even greater than the electromagnetic field over an infinitely conductive surface. This feature of the propagation of electromagnetic waves along forested and ice trails has been confirmed experimentally [2, 4]. Taking into account the influence of vegetation cover allows not only qualitatively, but also quantitatively assessing the features of the propagation of electromagnetic waves associated with the significant influence of the surface electromagnetic wave (SEW) in the MF, LF and VLF radio wave bands, when the field over the forested paths is greater at some distances from the emitter, than for the case of an infinitely conducting plane.

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