Analytical representation for 3D fields of antenna radiation in problems of georadar sounding.

[1,2]Rudenchik E.A., [1,2]Volkomirskaya L.B., [1,2]Varenkov V.V., [1,2]Reznikov A.E. and [1,2]Sahterov V. I.

1- Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation (IZMIRAN)
Russia, 142190, Moscow region, Troitsk, mila@izmiran.ru
2-ZAO "Timer"
Russia, 142190, Moscow region ,Troitsk, st. Solnetchnaya, 12

Abstract

This paper describes algorithmization representations for field of radiation of the antennas applied in GPR scanning of subsurface structures, in stratiform and two-layer soils in three-dimensional approach. Results include asymptotic representations for fields on small distances from the antenna and analytical representation for a superficial wave. Asymptotic representations of field allow eliminating singularity in numerical modeling, to consider field influence on a current in the antenna during solving of three-dimensional inverse problem of GPR-location. Asymptotic representation of superficial wave field allows to reduce time of solution finding in inverse problems of GPR scanning and to clear data of the observable reflected field.

Keywords: GPR, antenna, GPR "GROT –12", inverse solution

Interpretation of GPR sounding data for subsurface areas of the Earth means restoration of a profile for dielectric permeability coefficient inside soil on the base of electromagnetic field measurements of the reflected signals.

Development of a method for inverse problem of GPR scanning demands the decision of two problems: the analytical description of field singularity arising in a vicinity of the radiating antenna, and exact definition of current distribution in the antenna. Importance of the second problem is caused by the following reason: unlike the qualitative methods operating mainly with time delays of reflected impulses, the method of inverse problem completely uses all form of an impulse, and errors in a current profile can be transformed to inadequate definition of soil parameters. The current depends on properties of a spreading surface on which the antenna lays. The description of a current demands the mathematical model considering this dependence. It is obvious, that such model should describe inverse influence of electric field on a current, which besides demands calculation of a field near to oscillator.

In the purest form the information about the current form are contained in the superficial wave arising on the border "earth-air". Amplitude of this wave, as a rule, is significantly greater than level of the signals reflected from internal heterogeneousness. It gives the chance to estimate preliminary

dielectric permeability of a spreading surface and model parameters of a current on its profile. For this purpose it is desirable to develop procedure for fast and exact calculation of tangential (measured by a GPR) component of superficial wave, allowing operatively solving an inverse problem of current restoration. Exact calculation of a profile of a superficial wave is connected also with necessity to extract from its background the weak signals reflected from subsurface of objects. Besides, the superficial wave can be used in the formulation of boundary conditions for the description of distribution of a wave in the bottom half-space, along with a condition of absence of other waves falling on soil. It can enhance accuracy of inverse problem solution.

The fullest information about stratiform layers can be received using broadband reception-transfer systems with wide dynamic range. GPR of series "GROT" are among such systems, namely GROT-12. The basic design features of a GPR of a series "GROT" are described in [1]. In particular, GPR "GROT" use the dipole resistive loaded antennas as the most super broadband antennas, allowing to lower signal distortions and to increase GPR resolution [2].

Adequate method of the description of broadband signals - Laplace transformation with integration on contours in a complex plane as Fourier transformation, i.e. integration on a complex axis of Laplace transformation leads to slowly converging integrals from the oscillating functions demanding big time of calculations and resulting low accuracy of results [3].

In work [4] it is shown, that the tangential component of a superficial wave can be expressed through analytical function of two variables for any parameters of rupture. Integrated representation for this function is received, allowing to investigate its properties and to create the fast procedure of calculation similar to calculation procedures of standard special functions. Expression for fields near to the antenna representing a thin conductor of any form and laying in a rupture plane is found. Simple expressions for a field component with singularity in antenna vicinity are received.

From the point of view of inverse influence of the field on the current the singularity is not important: in field z-component that parallel to the current it brings the identical contribution both in the environment and in vacuum. Therefore, to describe this experimental fact it is necessary to consider a regular component of a field, actually, to calculate an exact field near antenna. Basic possibility to do it quickly is shown in [4].

Conclusions

At the present stage the main problem is the creation of mathematical model of a current in dipole resistive loaded antenna considering influence of the spreading surface. For this purpose it is planned to execute a number of experiments on the proving grounds as much as possible close to the two-layer soils. Data of these experiments, along with algorithm of restoration of a current on a tangential component of superficial wave, should check up adequacy and specify parameters of model of a current. Similar work has already been executed in the assumption of two dimensions of a field [5]. However, for use in algorithm of the inverse problem solution the three-dimensional space is basic. The mathematical model of a current will allow to close initial system of the equations within the limits of adequate assumptions and to make a new step in development of algorithm for restoration of parameters of strata areas according to GPR sounding.

References

1. L.B.Volkomirskaya, V.V. Varenkov, A.N.Lobzina, V.V. Lobzin, A.E.Reznikov, E.A.Rudenchik. The basic features of a design of a GPR "GROT-10" and "GROT-11", experience of their operation and

data processing// The monograph "Questions of strata form radar-locations" M. 2005г. Publishing house the Radio engineering, p. 246-259, c.12

2. T WU and R.W.P.King,-The Cylindrical Antenna with Nonreflecting Resistive Loading, IEE Trans. Ant. Prop

3. E.A. Rudenchik, L.B. Volkomirskaya, and A.E. Reznikov. Investigation of the Propagation of Signals in One-Dimensional Electrodynamics for Interpretating Electromagnetic Sounding Data. Consideration of the Analytic Properties of Permittivity. ISSN1541-308X, Physics of Wave Phenomena, 2008, Vol. 16 N 1, pp, 1-18, Allerton Press, Inc., 2008

4 Rudenchik E.A., Volkomirskaya L.B., Reznikov A.E., Sahterov V. I.

Analytical representation of 3D radiation fields in the two-layer soil and the inverse problem of georadar sounding. Publisher: "Radio engineering", «Successes of modern radio electronics» N 1, 2009. (In press)

5. E.A. Rudenchik, L.B. Volkomirskaya, and A.E. Reznikov. Array Current Reconstruction by SurfaceWave Measurements. Two-Dimensional Approximation., ISSN1541-308X, Physics of Wave Phenomena, 2008, Vol. 16 N 3, pp., 1-10, Allerton Press, Inc., 2008