IDENTIFICATION OF HETEROGENEITIES IN THE UPPER PART OF GEOLOGICAL MEDIUM WITH GROUND PENETRATING RADAR VIY3-300

INTRODUCTION

During the last 20-25 years ground penetrating radars (GPR) became widely used geophysical method for solving problems of near surface geophysics. There are two major groups of problems, which could be solved with GPR. 1. Geological structures mapping, geotechnical and hydrogeological problems – mapping of geological structures, evaluation of the depth to the ground water, evaluation of the ice thickness. 2. Identification and examination of artificial objects – pipelines, cables, buried industrial wastes, foundation of the building and natural soil) and geological structures to test productivity of applied VIY3-300 GPR with 300 MHz antenna for further investigations of such kind of objects.

THEORETICAL BACKGROUND

Ground penetrating radar is a device, which radiate electromagnetic waves and then record electromagnetic signal, which is reflected from the boundaries between parts of the medium with different permittivity.

As usual GPR device contains transmitting and receiving antennas. The transmitter radiate electromagnetic wave and receiver record reflected electromagnetic signal. In some occasions, GPR has one antenna, which radiate and receive signal. According to different construction of antennas, there are several types of them: monopoles, dipoles, conical and bow-tie antennas (Daniels, 2004, Vladov, 2004). Depending on the frequency of antennas and architecture of the devices, relative position between transmitter and receiver can vary and according to Daniels (Daniels, 2004) there are four modes of GPR surveying: common offset; common depth point; common source and common receiver. The most widely used is considered to be common offset, when distance between receiver and transmitter is fixed (Daniels, 2004). While surveying in each point (with exact step) of the profile trace is recorded. As a result, GPR profile or radargram contains all traces, which were recorded along each direction of surveying. Resolution of survey and depth of investigations primarily depend on frequency of the signal and permittivity of

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the medium – as higher frequency as shorter length of the electromagnetic wave and so smaller objects could be identified, as higher permittivity as stronger attenuation of the signal and so shallower depth of the surveying.

After signal processing with special tools (gain, filters of high and low frequencies etc.), anomalies could be localized and interpreted according to the next rule: a set of reflections can form a straight line in case of flat or tilted border, and hyperbola anomaly, when signal reflects from local objects (small point-like heterogeneity), and in this occasion object is in the top of this hyperbola (Persico, 2014). Moreover, according to theoretical basics of the method (Daniels, 2004 Persico, 2014), when angle between branches of hyperbola-like anomaly is known, it is possible to get information about velocity of electromagnetic wave propagation and geometrical parameters of the object.

DESCRIPTION OF THE DEVICE AND APPLIED TECHNICS
For investigations VIY3-300 GPR was applied. This equipment is manufactured by Ukrainian LLC «Transient Technologies». This device is designed to detect heterogeneities in the soil, building structures to the depth (thickness) of 8-12 m. This device may be applied to solve above mentioned problems. Odometer and/or GPS could be connected to the ground penetrating radar to know precise step in meters between measurement points. Device could be connected to the computer via Wi-Fi or with USB cable. VIY3-300 GPR is designed as a common offset modification with bow-tie antennas.

**Fig. 1.** Experimental polygon:

- **a** – cross-section with location of the objects according to their position during construction of the polygon: 1, 2 – steel pipes, diameter 5 cm, length 1 m; 3, 13 – steel pipes, diameter 5 cm, length 2 m with wire inside; 4 – metal box (0.5m×0.8m×0.4m, empty inside); 5, 6, 12, 14 – steel pipes, diameter 5 cm, length 2 m; 7 – styrofoam (1m×0.5m×0.5m); 8 – metal plane (0.8×0.8m); 10, 11 – plastic pipe diameter 20 cm, length 220 cm;
- **b** – radargram obtained on the polygon, numbers for anomalies correspond to the numbers on the picture with cross-section.
Main specifications of VIY3-300: antenna system frequency: 300 MHz; Analogue-to-Digital Converter range: 18 bits; Dynamic range: at least 135 dB; measuring speed: up to 55 traces per second; Step of measurement: from 30 mm to ~3200 mm; survey window: 66, 100, 133, 166 ns; the maximum number of samples per trace: 1000; Trace stacking number: up to 300; probing depth: to 12 meters (determined by the properties of rocks); spatial resolution: not worse than 0.3 m; trigger mode: single, internal, external; File size up to 1 million traces; Interface: USB2.0 or Wi-Fi; Dimensions: 610 x 312 x 170 mm; Weight: 9 kg; Operating temperature range: -20 °C to 40 °C; continuous operation time: not less than 8 hours (http://viy.ua/e/products/VIY3-300_Georoar.htm).

Such technical and design characteristics provide perfect coordination of electronics, antennas, high reliability and easy application of devices.

While measurements device was on the ground and operator dragged it across buried objects. Different settings of measurement (Chernov, Loshakov 2016) and up-to-date tools for GPR-data processing (wavelet function, gain function, frequency filters) in Synchro software (by «Transient Technologies») were applied to obtain representative results.

SITES OF INVESTIGATIONS
Results of investigations from three areas are shown in this paper:

1. Experimental polygon for the study of the upper part of the geological medium (near Institute of geology of Taras Shevchenko National University, Kyiv, Ukraine). This polygon was created for testing of different geophysical methods. There are different buried objects (fig.1 a), which reflect electromagnetic signal and could be identified on radargrams (fig. 1 b).
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2. Granite quarry (near Kornin city, Zhytomyrs’ka oblast, Ukraine). Granite structure of this region is characterized by fracturing and one of the horizontal fractures (on the depth of 3 m from the surface of investigations – fig. 2 a) was filled with water.

3. Region of crystalline rocks exposure on the earth surface and their diving under the sedimentary layer (location near granite quarry, Kornin city, Zhytomyrs’ka oblast, Ukraine) (fig. 2).

4. Evaluation of the depth to the borders between layers of soil under the foundation of the building. (Volodymyrs’ka str., Kyiv, Ukraine).

RESULTS
Experimental polygon. Figure 1 shows cross-section of the polygon (fig. 1 a) and resulting radargram after processing (fig. 1 b). Number near each anomaly on radargram corresponds to the number for objects on the cross-section. After choosing most applicable parameters of survey (step of measurement 30 mm; 1000 samples per trace; length of trace (depth) 70 ns) and after processing radargram depicts clear reflections from objects 1, 2, 3, which locate close to each other, and from 5, 6, which locate above each other. Such discretization is possible thanks to length of the electromagnetic wave, which was 0.3-0.5 m on this site. However, reflections from plastic pipes (10, 11), metal pipes (13, 14) and metal plane (8) are worse visible, as these objects located deeper and interference of the reflected wave from two metal objects prevent clear identification of the reflection from each of them separately. Reflections from styrofoam box (7), pipeline (12) and metal box (4) are clearly visible, because of their location and characteristics of the material, which result in strong anomaly.

Fig. 3. Exposure of granites on the earth surface:
a – a picture from site of investigation – border between outcrop of granites and sedimentary layer on the earth surface; b – radargram obtained on this site: with dashed line anomalies in the granite structure are marked and with solid line – border between sedimentary layer and granites.
Granite Quarry. Difference between radargram before processing (fig. 2 b) and after (fig. 2 c) approve, that several steps of processing are sufficient to distinguish useful signal. As a result, higher amplitude of the signal on the radargram (fig. 2 c) match to the real location of fissure with water (fig. 2 a). And lower another bright linear anomaly was indicated, which considered to be provoked by fissure between granite blocks.

Region of crystalline rocks outcrops. Depth to the crystalline rocks under sedimentary layer was evaluated and heterogeneities in granite were identified, which are visible on fig. 3 b. First bright linear anomalies on the depth 2-2.5 m correspond to the border between sediments and granite. In the central part of radargram (from 6 to 23 m along vertical axis) anomalies near the earth surface correspond to outcrops of crystalline rocks and anomalies beneath this part correspond to heterogeneities in the weathered rock. Beneath 2.5 meters anomalies considered to be provoked by presence of fissures in the granite.

Evaluation of the depth to the borders between layers of soil. With the use of VIY3-300 GPR depth to the natural soil under foundation of the building was determined. The results of GPR surveying were correlated with the results of drilling on this area (fig. 4). It was possible to distinguish different layers, because on the radargram different peculiarities for reflected signal match different layers as a result of GPR surveying, this is shown on radargram on fig. 4.

CONCLUSIONS
These investigations revealed that applied equipment, field technics and processing algorithms help to detect heterogeneities such as cracks filled with water, border between different rocks and soil types and artificial objects (pipes, iron boxes, wastes – products from tin, plastic). Obtained results prove that VIY3-300 GPR is reliable equipment, which can be applied for solving of wide range of near surface problems. During these investigations first attempts of VIY-3 GPRs informativeness evaluations were done.

Aims of further research of authors are development of GPR surveying technics and algorithms for obtaining the best quality of the results in the shortest period of time; development of processing algorithms and methods of work that will help to get information about physical properties of investigated medium and to solve inverse problem of geophysics with minimal deviation thanks to combination of GPR data with other methods.

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ОПРЕДЕЛЕНИЕ НЕОДНОРОДНОСТЕЙ В ГЕОЛОГИЧЕСКОЙ СРЕДЕ С ПОМОЩЬЮ ГЕОРАДАРА VIY3-300

В данной работе представлены результаты исследования геологических и сделанных человеком объектов. В статье приведено описание методики проведения работ и технические характеристики примененного оборудования. Результаты исследований представлены в виде радарограм, которые получены в результате исследований на экспериментально-обучающем полигоне, гранитного карьера и места выхода и погружения под осадочный слой кристаллических пород. Результаты исследований показали, что при помощи георадара VIY3-300 (частота антенного блока 300 MHz) возможно обнаружить пластиковые и металлические трубы, трещины, границу между породами с разной диэлектрической проницаемостью.

Ключевые слова: георадар, радарограмма, инженерная геология, гранит, приповерхностная геофизика

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