GEORADAR

TR-GEO-01-08

BRIEF TECHNICAL DESCRIPTION

MOSCOW 2014

1. Principle of operation, designation, field of usage, of the georadar TR-GEO-01-08.

1.1 Principle of working, objects and results of sounding.

In the georadar TR-GEO-01-08 pulse method of sounding is used. Short electromagnetic pulse is induced by a generator, radiated by the transmitting antenna, propagates through the ground, reflected by some objects of sounding, and comes back to the receiving antenna. Objects of sounding are artificial objects and also natural heterogeneities of a soil, differing from neighboring soil in dielectric permittivity and conductivity, and having sufficiently large size.

Georadar TR-GEO-01-08 is designed for sounding in soils and rock with low and moderate attenuation of radio waves: in sandy soils, moist and dry, in dry clay loam, in rock, limestone, permafrost.

A final result of the sounding and processing of signals is radiolocation image of objects and heterogeneities of a soil, imaging of reflecting boundaries and objects, obtained by the processing. The image may be 3-dimensional (3-D), as a number of vertical and horizontal sections of a volume. The image does not give the distribution of dielectric permittivity (density and moisture of a soil), but shows only reflections from boundaries between different layers of soil and heterogeneities or objects. Uniform medium (soil) will not be visible.

By georadar sounding one can distinguish metallic objects or moist areas from cavities in the ground by sign of reflected signal (by colors on radiolocation image).

1.2 Main field of usage.

- Sounding of underground communications.
- Sounding of various metallic and non-metallic objects, having rather large size (not less than about 0.3-0.5 m), cables, pipes.
- Drawing of geological sections of upper layers of a ground, finding of boundaries of water lenses, alluvia.
- Sounding of cavities and moist areas under road pavement.
- Sounding of cracked areas in rocks, filled by water.
- Sounding of karst cavities, big stones.
- Search of anti-tank mines, unexploded ordnance.

1.3 Main features.

- Shielded (slot) antennas, low radiation to back direction.
- Good quality of sounding pulse.
- The georadar can work in real time with a computer or independently without a computer with saving the data into built-in flash memory (**Fig.1-3**).
- Water proof (hermetical) antenna units, separable replaceable batteries.
- Convenient foldable design of antenna unit, fast preparation for work.
- Using of video-camera, storing of video frames with the results of sounding.
- Certificate of compliance with European standards on electromagnetic compatibility ETSI EN 302-066-1 and -2 V1.2.1: 2008.

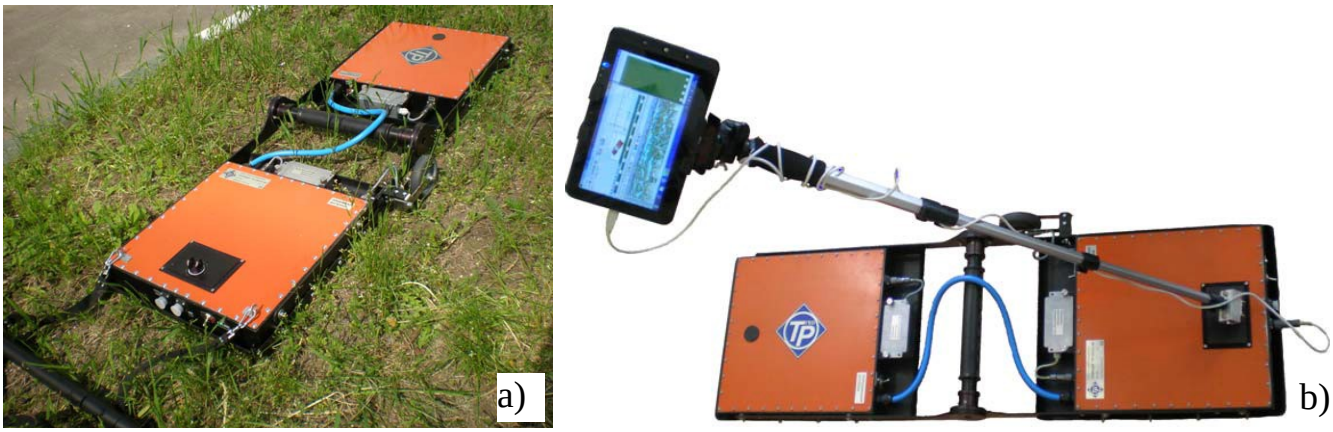

Fig.1 Georadar TR-GEO-01-08 in working state: a) for work without a computer with saving the data into flash memory, b) for work in real time with tablet-PC.

Fig.2 Working with a computer and independently without a computer with saving the data into built-in flash memory.

Fig.3 Working without a computer with saving the data into built-in flash memory.

1.4 Types of sounding.

- Working with a computer with connection by USB. In this mode the result of sounding (vertical radiolocation profile) is displayed on computer monitor in real time.
- Independent work (without a computer) with storing of the measured signals into build-in flash-memory. Then the signals should be rewritten into computer by USB. This mode is very useful in circumstances, when work with a computer is not convenient and quite impossible (**Fig.3**). This mode is very convenient and enables measure signals under unfavorable weather and temperature conditions.
- Georadar has a path sensor (wheel). Sounding with the path sensor (over level surfaces) enables accurate positioning of the antenna unit.
- It is possible to measure signals in separate positions of antenna unit with large number of averaged signals at each point.

2. Main technical performance.

2.1 Depth of sounding.

Approximate estimation of depth of sounding:
- in dry sandy soils, rocks, permafrost – up to 20 m,
- in wet sandy soils, limestone - up to 10-12 m,
- in dry clay loam - up to 5-7 m,
- in wet clay loam - up to 1-5m.

Georadar TR-GEO-01-08 provides the following depths of sounding for local and linear objects (pipes), given in **Table.1**. The indicated depths of sounding are found for energy potential of the georadar of 120 dB (see below).

Table.1 Maximal depths of sounding of linear and local objects depending on conductivity of a soil .

Conductivity (S/m) of a soil	Depth of sounding (m) of metallic pipe with ∅15 cm	Depth of sounding (m) of empty plastic pipe with ∅15 cm	Depth of sounding (m) of metallic sphere with ∅50 cm
0.03	2.5	2.3-2.5	2.3
0.02	3.5	3.2-3.5	3.2
0.01	6.3	5.7-6.3	5.4
0.005	11-11.2	10-11	9.1

NOTE. Depth of sounding depends on both electrical properties of a soil, and size and type of objects of sounding. Depth of sounding depends on content and conductivity of clayey component of a soil, on moisture and conductivity of soil solution, on temperature. Long storing and averaging of signals, measured in separate positions of antenna unit, may increase depth of sounding in clay and loam.

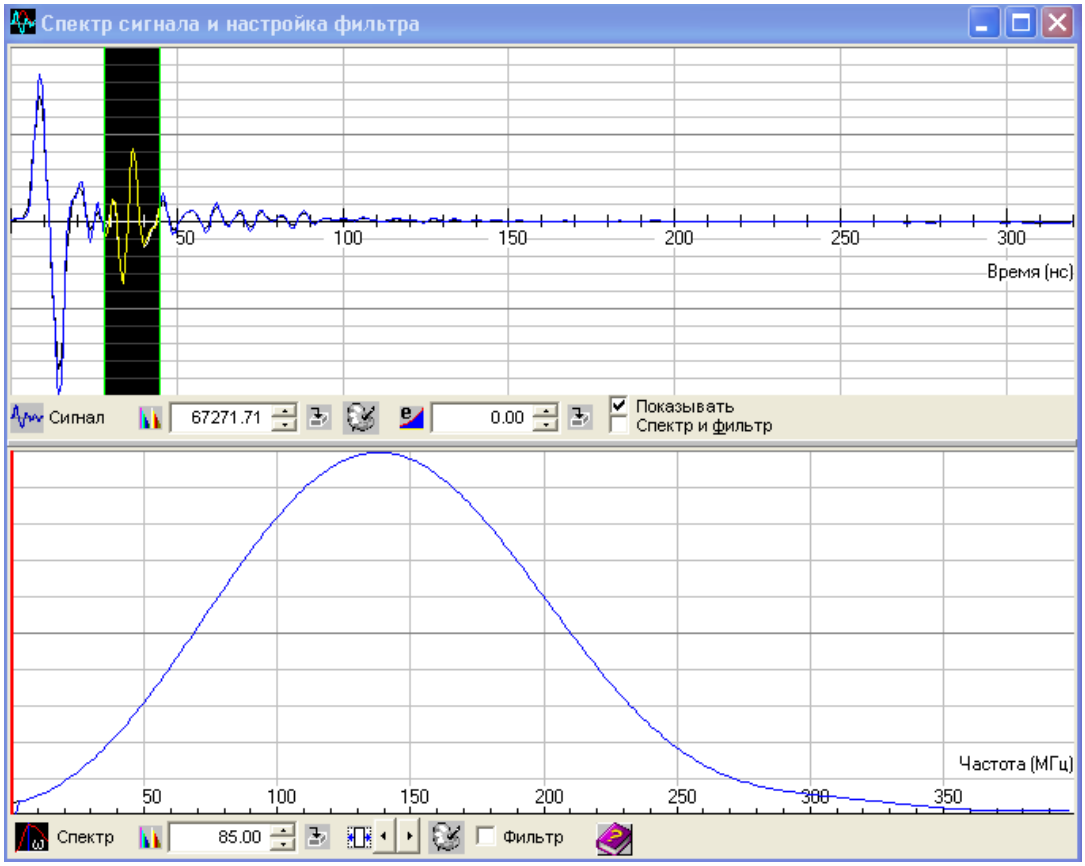

Fig.4 Typical measured signal of the georadar (above) and spectrum of sounding pulse (below). Measured signal includes directly passed pulse and reflected pulses. One of the reflected pulses is shown within the black rectangle. This pulse was reflected by a plane horizontal boundary in a soil. Spectrum of this reflected pulse is shown below.

2.2 Frequencies of sounding, resolving power and sizes of objects of sounding.

Duration of sounding pulse (by two main half-periods) – about 6-7 ns.
Sounding pulse is shown on **Fig.4**.

Mean frequency of spectrum of sounding video-pulse about 140 MHz.
Bandwidth of the spectrum of sounding pulse as a ratio $\mathbf{f_2:f_1}$ of upper f_2 and lower f_1 frequencies:

- by amplitude level 0.5 of the spectrum - **about 3** ($f_1 \approx$ 70-75 MHz; $f_2 \approx$ 210-220 MHz);
- by amplitude level of the spectrum –10 dB - **about 4.5** ($f_1 \approx$ 50-60 MHz; $f_2 \approx$ 230 MHz).

The spectrum of sounding pulse is shown on the **Fig.4**.

Resolving power in distance (depth) - 0.2-0.4 m (depending on moisture of soil).

Minimal sizes of objects of sounding:
- for local objects - 0.3-0.5 m,
- diameter of metallic linear objects (pipes, cables) - 0.05-0.2 m.

2.3 Operational performance.

Construction features.

Georadar has foldable antenna unit. Preparing for working of the georadar (in mode without computer) consists in only in unfolding of the antenna unit in the working "unfolded" state and connecting of straps with a handle for manual movement of antenna unit. When working with the path sensor, the path sensor (wheel) is also connected. No other assembling, connections of electrical or optical cables are not needed. (Transmitting and receiving antennas are connected with each other by permanently joint fiber optic cable for synchronizing of receiver and transmitter.)

Antennas of the georadar are waterproofed (hermetical). Electronic units of generator, receiver and unit of control and signal storing are situated inside transmitting and receiving antennas, and are protected from moisture and dust. Antennas have plastic shields on its bottom side for protection from wear, moisture and mud. The georadar is suited for using in field conditions and in any weather.

Georadar has separable replaceable hermetic battery units, which are mounted on the antennas. One can easily replace the batteries during the work. This enables working long time in field conditions.

Overall dimensions:

Single antenna - 41×40×6 cm, antenna unit in unfolded state - 133×43×13 cm.

Weight.

Weight of the georadar in working state (antennas unit) - 13.5 kg.

Temperature range.

For work without computer - from −20˚ up to +40˚ C.

Power consumption.

Separable hermetic battery units are mounted on the transmitting and receiving antennas. Batteries – led acid, sealed (AGM technology).

Voltage of the batteries 12 V. Capacity of the batteries on transmitting and receiving antennas – 1.2 A·h. Time of continuous working (without charging or changing) of battery unit: transmitting antenna – 3.5 h, receiving antenna – 2.5 h.

Time sweep performance.

Number of sampling points of the signal on time sweep can be 128, 256, 512.
Duration of time sweep for the georadar signal may be tuned by user.

Performance of flash-memory.

Writing of measured data may be performed to built-in flash memory. Maximal number of signals in the flash-memory of the georadar (for number of sampling points per time sweep 512) – 65 275. Usually it is sufficient for 4-6 hours of continuous work.

Connecting with a computer – by USB.

Rate of measuring of signals.

Rates of signals measuring are given for number of time sweep sampling points 512. Rates of signals measuring are given for stroboscopic frequency (pulse repetition frequency of the generator) 105 kHz, for work with writing of signals to built-in flash- memory.

Rate of single georadar signal measurement and energy potential “E” (see ch.2.5) at the end of time sweep:

- without exponential hardware accumulation with constant store number 10 – about 9 signals per second, E = 105 dB;
- with numbers of exponential hardware accumulation of signal from 5 to 1000 – about 1 signal per second, E = 125 dB;
- with numbers of exponential hardware accumulation of signal from 10 to 3200 – about 1 signal during 3 seconds, E = 130 dB.

In mode of long hardware and software accumulation (storing) signals in separate points (positions of antenna unit):

- with numbers of exponential hardware accumulation of signal from 10 to 3200, with storing of signals during 1 minute – E = 145 dB at the end of time sweep.

2.4 Electric performance, amplifying by hardware accumulation.

Voltage and power consumption.

Working voltage - 12 V. Power consumption of the transmitting antenna - 5 W, receiving antenna – 7.2 W.

Peak amplitude of voltage of the generator – 54 V.
Number of ADC bits – 16.
Frequency of stroboscopic analog-digital conversion (pulse repetition frequency of the generator) – 105 kHz.

Sweep of amplification.

Variation of amplification depending on time during time sweep is carried out in stroboscopic time by adjustable function (number) of hardware accumulation for each sampling point of a signal. Function of hardware accumulation varies on the time sweep, and consists in tunable constant and exponential parts.

Using of large number of hardware accumulation of signals at the end of time sweep enables to compensate large attenuation of sounding pulse in the soil and significantly increase dynamic range of received reflected signals.

Receiver sensitivity:

- ADC threshold – 37 μV;
- level of thermal and own noise of the receiver, considered on the input of the receiver, without hardware accumulation - 50 μV;
- level of measured signal at signal to noise ratio 10 dB and number of hardware accumulation 16 and 32 – about 40 and 27 μ correspondingly;
- level of measured signal at signal to noise ratio 10 dB and number of hardware accumulation 256 and 1024 – about 10 и 5 μV correspondingly.

2.5 Energy potential of the georadar.

Energy potential of the georadar expended to attenuation of radio waves in the ground, spherical divergence of the georadar wave and losses during reflection from objects of sounding. Values of energy potential “E” of the georadar indicated below are given for signal to noise ratio 10 dB, when the signal is well distinguished in noise.

Energy potential of the georadar is equal to:

- 105 dB with constant store number 10 (without exponential accumulation).
- 130 dB at the end of time sweep with number of exponential hardware accumulation of signals from 10 to 3200.

3. Set of equipment.

1) 

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Fig.5 Set of the georadar TR-GEO-01-08 in transport case.

*Set of equipment (**Fig.5**).*

1) Foldable antenna unit of the georadar with generator (built-in into transmitting antenna), receiver, control and store (flash-memory) unit (built into receiving antenna).

2) Two replaceable hermetic battery units.

3) Two battery chargers.

4) Path sensor (wheel).

5) USB cable for connection of the radar to a computer during transmitting of data to a computer or for working in real time mode.

6) Handle with straps for manual movement of antenna unit by operator.

7) Software – program “Radar” for reading of data from the georadar, processing of signals and for imaging of results in form of 2D (profiles) and 3D (volume) images.

8) Documentation set, which includes:

- Brief technical description of the georadar and user manual;
- Description of the program “Radar”;
- Methodology of sounding and interpretation of results of sounding.

9) Program “Radar” on installation disc.

10) Transporting case.

4. Software.

For processing of signals and visualization of results the program “Radar”, is used. This program is used also for measuring of signals in real time mode and for reading of the data from the device flash-memory.

Processing of signals includes preliminary processing, inverse filtering algorithms, 3-D focusing (aperture synthesis), and 3-D visualization.

Preliminary processing includes algorithms of finding of the direct signal between antennas, subtraction of this signal, filtering (band-pass, white noise filter).

Windows of the program “Radar” are shown on **Fig.6** (window for measuring of signals) and **Fig.7** (main window and windows for viewing results of sounding). Example of results of sounding is given on **Fig.8**.

The program “Radar” provides the following possibilities.

- Writing of signals in real time mode, when computer is connected to the radar.
- Imaging of vertical radiolocation profile along the scan line in real time mode and after measurements (window “Vertical profile”).
- Imaging of positions of the georadar antennas (window "Antennas”).
- Imaging of measured signal in the selected antenna position (window "Signals").
- Visualization of radiolocation images in form of vertical, horizontal sections of volume and in form of 3D image.

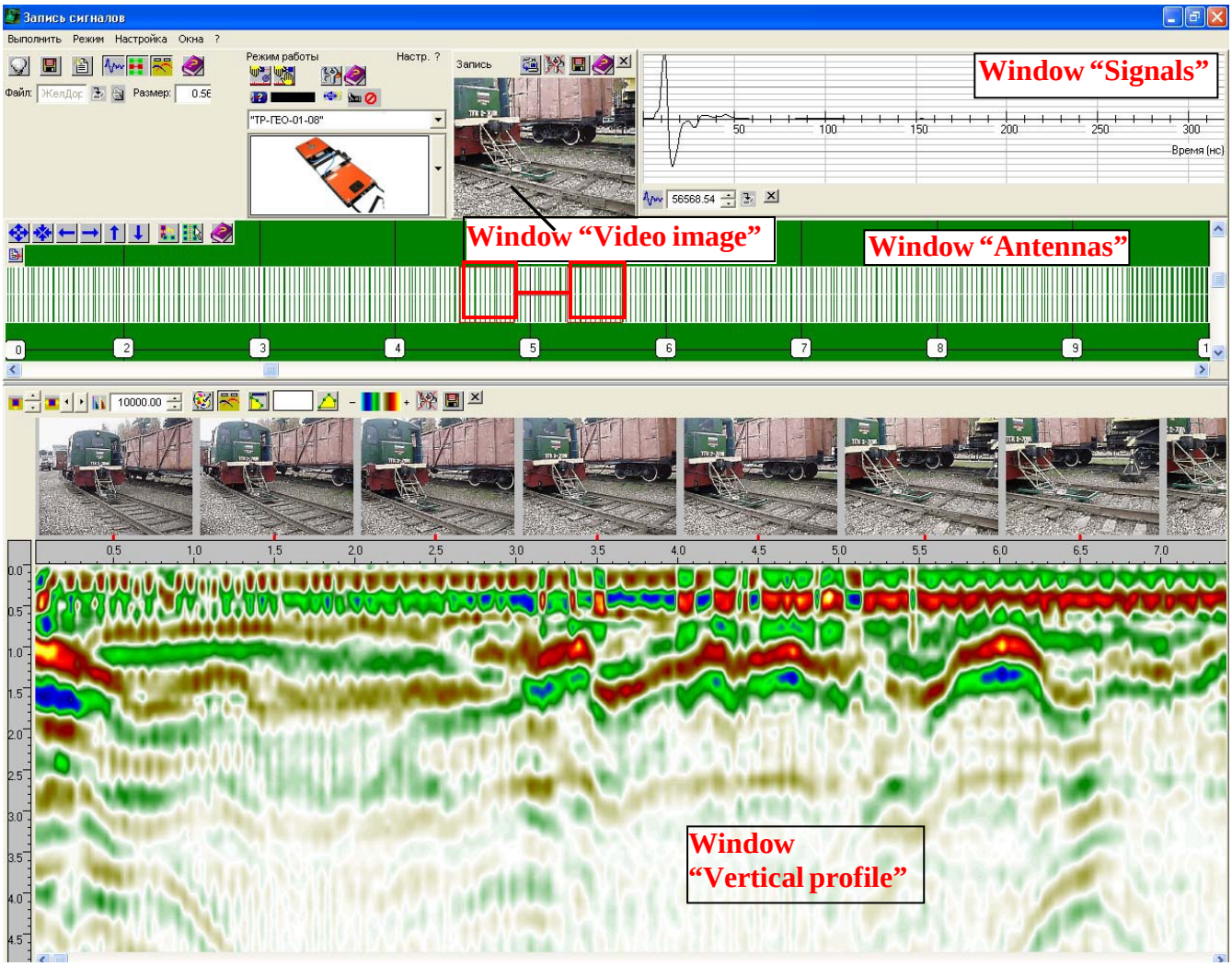

Fig.6 Window for measuring of signals in real time and for reading data from flash memory of the radar. This window is also used for viewing of results of sounding.

- Imaging of spectra of signals and adjustment of band-pass filter
- Imaging of video frames in selected positions of antenna unit.

Window for measuring of signals in real time mode is shown on **Fig.6**. In this window user can view (in real time) measured vertical radiolocation profile, positions of antennas (window "Antennas"), measured signal (window "Signals"). Also video image from a camera, connected to the computer, will be stored in real time mode (window "Video image").

Window "Measurement of signals" can be also used for viewing of results of sounding. The program "Radar" enables to translate video images, written in format "*.avi", together with the results of sounding. Video should be written separately for each scan line (profile) and should begin and end synchronously with each radar record for scan lines. One can use any camera, or a camera, connected to the computer (in this case video will be stored in a file together with the georadar data by the program "Radar") or the video camera from the radar set in mode of work without computer. Showing of video frames together with the results of sounding (**Fig.6**) enables identify found objects and its position in terrain.

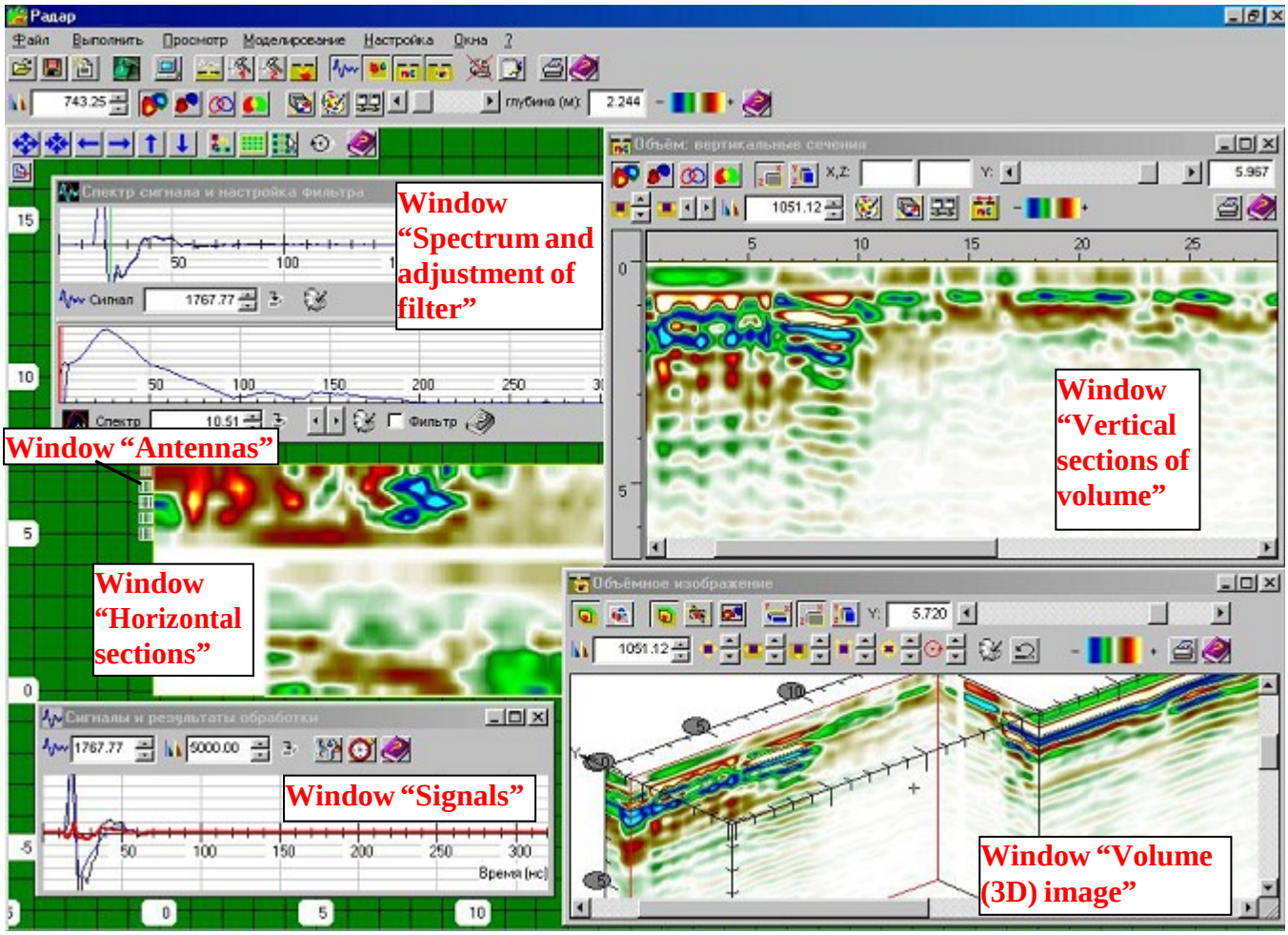

Fig.7 Main window of the program "Radar" with opened windows for viewing of the results of sounding. (Size and positions of the windows can be tuned by user.)

Main window of the program "Radar" with windows for viewing of results of sounding is shown on **Fig.7**.

Radiolocation images may be shown in form of vertical, horizontal sections of volume and in form of 3D image (windows "Vertical sections", "Horizontal sections", "Volume (3D) image"). Window "Horizontal sections" is situated on the window "Antennas". If both windows "Horizontal sections" and "Vertical sections" are opened, user can easily select desired section in one window by moving mouse cursor in another window. This interactive mode is very convenient.

Images in vertical and horizontal sections and in 3-D image may be shown by various kinds (**Fig.9**): as superposition of images (in red-green palette) over given layer of volume, as separate single sections, as a number of sections in transparent volume.

Colors on the radiolocation images represent sign and intensity of each oscillation of reflected signals. Sign of the first oscillation of the reflected signal gives information about sign of reflection. Metallic objects, moist areas, more dense objects, than the neighboring ground, give reflections of negative sign. Cavities, less dense non-metallic objects give reflections of positive sign. User may tune palette of colors.

The program "Radar" can save the results of sounding in commonly used geophysical format "SEG-Y".

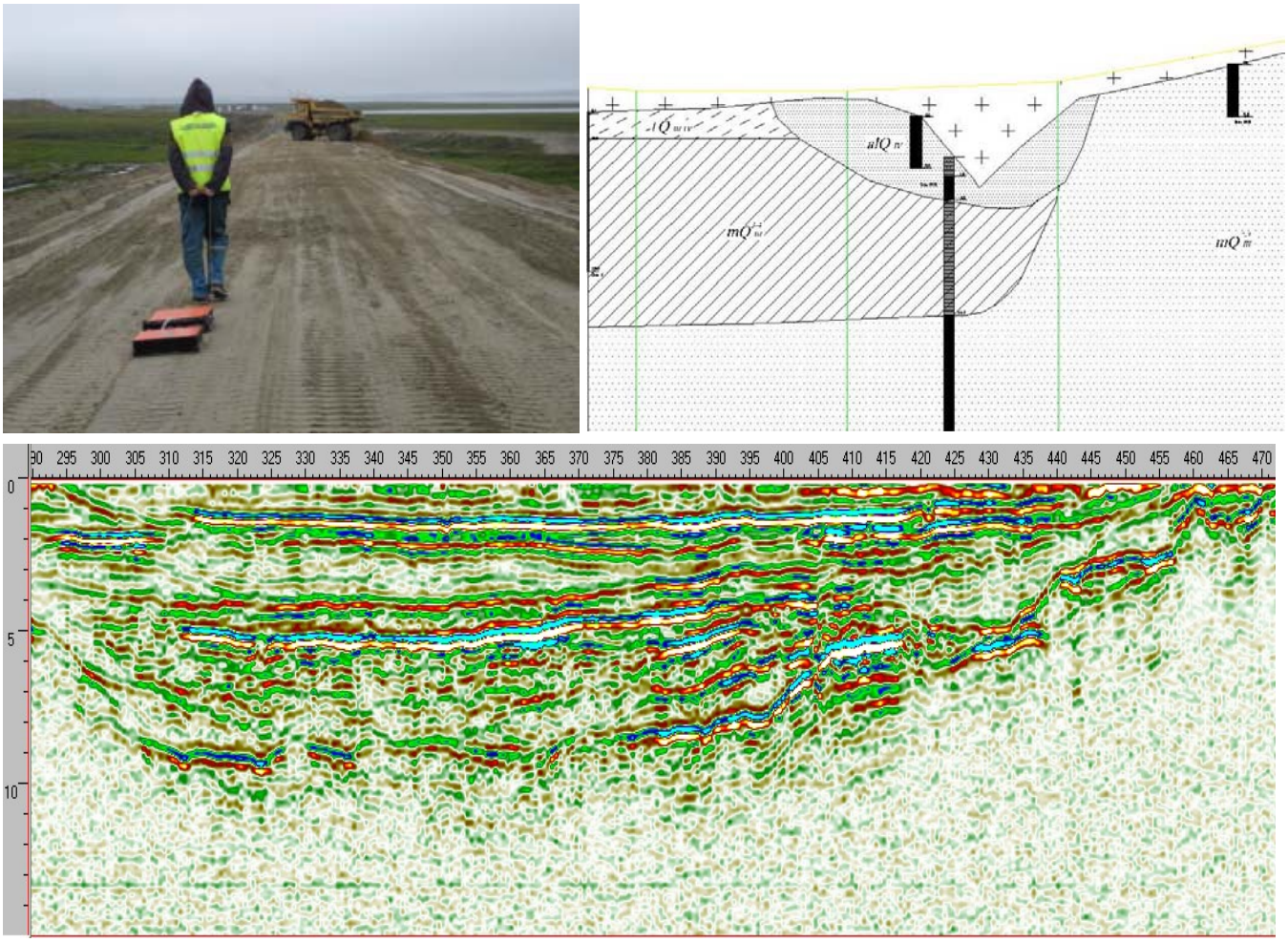

Fig.8 Results of sounding by georadar TR-GEO-01-08 in permafrost region in Russia. Wave radiolocation vertical profile (below) enables to make more precise study of geological section, than the results of borehole prospecting (above).

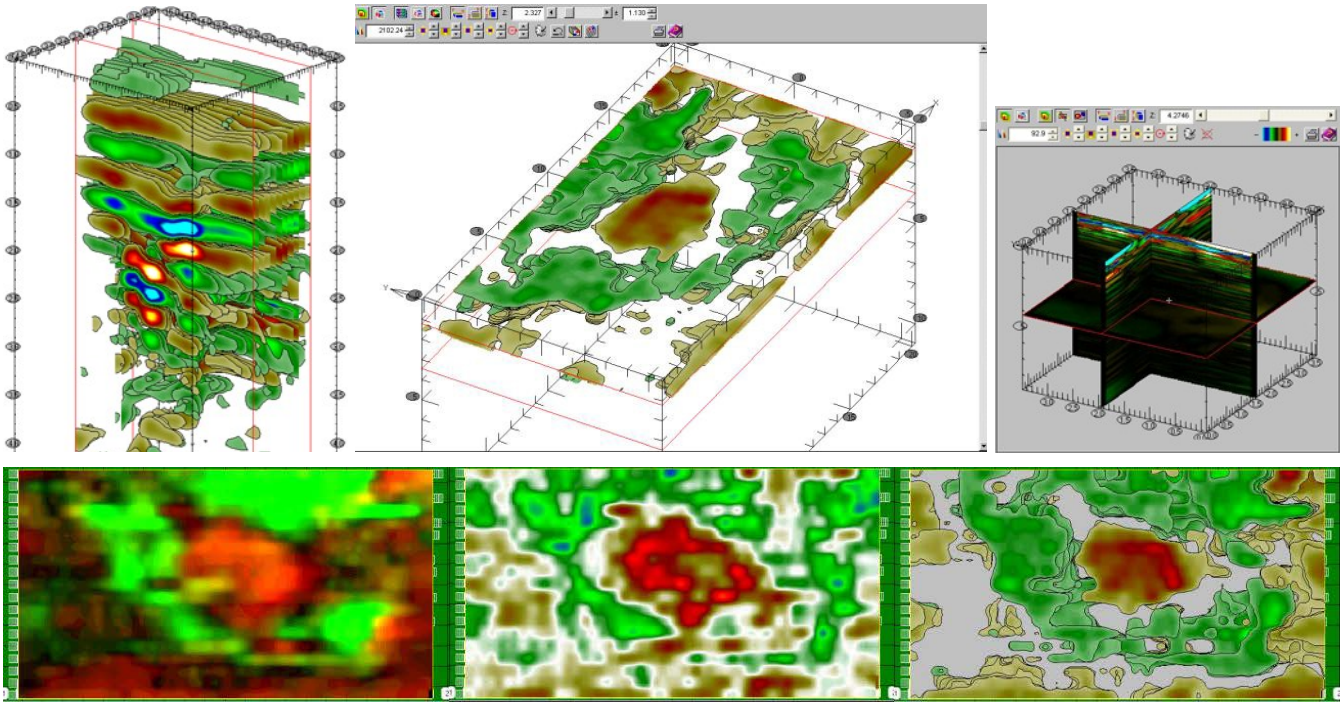

Fig.9 Methods of showing of 3-D images and horizontal section in program “Radar”.