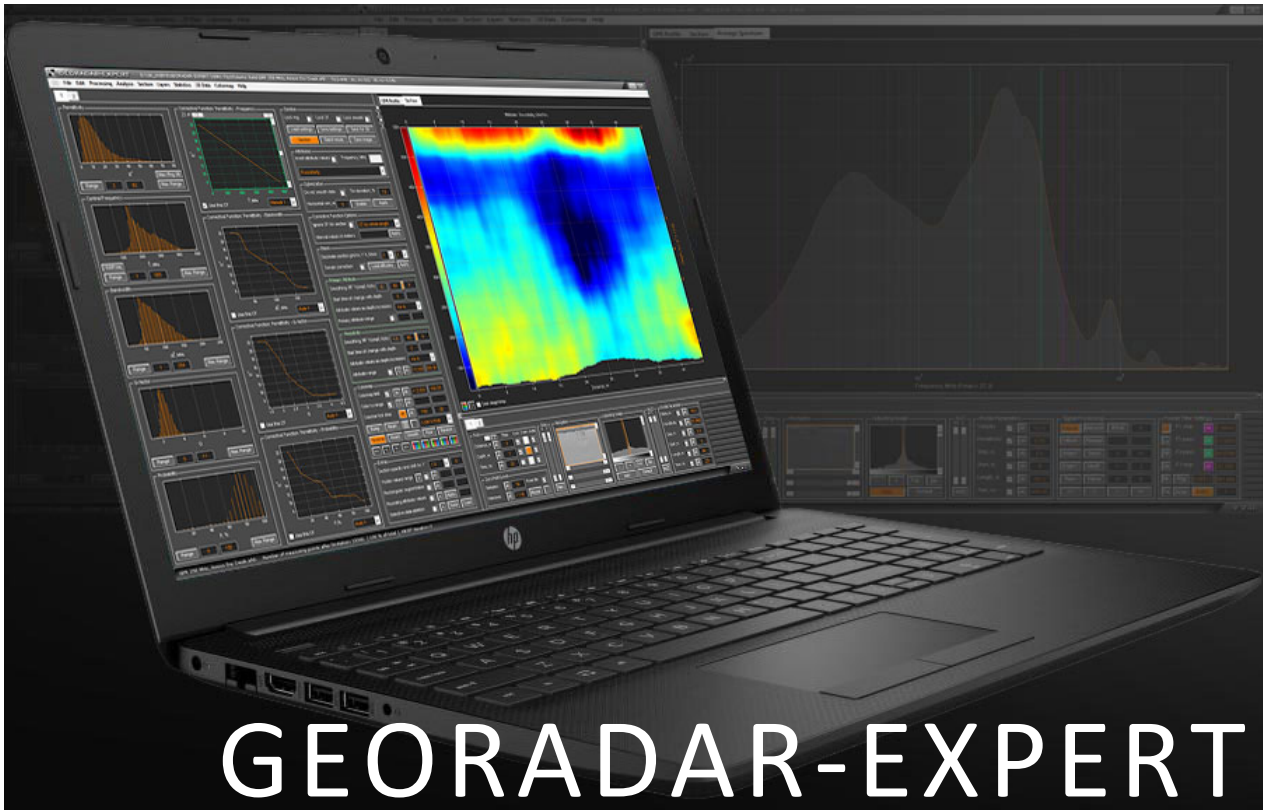


*Since 2009 on the GPR  
Industry Software Market*



# GEORADAR-EXPERT

AUTOMATED PROCESSING OF GPR DATA

SOFTWARE OVERVIEW

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## Introduction



The idea of developing the GEORADAR-EXPERT software system arose as a result of generalization of many years of professional experience in the field of georadar research. Practical skills acquired at all stages of GPR work, such as communication with the customer of GPR surveys, development of field survey techniques, GPR data processing and the formation of a technical report, allowed the developers of GEORADAR-EXPERT to form an understanding of what state-of-the-art software for GPR processing data should be and in what form the final result of this processing should be presented.

As a result, three main directions of development of software for processing GPR data were identified:

1. Development and implementation of algorithms that serve to achieve a greater depth of GPR investigation without deterioration of the vertical resolution of the GPR profile;
2. Increasing the informativeness of GPR investigation by switching from the representation of data on a subsurface environment as a set of amplitudes of reflected signals in the form of a radarogram to the characteristics of this environment and the wave field reflected from it in the form of an attribute section;
3. Minimizing the influence of the human factor on the processing of GPR data by automating this process. Due to the growing volumes of GPR investigations around the world, the relevance of this area is also increasing.

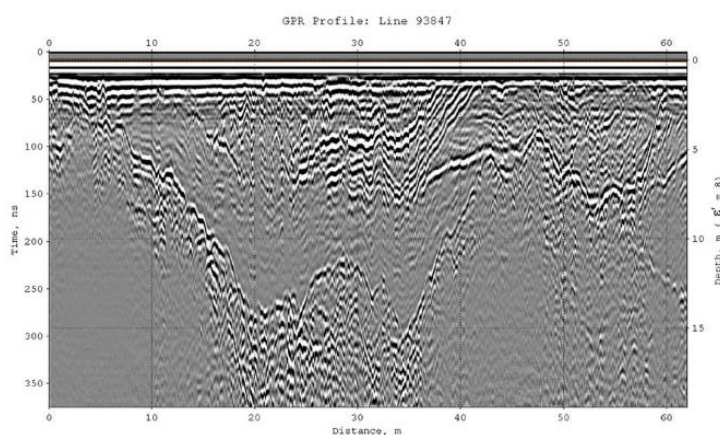
The GEORADAR-EXPERT software system was developed taking into account all these factors. The software system includes both widely used GPR data processing options implemented in each GPR software, and algorithms and methods developed specifically for the GEORADAR-EXPERT that increase the depth and informativeness of GPR investigations.

The main such development is automated BSEF (Back-Scattering Electromagnetic Field) analysis. The final result of processing GPR data by automated BSEF analysis is sections of attributes, which are the electrophysical characteristics of the subsurface environment and the wave field reflected from this subsurface, as well as the values calculated on the basis of these characteristics.

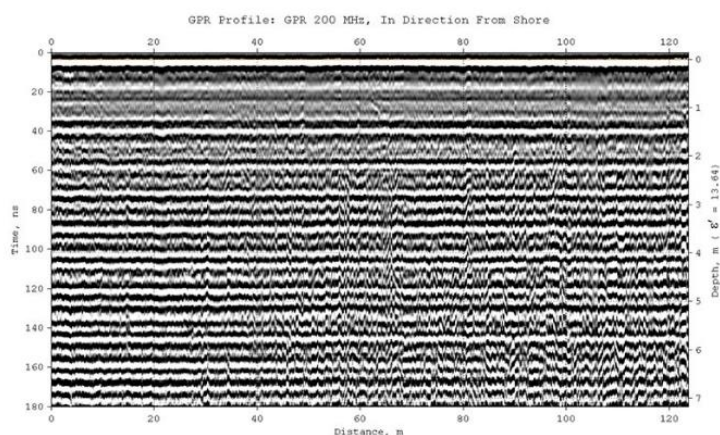
## BSEF Analysis

When working with GPR data, specialists may encounter a situation where the quality of the result of the GPR profiling performed by them is worse than in the promotional materials of geophysical equipment manufacturers. The GPR advertising profiles clearly show the boundaries between the layers and diffracted reflections from local objects, from which it is easy to determine the wave propagation velocity in the subsurface environment and the permittivity in the layers. However, this does not mean that GPR manufacturers are trying to mislead potential customers. It's just that these exemplary GPR data were obtained during GPR profiling of subsurface with low losses and contrast layers that best reflect the quality of GPR equipment.

The following is an example of a GPR profile obtained during the investigation of a high-contrast subsurface medium with low losses. This field record does not require processing, since it already contains enough information about the structure of the subsurface.



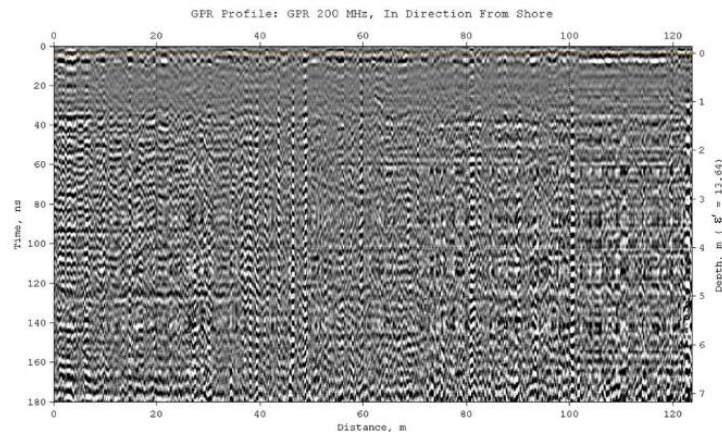
But along with such subsurface environments favorable for GPR surveys it is necessary to investigate low-contrast strata with a high level of absorption of electromagnetic energy, which do not have sharp transitions between layers, under conditions of interference of various nature. Often there are such field recordings:



This profile is recorded by GPR 200 MHz on the sea beach. During the profiling process, the GPR moves away from the coastline in a direction perpendicular to it. The peculiarity of this survey is that the coastal saline soil is probed, which has a high conductivity. For this reason, GPR pulses quickly fade out, and already at a

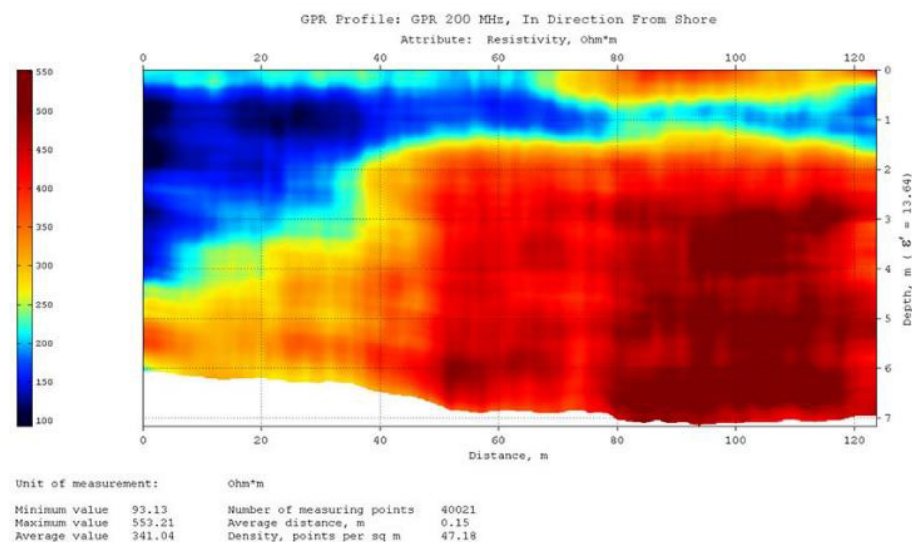


shallow depth, the intensity of reflections from the boundaries of the layers becomes comparable to the noise level on the GPR profile. Noise and interference mask useful reflections, so visual analysis of this profile does not give a positive result. The use of various types of filtering to remove interference also does not lead to success. After removing the interference, the boundaries of the layers are still not visible:

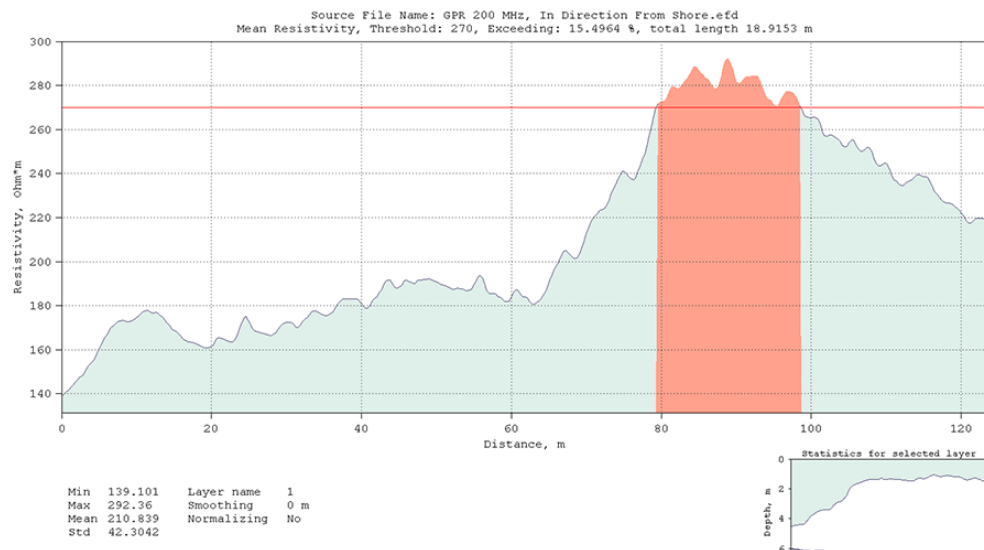


The fact that after suppression of interference on the GPR profile, reflections from the boundaries of the layers do not become noticeable does not mean that they are absent. When useful reflections are close in their characteristics to interference, during the filtering process, these reflections are removed together with interference. The BSEF automated analysis algorithm works more selectively, and is able to separate useful signals from interference close to them.

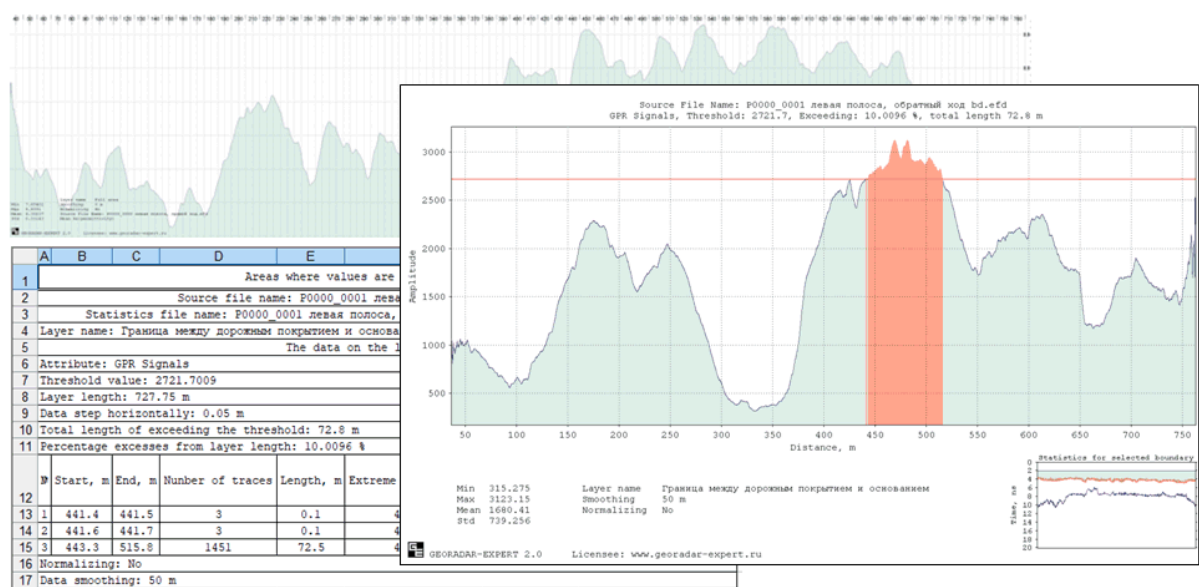
The figure below shows a section of the **Resistivity** attribute created based on the results of automated BSEF analysis of the GPR profile in question. In contrast to the visually uninformative profile, the attribute section displays the structure of the subsurface environment well. Within the investigated subsurface, two main layers are distinguished. The upper layer is characterized by reduced resistivity values, this layer is displayed mainly in blue colors on the section. The lower layer has higher resistivity values and is represented by yellow-red shades. According to the section, it is possible to trace how, as you move away from the coastline, the thickness of the layers of coastal soil and the electrical resistivity inside these layers change.



A visual representation of the variability of the section attribute can be obtained using the statistical module of the GEORADAR-EXPERT software system, which provides information in the form of graphs and tables for 12 statistical indicators. Indicators can be calculated for each layer, for user-specified layers, for each layer boundary, or for the entire section as a whole. As an example, the figure below shows the result of using a statistical module in the form of a graph of changes in the average values of the electrical resistivity in the upper layer of the **Resistivity** attribute section. The area of the graph that exceeds the user-defined threshold is highlighted in red. At the bottom right is a thumbnail of the section, which shows the boundaries of the layers. The fill highlights the layer whose data is represented by the graph.



The threshold on the statistical graph is displayed as a horizontal red line. If the user has set a threshold, then when saving the image of this graph, a table is formed in MS EXEL format, which contains information either on areas exceeding the threshold, or on areas not exceeding the threshold, depending on the user's choice. This is convenient to use in studies where the violation indicator is increased or decreased values of the section attribute – for example, for monitoring the road surface.



It is obvious that the switch from the representation of data on the subsurface environment in the form of a set of amplitudes of reflected signals (GPR profile) to the characteristics of this environment obtained as a result of the application of the BSEF automated analysis method (attribute section) significantly increases the informativeness of the GPR survey. The result, presented in the form of an attribute section, is more understandable to the customer of this survey. The list of attributes used in the GEORADAR-EXPERT software system is quite wide. The list of attributes and their description can be found in the Section List of Attributes section of the user manual, which is available for download at the [FOLLOWING LINK>>](#).

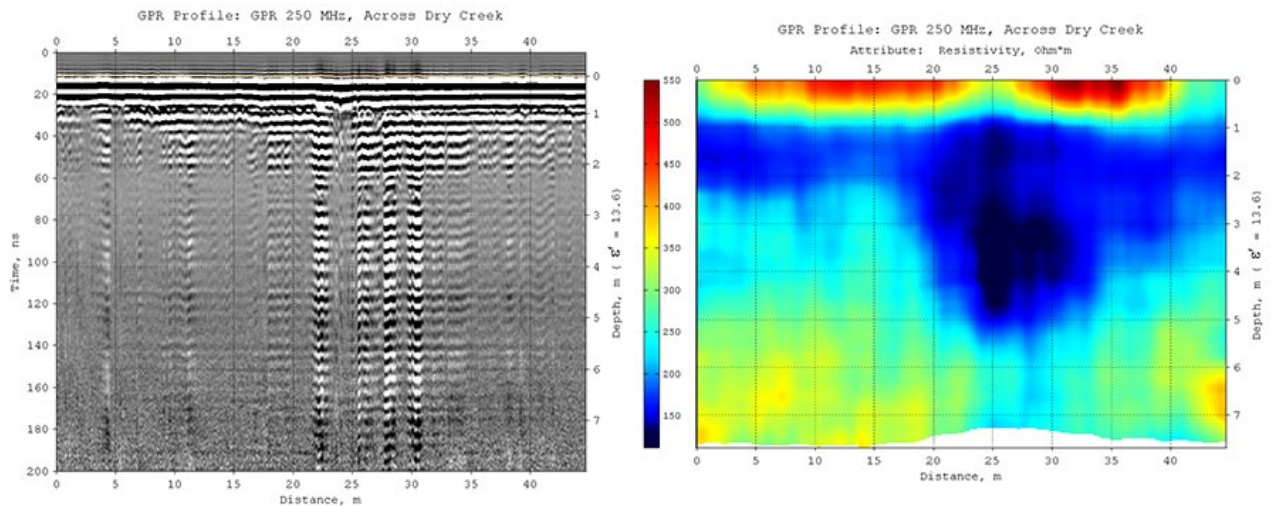
One of the advantages of automated BSEF analysis over other methods of processing GPR data is the ability to study subsurface environment with this method, the electrophysical characteristics of which change vertically smoothly, without sudden jumps. Abrupt changes in the properties of the subsurface in the vertical direction create conditions for the reflection of probing pulses and their reception by GPR. Environments that have a smooth character of changing electrophysical properties cannot form reflections. In such places, only high-frequency noise and various kinds of interference are present on the GPR profile, provided that the studied environment in these places does not contain local objects.

Local objects are objects in a subsurface environment whose linear dimensions are comparable to the wavelength of the GPR probing pulse, and the electrophysical characteristics of these objects differ from the electrophysical characteristics of their host environment. For example, stones in the ground can act as such objects. Local objects have an important feature. It consists in the fact that when the GPR probing pulse interacts with local objects, these objects become a source of diffracted waves, the kinematic and dynamic characteristics of which carry information about the properties of the subsurface environment.

Due to the low intensity of diffracted waves, which is often comparable to the level of interference, visual analysis can detect only a small part of these waves on the GPR profile. As a rule, this amount is not enough to obtain a detailed information about the structure of the subsurface environment based on the measured characteristics of these waves.

Further, the figure on the left shows the result of GPR profiling of soil with a smooth change in electrophysical characteristics. The profile was obtained by a GPR 250 MHz. The profile crosses the dry bed of a seasonal stream, the talweg of which is 25 m from the beginning of the profile. The electrophysical characteristics of soils in this profile change smoothly with depth, without sudden jumps forming reflections on the GPR profile. For this reason, the profile does not contain characteristic extended reflections, which are interpreted as reflections from the boundaries of the layers. Under these conditions, it is possible to obtain information about the structure of the studied environment using automated BSEF analysis.

The figure on the below shows a section of the **Resistivity** attribute. The section of the attribute shows the position and shape of the channel stream deposits, as well as the distribution of resistivity within these deposits. The section shows that the boundary between dense soil and loose sediments has a concave shape and reaches a maximum depth of 5.5 meters in the talweg area of the stream. The lowered values of the section attribute indicate that the stream has not completely dried up, and the lowest resistivity, indicating the highest humidity, is located in the talweg area of the stream, at depths of more than 1 meter.



The processing time spent on performing automated BSEF analysis and section calculation is relatively small. Processing of the GPR profile in question lasted a little less than a minute on a computer with a quad-core 2.4 MHz processor and Windows 10 operating system. Significant time savings occur in the case of processing a large amount of GPR data in batch mode.

Saving time is especially relevant for processing the results of GPR profiling of extended multi-kilometer objects, such as roads and railways, or the threads of trunk pipelines. After setting up the parameters and starting the automated processing process, the user can switch to other tasks, and the software system will independently load GPR profiles and save the processing results to the computer's hard disk.

The GEORADAR EXPERT provides for the export of processing results to graphic formats, to MS EXCEL spreadsheet formats, to ASCII universal text format tables, as well as to the GRD grid data format of the Surfer software. Exporting data to these formats makes it possible to use the results of processing more widely using third-party software. For example, for additional analysis or integration into various geoinformation systems. Images of attribute sections or 3D assembly slices saved in a graphical format can be used as a substrate in a geo-base drawing in AutoCAD or for insertion into a GPR research report.

The use of automated BSEF analysis has the following advantages over other methods of processing GPR data:

- The depth of GPR investigation increases. The BSEF automated analysis algorithm has high selectivity and well detects useful reflections among interference even in conditions of strong noise at great depths;
- The informativeness of GPR research increases. The attribute section, calculated based on the results of automated BSEF analysis, allows you to obtain information about the structure of the subsurface environment even under conditions of a smooth change in its electrophysical characteristics, when there are no reflections from the boundaries of layers on the GPR profile. If these boundaries are present on the profile, then information about changes in the electrophysical characteristics inside each layer is also of interest to the researcher;

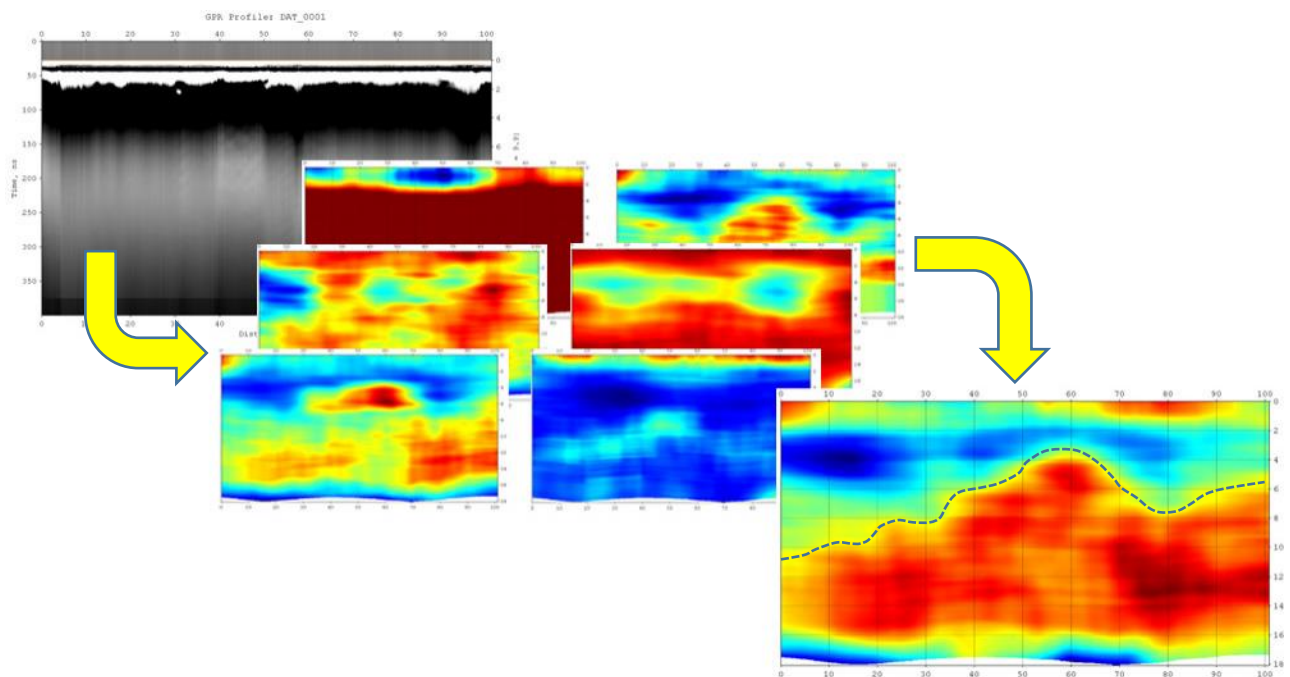


- The processing speed of GPR data is increasing, which is important with the constantly increasing volumes of GPR investigations, especially in the road and railway industries;
- The scope of GPR applications and the list of tasks solved by it are expanding;
- The influence of the so-called human factor on the processing and interpretation of GPR data is minimized;
- The possibilities for the study of complexly constructed subsurface environments are wider, compared with other methods of processing GPR data.

## Sections Summation

The GEORADAR-EXPERT software system has a fairly wide set of attributes for solving a whole range of GPR tasks. It happens that a section of one attribute does not provide complete information about the object under study, but various fragments of this information are distributed across several attribute sections. In this case, the summation of sections allows you to combine disparate information about the object of study into one summary section. Also, summation eliminates artifacts caused by the accumulation of errors in the process of collecting and processing GPR information.

The figure below on the left shows the GPR profile recorded during the study of the paleodoline by a GPR 100 MHz. The center shows a set of attribute sections for summation, created based on the results of automated BSEF analysis of this profile. The result of summing these sections is shown on the right.



Visual analysis of the GPR profile shows that this profile is uninformative, starting from a depth of 2 meters. The base of the paleodoline, according to a priori information, is below this value. The attribute sections show some details of the buried relief, but each of the sections separately does not provide complete information about the structure of the studied subsurface.

The summation operation combined this disparate information into one whole. The relief of the base of the paleodoline on the summation section is well traced along its entire length. In the figure, the base of the paleodoline is indicated by a dotted line. This example illustrates how the use of the summation module allowed solving the problem of insufficient information content of the GPR profile and individual sections of attributes by this profile.

## **GPR Profile Signal Processing**

Along with automated BSEF analysis and the creation of the attribute sections of the investigated subsurface environment and the wave field reflected from it based on this analysis, the GEORADAR-EXPERT implements a complete set of data processing methods that should be present in every software for processing GPR information. These are various types of signal transform, control of the geometry and visualization of the GPR profile, working with manually created user layer boundaries, combining two-dimensional GPR data into a three-dimensional assembly, and much more. In other words, the GEORADAR-EXPERT software system has everything that a GPR specialist is used to working with.

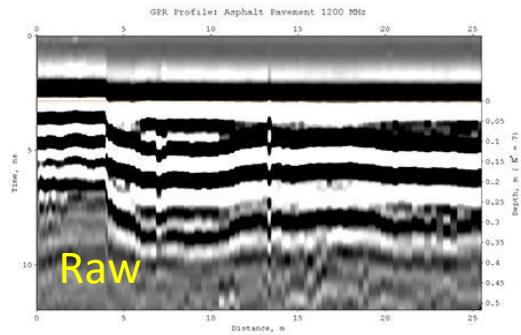
Along with the widely used methods of processing GPR data, algorithms and methods have been specially developed for the GEORADAR-EXPERT to effectively increase the resolution of GPR profile signals and suppress difficult interference.

## **GPR Data Resolution Increase**

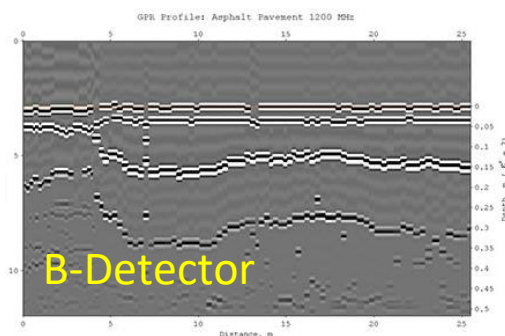
The B-Detector (Boundaries Detector) method, specially developed for the GEORADAR EXPERT, is designed to suppress interference and increase the vertical resolution of the GPR profile, which makes it easier to distinguish nearby, vertically, reflections from the boundaries of subsurface layers. Using B-Detector, the user increases the frequency and spectrum width of the GPR profile signals, thereby reducing the duration of these signals and increasing the degree of detail of the GPR profile.

As a result of processing by the B-Detector method, the GPR profile obtained using a low-frequency antenna looks as if the frequency of the GPR antenna for recording this GPR profile was tuned to a frequency several times higher than the actual frequency of the antenna. Compared to the original GPR profile, the vertical resolution of the GPR profile after processing by the B-Detector method is several times higher. If necessary, the B-Detector method can lower the central frequency of the GPR profile signals.

Further, as an example of the application of the B-Detector method, the GPR profile recorded during the survey of the road pavement with a 1200 MHz GPR is considered. Starting from the 4 m distance along the profile, the asphalt concrete pavement of the highway consists of two layers. According to a priori information, the upper layer of asphalt concrete has an average thickness of 0.04 m, the lower boundary of the second layer of asphalt concrete lies in the depth range from 0.12 to 0.15 m from the surface of the pavement. Below is a layer of crushed stone base, the thickness of which, on average, is 0.15 m. Not all reflections from the boundaries of these layers are noticeable on the raw GPR profile. For example, it is difficult to detect a reflection from the contact boundary of asphalt concrete layers at a depth of 0.04 m. From this it can be concluded that the 1200 MHz antenna does not provide sufficient resolution of the GPR profile for a detailed study of the road layers.

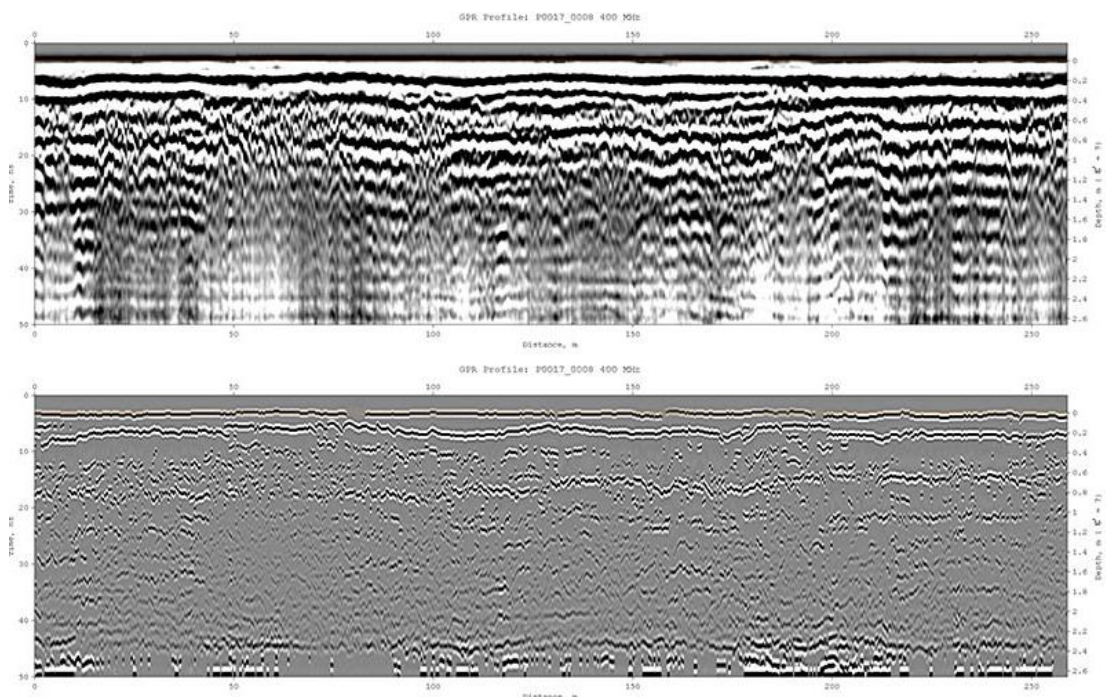


level, to some extent, this problem can be solved using the B-Detector method.

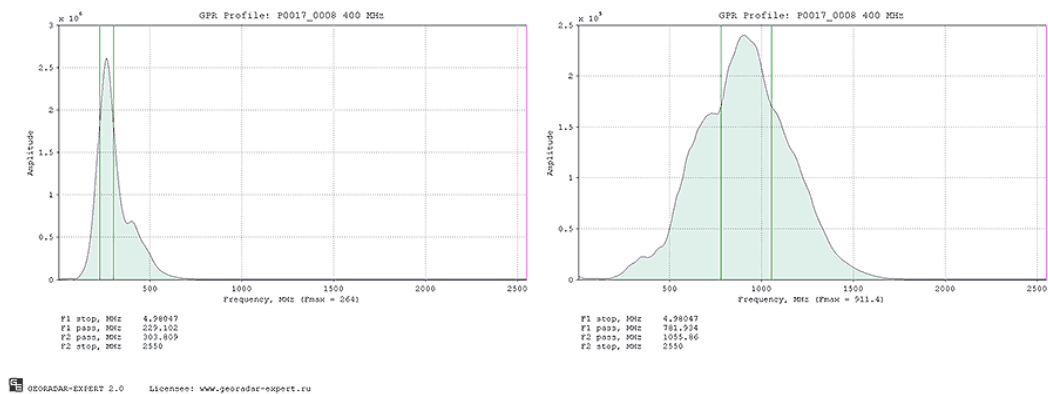


The figure left shows the result of processing the considered GPR profile by the B-Detector method. As a result of using this method, the resolution of the GPR profile has significantly increased. Reflections from the boundaries of road layers have become compact, do not overlap each other, and are well distinguished. Phase distortions caused by the mutual influence of reflections from nearby boundaries have disappeared. Aligned reflection phases make the GPR profile well adapted to the process of automated boundaries picking, which is implemented in the GEORADAR-EXPERT software system. The availability of the automated boundaries picking option is important for processing large amounts of data, for example, obtained during road or railway GPR surveys.

Next, as another example, the result of GPR profiling of a highway with a 400 MHz GPR is presented. The upper figure shows the raw GPR profile, below is the result of its processing by the B-Detector method.



As a result of the application of the B-Detector method, the lower boundary of the road pavement is clearly visible on the processed GPR profile, the depth of which varies around the 0.2 m tick. This boundary is difficult to fully detect on an unprocessed GPR profile. The figure below shows on the left the amplitude-frequency spectrum of the signals of the original GPR profile, on the right is the spectrum of the GPR profile after applying the B-Detector method.



As a result of using the B-Detector method, the central frequency of GPR profile signals increased approximately 3.5 times – from 264 MHz to 911.4 MHz. The width of the signal spectrum has increased 3.7 times – from 74.7 MHz to 277 MHz. An increase in the width of the signal spectrum indicates a decrease in its duration, which leads to an improvement in the vertical resolution of signals on the GPR profile. Thus, as a result of using the B-Detector method, the GPR profile looks as if it was obtained not by a 400 MHz GPR, but by a hypothetical higher-frequency GPR with a central frequency of  $400 \times 3.5 = 1400$  MHz, providing a greater penetration depth of the probing pulse, which is not typical for a high-frequency GPR.

Often, in a road survey, it is required to obtain two GPR profiles for the same location. One GPR profile is recorded using a high-frequency antenna that provides penetration of the probing pulse to a depth of about 1 meter. This entry is used to study the pavement layers. The second GPR profile is recorded using a lower frequency antenna that provides a depth of 3 - 8 meters. Such an antenna is suitable for the study of soils under the road.

If a single-channel GPR is used, which does not provide simultaneous operation of two antennas tuned to different frequencies, then to record two GPR profiles in the same place, it is necessary to pass the same route with different GPR antennas twice.

In such a case, using the B-Detector method, it is possible to achieve a compromise between the time spent on recording and processing GPR data and the quality of the GPR study result. Using the B-Detector method and one midrange antenna, for example, a 400 MHz antenna, as in the example under consideration, will reduce the volume of field and cameral work by half. Taking into account the significant mileage of GPR profiling during road works, this is a significant economy.

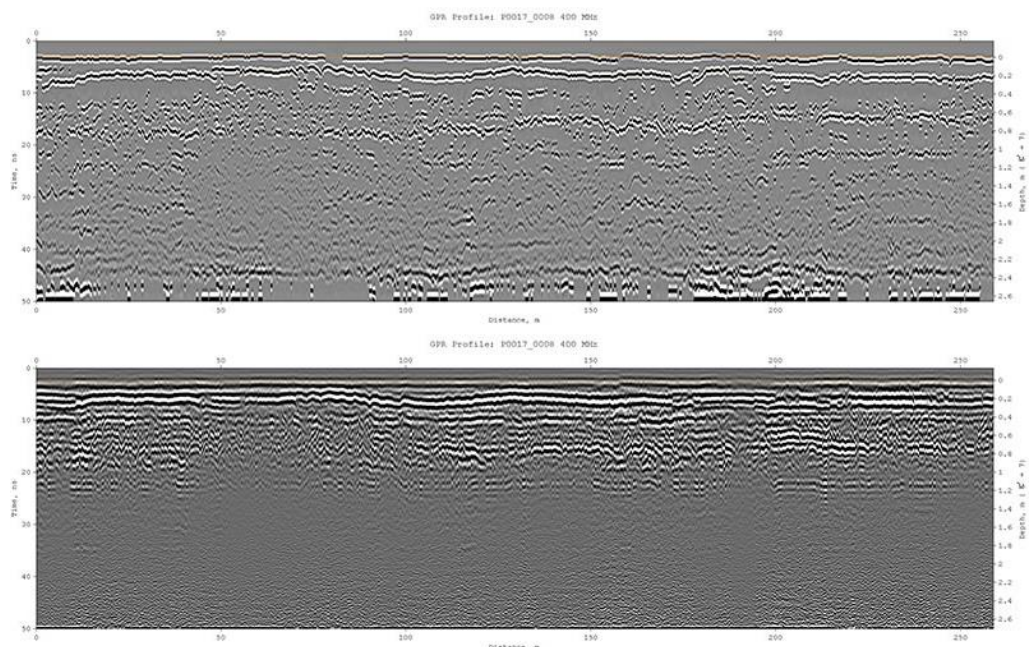
Another argument in favor of using the B-Detector method. A small geophysical company may not have a full set of GPR antennas that cover the entire range of operating frequencies of georadolocation to solve a wide range of tasks. The acquisition of a large amount of geophysical equipment requires significant financial costs, and this is sensitive for a small company. The use of the B-Detector method will allow you to save on



high-frequency antennas, allowing you to have one medium-frequency and one low-frequency antenna available for some time, for example, 500 and 100 MHz.

Along with the B-Detector method, an increase in the vertical resolution of the GPR profile in the GEORADAR-EXPERT software system can be performed using wavelet decomposition. This transform resembles a windowed Fourier transform, only in the Fourier transform the signal is decomposed into components in the form of sines and cosines, and in the wavelet decomposition the decomposition is performed using special functions - wavelets, the graph of which resembles a GPR probing pulse in shape. After the wavelet decomposition, the signals is restored by high-frequency decomposition levels. The central frequency of the restored signals and the width of its spectrum is greater than that of the original signals, which means that the restored signals is shorter than the original one. And if the signals is shorter, then the vertical resolution of such signals is better.

Below is a comparison of the results of using the methods of B-Detector (upper image) and wavelet decomposition of signals.

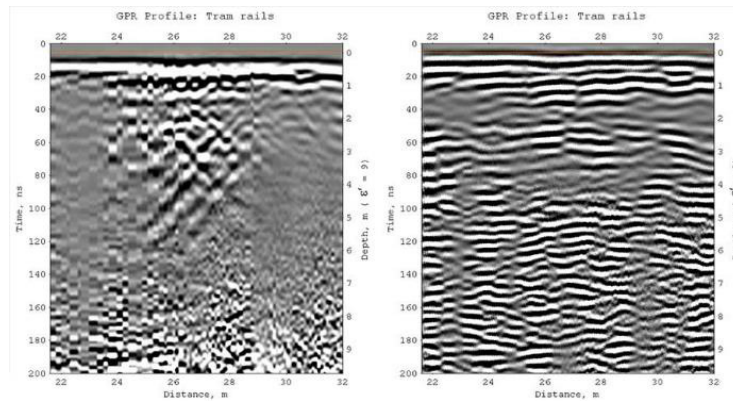


Each of the presented methods of increasing the resolution of GPR data has its advantages. The user, depending on the features of the GPR profile wave field and the tasks of GPR research, can choose which of these methods to use in each specific case.

## Interference and Air Reflections Suppression

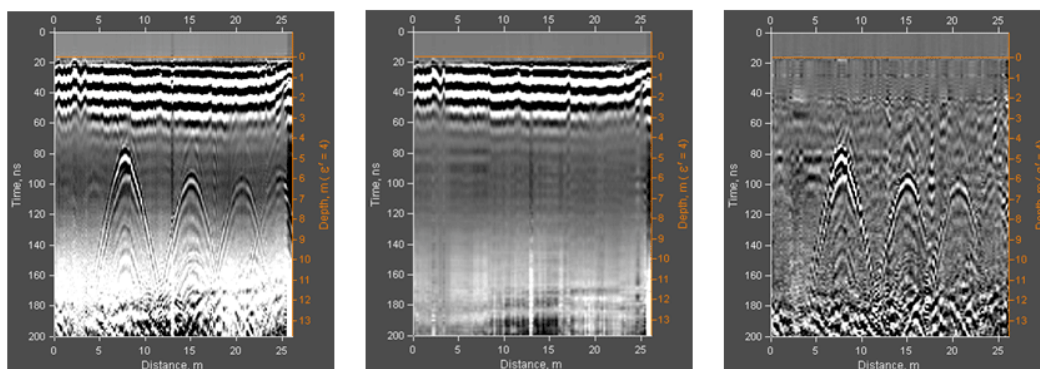
One of the problems faced by a specialist in processing GPR data is the suppression of reflections from objects located on the surface. These so-called air reflections often have a high level of amplitudes, which allows them to mask reflections from subsurface objects well. Shielding GPR antennas does not allow you to completely get rid of these air reflections. To the greatest extent, air reflections are manifested on GPR profiles obtained using dipole low-frequency antennas, where shielding is not provided. Also, diffracted reflections from contrasting local objects lying at a shallow depth can act as interference.

The spatial filter implemented in the GEORADAR-EXPERT software system allows you to solve the above problem. As an example of suppressing intense masking interference using a spatial filter, a profile obtained by a 150 MHz GPR that crosses tram tracks is taken. The figure below on the left shows the raw GPR profile, in which intense reflections from metal rails and ground infrastructure objects are superimposed on weaker reflections from the boundaries of layers in the ground. The result of spatial filtering is shown on the right. Diffracted reflections-interference is suppressed and does not mask reflections from the boundaries of the layers.



Along with the spatial filter, the GEORADAR-EXPERT software system implements interference removal by decomposing GPR profile signals into components. If the GPR profile signal matrix is decomposed into components, and then restored, having previously discarded those decomposition levels that contain information about interference, then there will be no interference on the restored GPR profile. Each level of decomposition contains its own characteristic features of signals. The lower levels contain spatially extended horizontally oriented components of the GPR profile. The higher the decomposition level, the more compact the decomposition components become.

The following is an example of the application of decomposition into components. On the left is an example of a GPR profile that contains two types of waves. These are extended subhorizontal reflections and diffracted reflections, which look like hyperbolas on the GPR profile. The center shows the result of the restoration of this GPR profile by the lower levels of decomposition. It is noticeable that characteristic reflections in the form of hyperbolas have disappeared on the profile. On the right is the result of recovery by the higher levels of decomposition. In this case, information about subhorizontal extended reflections is discarded, and diffracted reflections are not affected.



The GEORADAR-EXPERT software system has more than two dozen options designed for processing GPR profile signals. With the help of these options, almost the entire range of tasks that a user may have in the process of processing GPR data is solved. The user can save the sequence of applying data processing options to a file and apply this sequence in the future.

Automation of user actions for processing the same type of GPR data frees him from being at the computer. In batch processing mode, the user has to set processing parameters and select a group of GPR profile files, after which the downloading, processing and saving of the processing result is done automatically, without the user's involvement.

## **Graphical User Interface Overview**

The GEORADAR-EXPERT graphical user interface is organized as tabs combined into groups. Each group of tabs is designed for certain tasks and contains panels with controls for these tasks. There are three groups of tabs, conditionally named according to their location in the main window of the software system - the left group, the top group and the bottom group.

The left tab group is located in the left part of the main window of GEORADAR-EXPERT and contains panels of visualization of the results of automated BSEF analysis in the form of histograms, as well as panels with control elements of attribute section creation parameters. When GPR profile data file is loaded into the program, which does not contain the results of BSEF analysis, the left tab group is hidden and only the top and bottom tab groups remain in the main window of the software system.

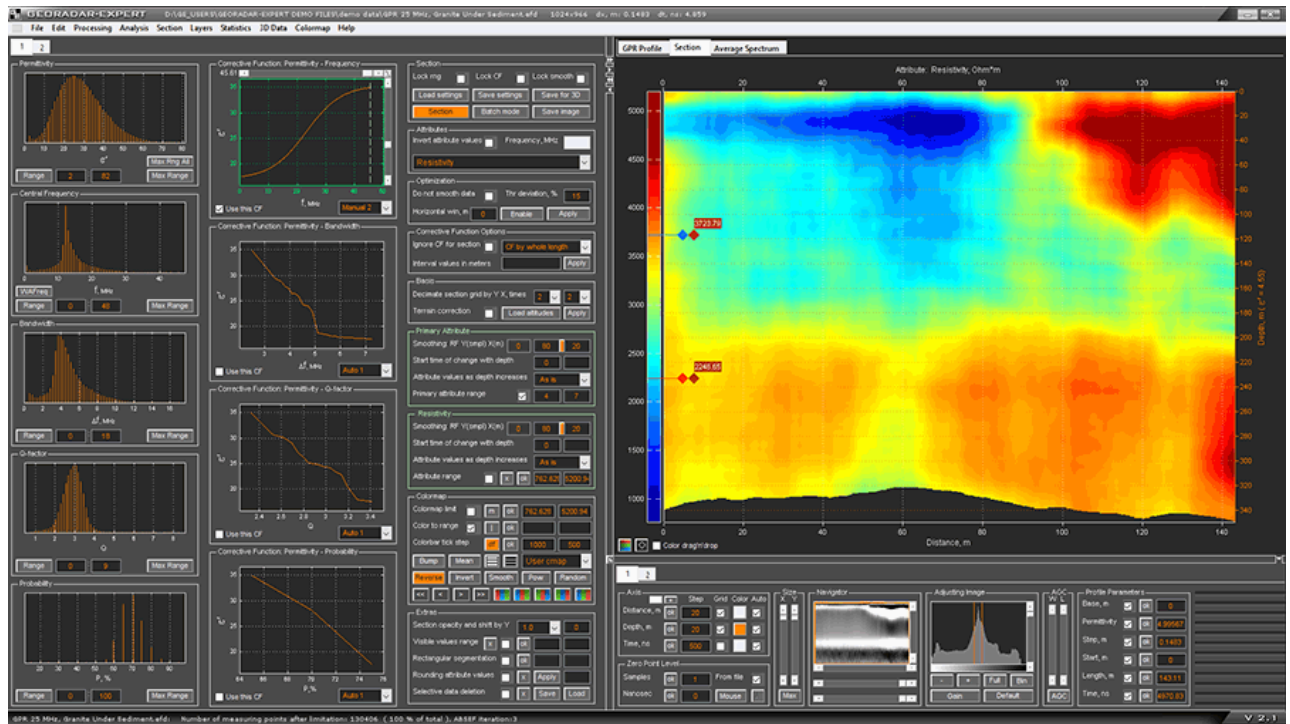
The bottom tab group is located in the bottom part of the main window of the software system and is used to place panels with control elements for processing and visualization of GPR profiles. The top group of tabs occupies the space limited by the left and bottom groups of tabs and is intended for visualization of GPR data and results of their processing. The user can change the ratio of tabs sizes, as well as hide the left and bottom groups, thereby increasing the data visualization area in the top tab group.

The GEORADAR EXPERT provides two ways to organize the workspace of the main program window – 2D mode and 3D mode. Depending on what type of data is being loaded, the software system automatically selects the workspace mode corresponding to the loaded data.

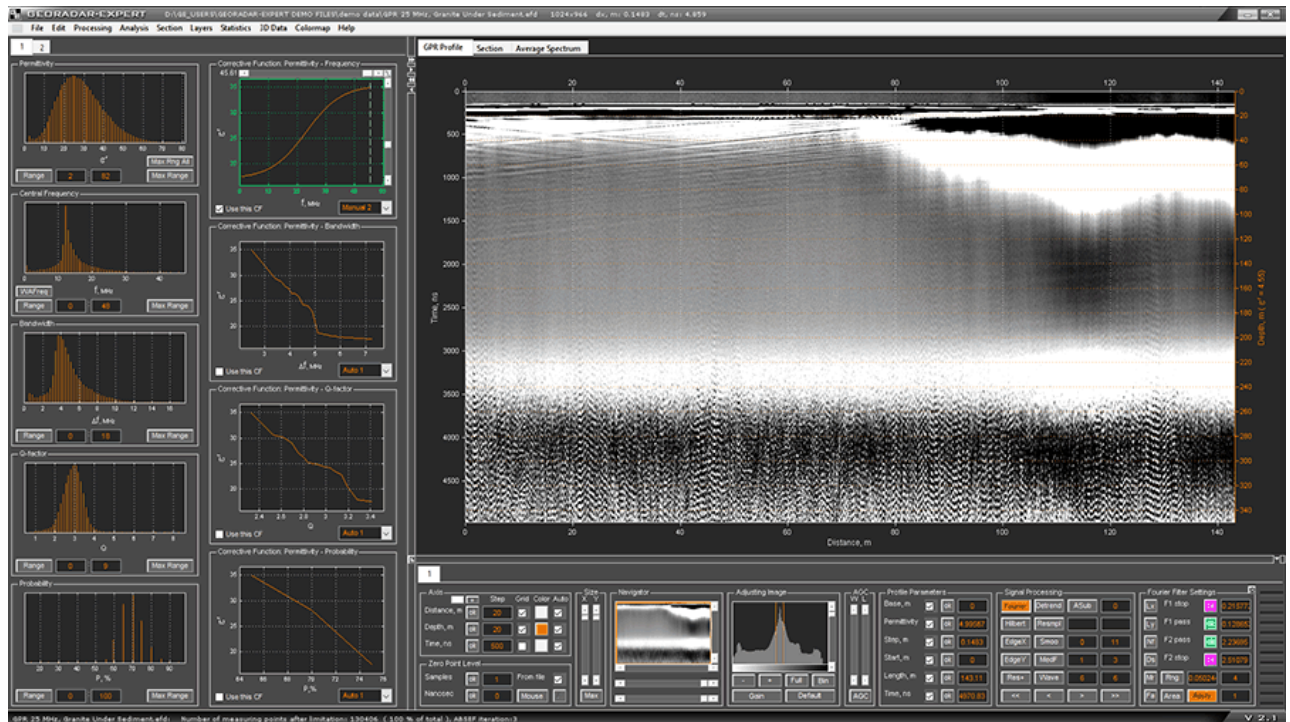
2D mode is designed to work with two-dimensional data, such as GPR profile and attribute section. 3D mode is used to work with a three-dimensional assembly of attribute sections created based on the results of BSEF automated analysis of GPR profiles obtained during GPR research, where a grid of GPR profiles covers the area of the object under survey.

Further are screenshots of the main window of the GEORADAR-EXPERT software system in various configurations. Below is the main window in 2D mode with a tab for visualizing the attribute section. The tab ratio is set by default for a computer screen with a Full HD resolution.





The main window of the GEORADAR-EXPERT software system with the GPR profile visualization tab is shown below. Unlike the previous example, the ratio of tab groups has been changed, the width of the top and bottom tab groups have been increased by reducing the width of the left tab group.

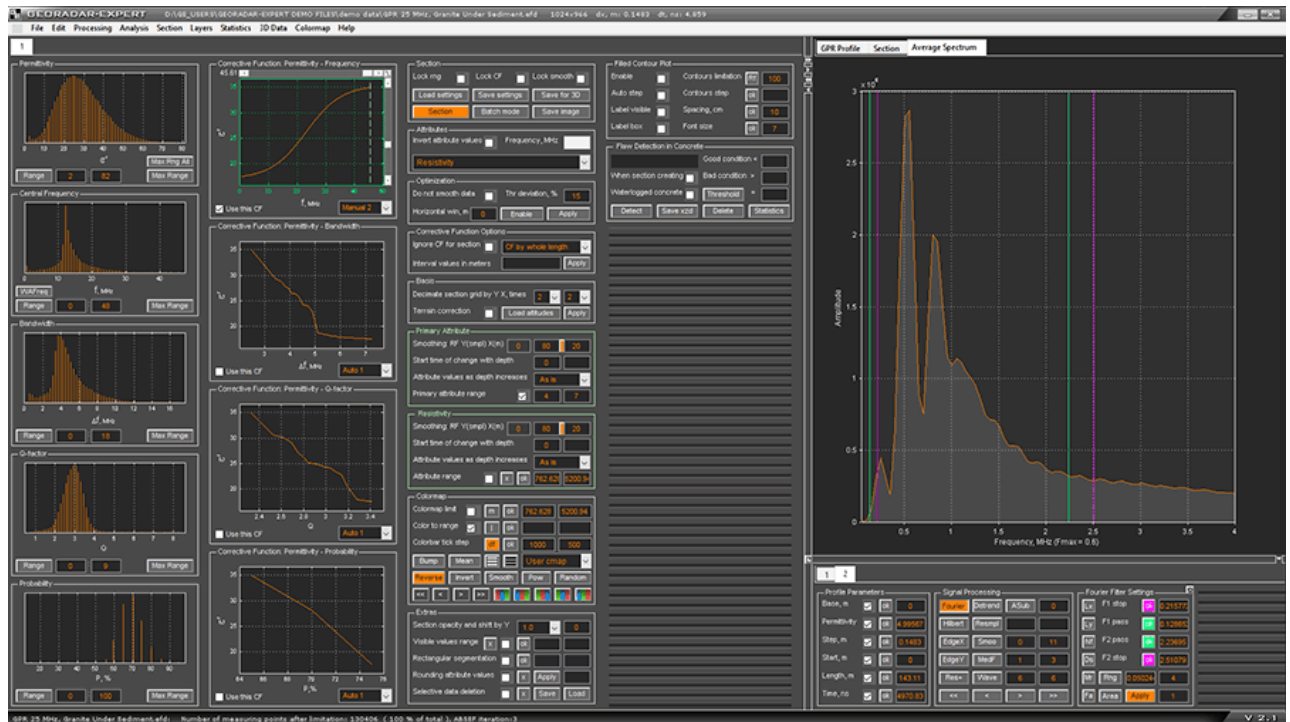


Next, the main window of the GEORADAR-EXPERT software system is shown with a tab for displaying the amplitude-frequency spectrum of GPR profile signals. The width of the left tab group has been increased by reducing the width of the top and bottom tab groups.

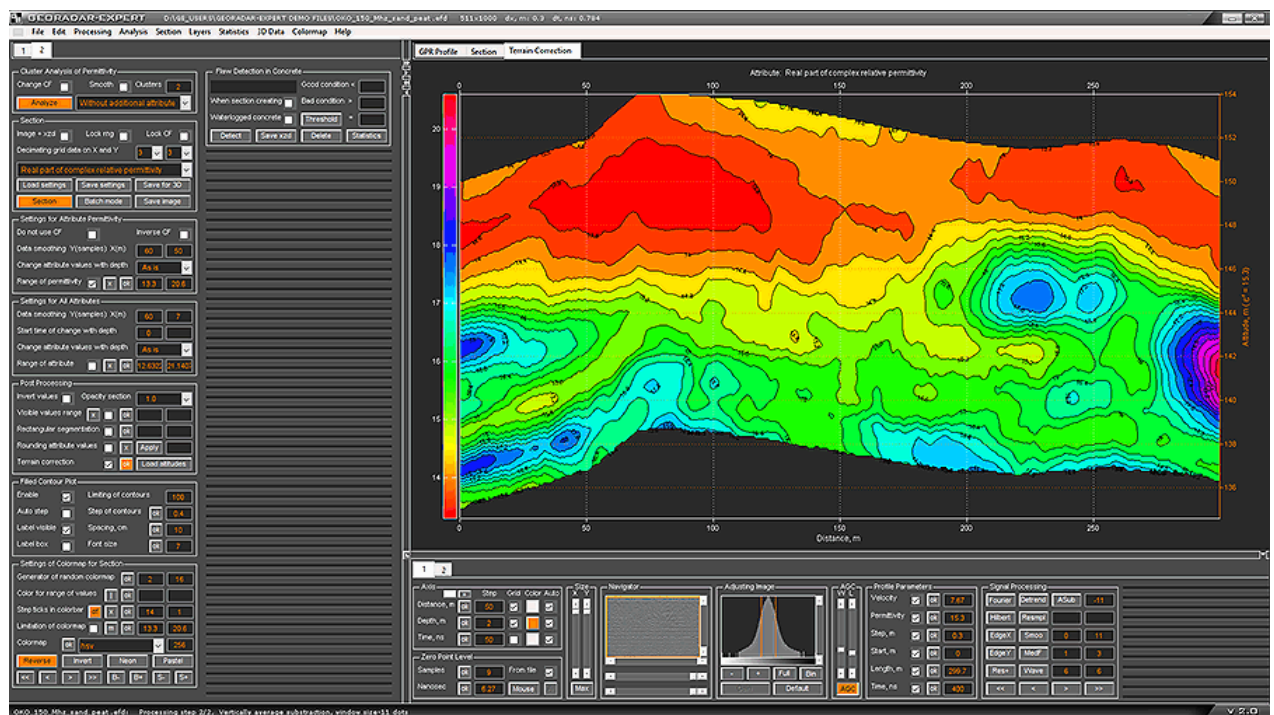


# GEORADAR-EXPERT

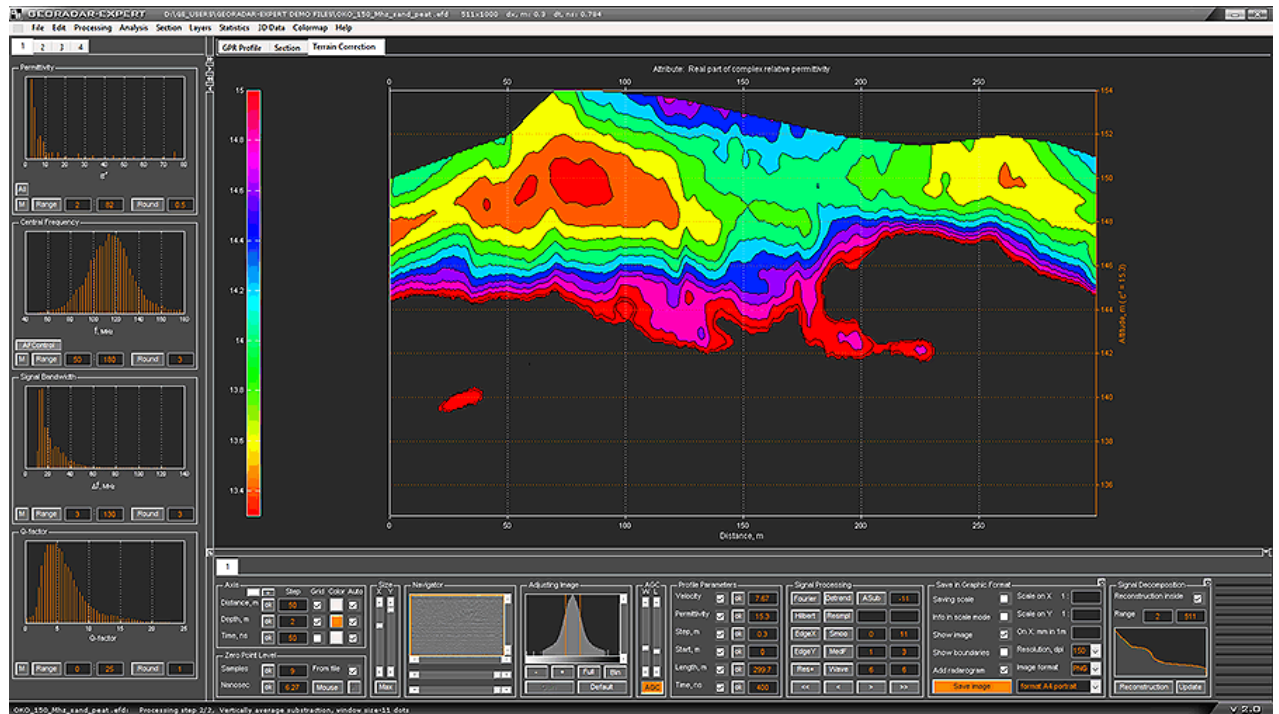
## Software System for Automated Processing of GPR Data



Below is the main window of the GEORADAR-EXPERT software system with a tab for visualizing the section of the attribute created taking into account the terrain correction.



Next, the section visualization tab is shown, taking into account the terrain correction in the attribute visibility limitation mode. In this mode, those areas of the section whose attribute values go beyond the boundaries of the user-defined range are set transparent. Transparent areas are not taken into account in the process of statistical and other analysis of the section.



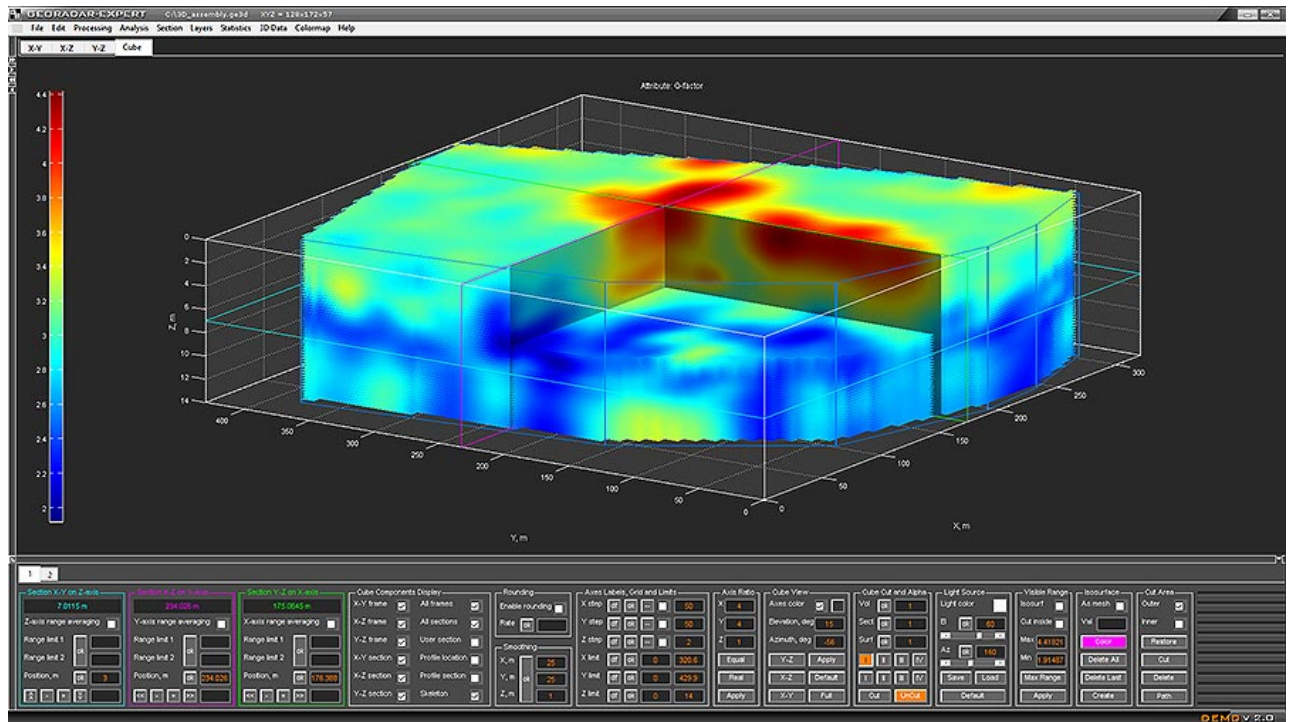
As noted above, the 3D mode of the main window of the GEORADAR-EXPERT software system is designed to work with the results of a GPR survey, where a grid of GPR profiles covers the area of the object under survey. This mode is used to visualize the three-dimensional assembly of sections created based on the results of automated BSEF analysis of GPR profiles of unequal length and arbitrary orientation. In the process of forming a 3D assembly of sections, it is possible to take into account their position in accordance with the coordinates of global positioning systems.

In 3D mode, the left tab group is hidden. The top tab group contains 3D volume visualization tabs, three mutually perpendicular 3D volume cross-sections, as well as custom 3D volume cross-sections, which, unlike mutually perpendicular cross-sections, can have a curved shape. The bottom tab group is used to place 3D visualization controls.

The following shows the main window of the GEORADAR EXPERT software system in 3D mode with the 3D assembly volume visualization tab. The volume is divided into parts by three orthogonal cross-sections, one horizontal and two vertical. The result is eight sub-volumes, i.e. voxels. Four voxels lie above the horizontal cross-section and four are located below this cross-section. You can change the size of voxels by moving orthogonal cross-sections along their respective axes. In the example presented, one upper voxel of the 3D assembly volume is cut out.

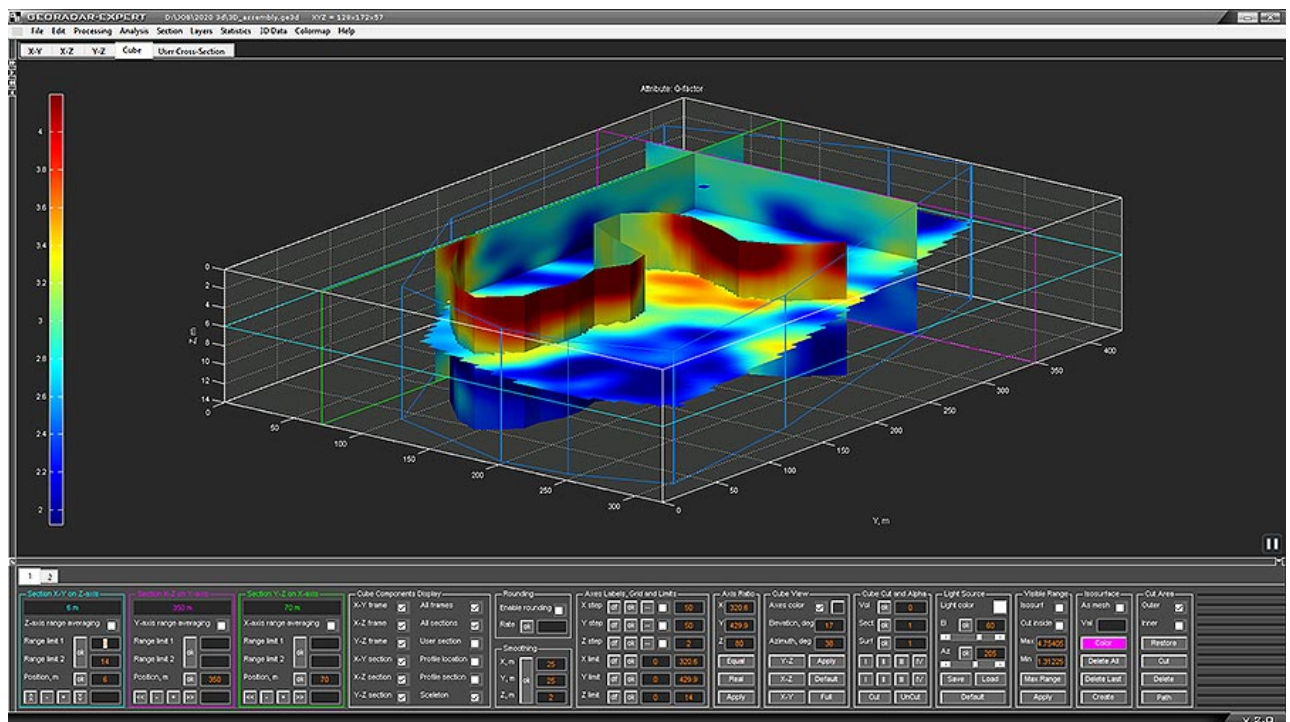
# GEORADAR - EXPERT

## Software System for Automated Processing of GPR Data



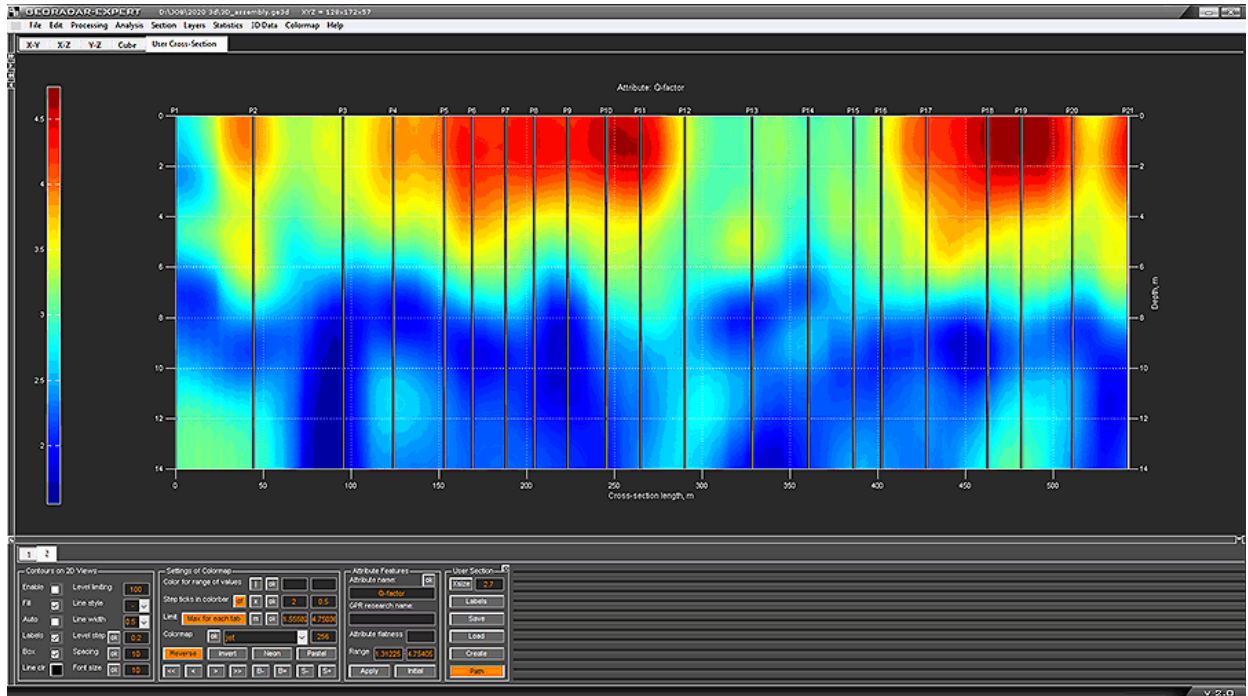
The user can change the position of the orthogonal cross-sections of the 3D assembly, average the specified thickness of the 3D volume in all three directions X Y Z, create their own sections of arbitrary shape, save these sections to a file and load them to the 3D assembly from a file.

The following shows the main window of the GEORADAR EXPERT software system with a 3D volume visualization tab containing three orthogonal cross-sections and one user curved cross-section.

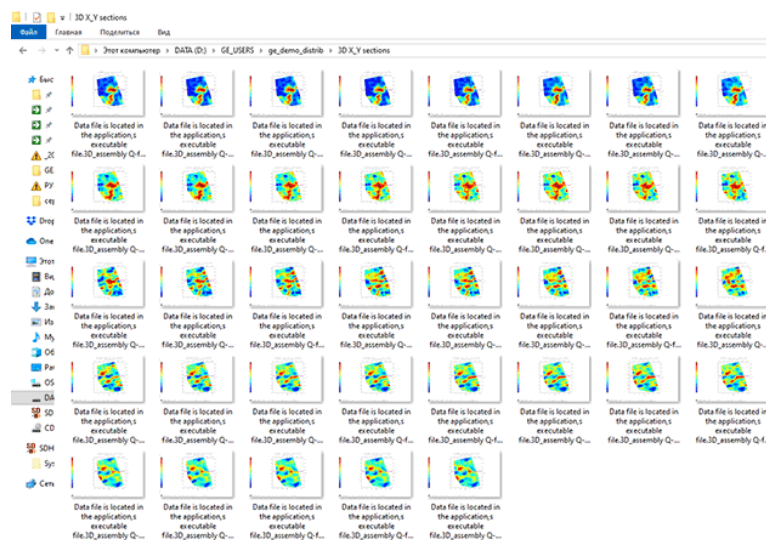




The visualization tab of this curved cross-section is shown below in expanded form. Vertical lines indicate the position of the nodal points of the curve through which this cross-section passes. The names of the nodal points are displayed above the upper border of the cross-section. For each nodal point, it is possible to obtain a graph of the logging curve and a table of its values.



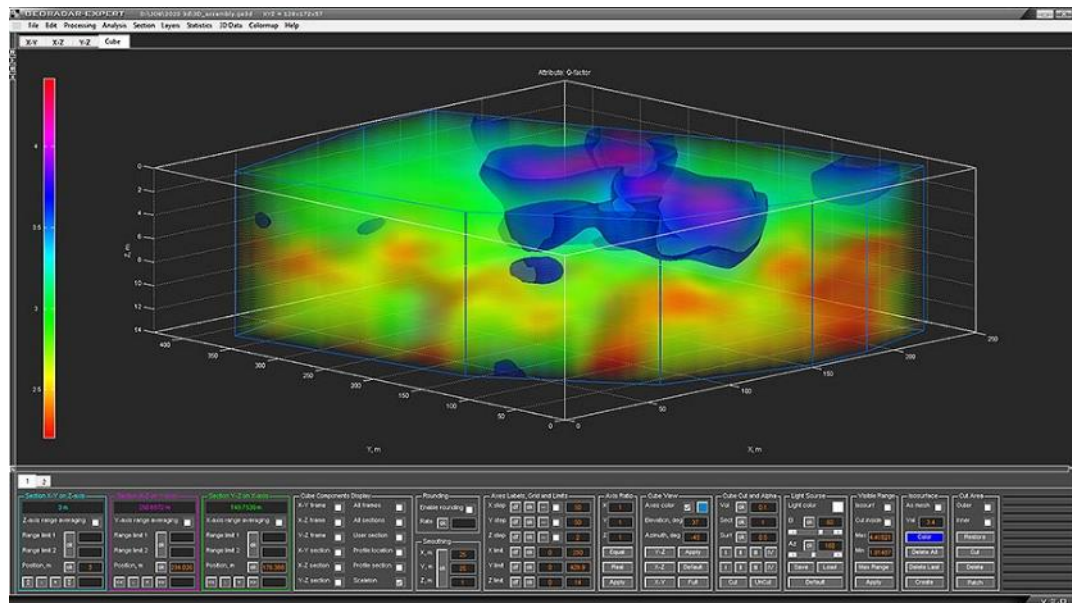
The user can save a series of images of cross-sections of 3D volume to the computer's hard disk in automatic mode with a specified step along the corresponding axis. In comparison with the manual mode of saving sections, the automatic mode significantly saves time. In manual mode, you first need to perform actions to move the section to the desired point on the axis, and then interact with the image saving dialog box. When the number of sections is several dozen, the process of manual saving takes a relatively long time. The figure below shows the directory for saving a set of horizontal sections in Windows Explorer in the file contents display mode.



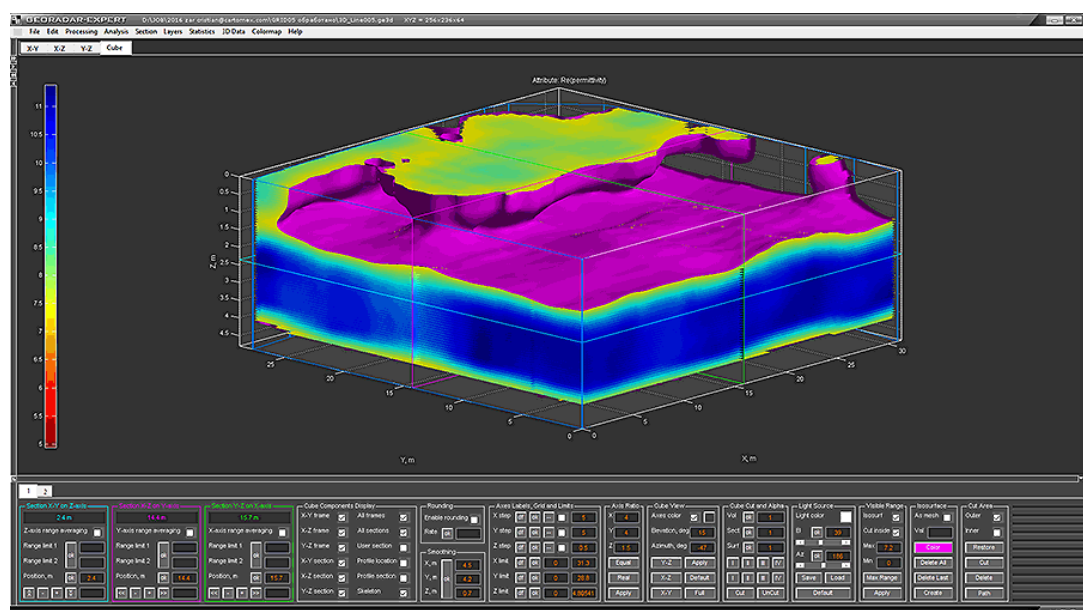


In 3D mode, all the necessary visualization options are provided, including the ability to control the transparency of the elements of the 3D assembly array. This allows you to show objects hidden inside the 3D assembly volume, which gives more clarity in the presentation of the results of the GPR survey.

The figure below shows an example of 3D visualization, which includes isosurfaces and the volume of 3D assemblies with varying degrees of transparency. In the translucent volume of the 3D assembly, interstratified layers of rocks are visible in the form of areas of red shades. The boundaries of soil anomalies are represented by isosurfaces of blue color. Translucent isosurfaces do not overlap each other, and this allows us to observe the shape of these anomalies completely.

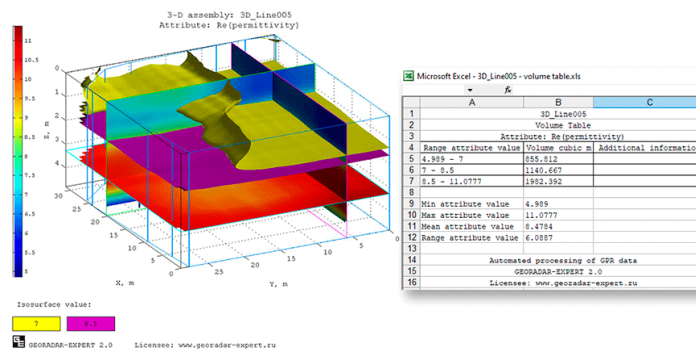


Below is a variant of visualization of the 3D assembly volume, in which full transparency is defined by the user-specified range of attribute values, and the isosurface is the boundary between the transparent and opaque regions.

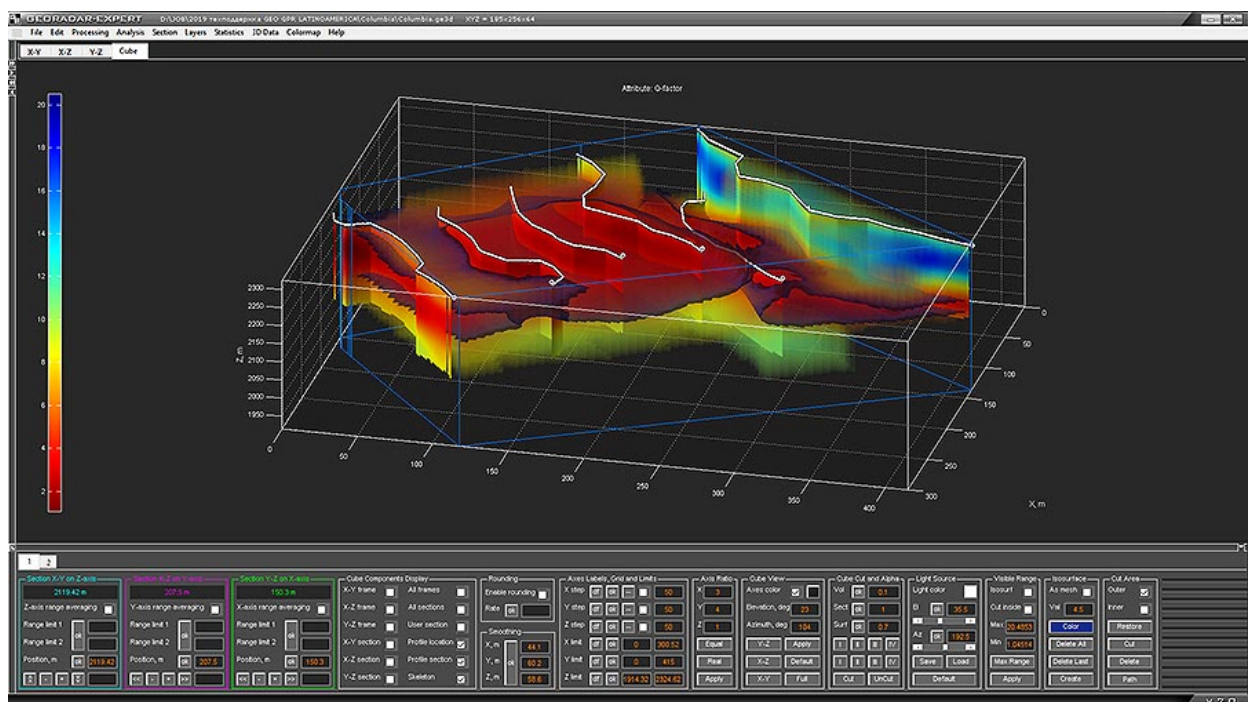


If the 3D assembly contains isosurfaces, then these isosurfaces divide the volume of the 3D assembly into parts. The user can create isosurfaces so that they pass along the contact boundaries of the layers of the investigated subsurface. The ability to obtain information about the volume of these layers is of undoubted practical interest. GEORADAR-EXPERT provides this opportunity.

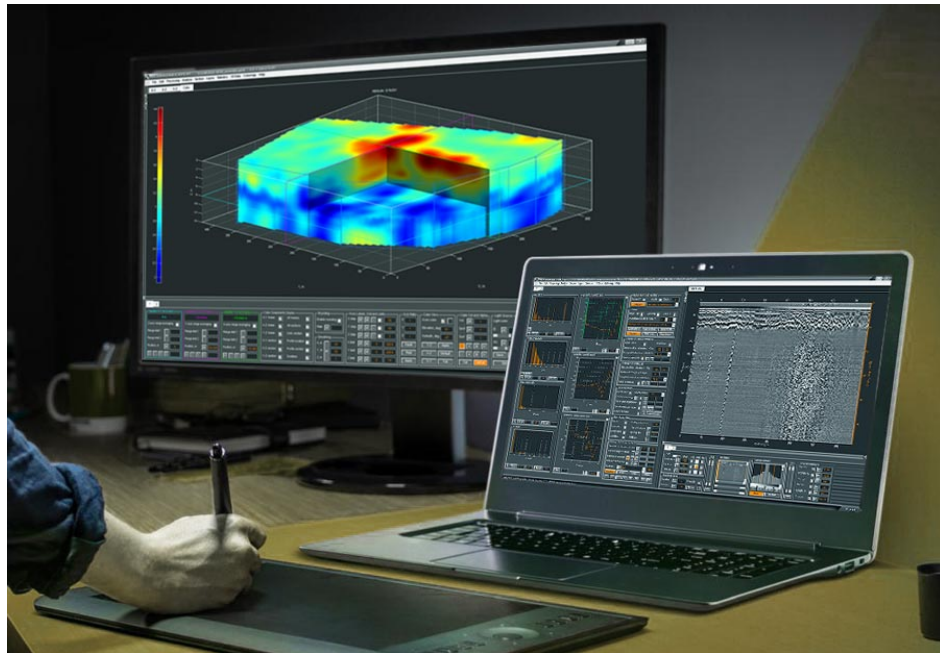
The figure below on the left shows the axes of the 3D assembly from the previous example, on which orthogonal slices and two isosurfaces are placed - one yellow, the other purple. The values through which these isosurfaces pass are shown in the lower left corner of the image in the rectangles of the corresponding colors. The right-hand side of the image shows an automatically generated table of volumes bounded by these isosurfaces. Similarly, you can get information about layer area in square meters in 2D mode. Only in this case the layers do not limit the isosurfaces, but the lines of the boundaries of the layers.



Below is an example of a 3D assembly, which was created taking into account the coordinates of the GPS positioning system. In a three-dimensional view, the positions of GPR profiles and vertical slices along these profiles are visualized. An isosurface passes through the 3D assembly volume, showing the contact position of soils with various electro physical characteristics. For isosurface and 3D assembly volume, various degrees of transparency are specified.



## Using GEORADAR-EXPERT Advantages



The GEORADAR-EXPERT software system, developed as a result of generalization of many years of experience in processing GPR data, is an effective tool for solving a wide range of georadiolocation tasks, including in cases where the use of third-party GPR data processing software does not lead to positive results.

The informativeness and quality of the camera work performed using the software system ensures that the organization using the GEORADAR EXPERT in its research is highly competitive in the market of geophysical services. The following is information about the similarities and differences between the GEORADAR EXPERT and third-party software for GPR data processing.

### Similarity

The GEORADAR-EXPERT software system implements a full set of GPR data processing options, which is included in every professional georadiolocation software. In other words, the GEORADAR-EXPERT has everything that a GPR specialist is used to working with.

### Differences

The difference between the GEORADAR-EXPERT software system and software products from other manufacturers is the availability of specialized algorithms, the use of which brings the quality of GPR data processing to a new level. The GEORADAR EXPERT includes the following specially designed options:

- **Automated BSEF (Back-Scattering Electromagnetic Field) analysis.** It makes the transition from the representation of data on the subsurface environment in the form of a set of amplitudes of reflected signals in the form of a radarogram to the characteristics of this environment and the wave field reflected from it in the form of an attribute section. This representation makes the result of processing GPR data more understandable. BSEF analysis works effectively in areas of high noise

located in the lower part of the GPR profile, which allows you to increase the depth of the GPR survey. Along with this, BSEF analysis allows obtaining information about the structure of the studied subsurface environment even under conditions of a smooth change in its electrophysical characteristics, i.e. when reflections from the boundaries of layers are absent on the GPR profile. The use of automated BSEF analysis provides the specialist with more opportunities to study complex subsurface environments.

- **B-Detector (Boundaries Detector).** This method is designed to suppress interference and increase the vertical resolution of the GPR profile, which makes it easier to distinguish nearby, vertically, reflections from the boundaries of subsurface layers. Using B-Detector, the user increases the frequency and spectrum width of the GPR profile signals, thereby reducing the duration of these signals and increasing the degree of detail of the GPR profile. As a result of processing by the B-Detector method, the GPR profile obtained using a low-frequency antenna looks as if the frequency of the GPR antenna for recording this GPR profile was tuned to a frequency several times higher than the actual frequency of the antenna. Compared to the original GPR profile, the vertical resolution of the GPR profile after processing by the B-Detector method is several times higher. If necessary, the B-Detector method can lower the central frequency of the GPR profile signals.
- **Method for decomposing a radarogram into components.** This is not a wavelet decomposition of signals, although it is also implemented in the GEORADAR-EXPERT. This method converts a signals matrix of GPR profile into a set of matrices. Each matrix from this set contains only one unique type of reflected waves. The user discards the matrices with those types of waves, which he defined as interference, and then summarizes the remaining matrices. Thus, interference are excluded from the GPR profile signals. Using the same method, it is possible to remove diffracted reflections, including air ones, leaving behind only the boundaries of the layers on the radarogram. This is useful, for example, for road research. Or vice versa, you can remove all the boundaries of the layers, leaving only diffracted reflections. For example, to better detect reinforcement in a concrete structure.
- **Statistical analysis module.** This module is intended to summarize the results of GPR profiling and to better presentation the variability of the electrophysical characteristics of the GPR profile. Using the results of statistical analysis, presented in the form of tables and graphs, it is possible to establish a relationship between the physicommechanical characteristics of the investigated subsurface environment (for example, soil or building structures) and various statistical indicators. Thus, a feature set is created that can be used in the future to assess the state of similar objects. Statistical data sources are GPR profiles, attribute sections, which are calculated based on the results of BSEF automated analysis, and slices of the 3D assembly. If the user has drawn the boundaries of the layers on the GPR profile, on the attribute section or on the 3D assembly slice, the statistical indicators are calculated inside each layer, along the boundary of each layer and for the whole object, without regard to separation into layers. Using the statistical analysis module implemented by GEORADAR-EXPERT raises the quality of GPR research results to a new, higher level.



- **Flaw detection module of building structures.** Flaw detection of concrete and reinforced concrete building structures is based on the identification of zones on the section with abnormal deviations of the values of the Q-factor attribute. Flaw detection results are saved in the form of a section of the attribute, on which the defective zones are highlighted, and a defective list, in which for each GPR profile a quantitative and qualitative assessment of the state of the object is given, during the study of which one or another profile is obtained.
- **2D data summation module.** Designed to summarize sections of heterogeneous attributes or cross-sections of a 3D assembly. As a result of summation, artifacts caused by the accumulation of errors in the process of collecting and processing GPR information are eliminated, and the model of the subsurface medium is restored from summation elements (attribute sections or cross-sections of a 3D assembly), each of which contains only some of the useful information.
- **Converting a radargram image from a graphic format to a full-fledged GPR profile format.** The need for such conversion may arise when the GPR profiling data file is lost, and there is only an image of this profile on paper or on the page of an electronic document. As a result of the conversion, the user gets the opportunity to apply to the GPR profile all signal processing options and all types of GPR data analysis implemented in the GEORADAR EXPERT.

## Useful Links

The GEORADAR-EXPERT web site:

<https://gpr-soft.com/>

The GEORADAR-EXPERT user manual:

[https://gpr-soft.com/download/georadar\\_expert\\_manual\\_eng.pdf](https://gpr-soft.com/download/georadar_expert_manual_eng.pdf)

Watch or download video tutorials:

<https://gpr-soft.com/Video.html>

Information brochures:

[https://gpr-soft.com/download/ge\\_software\\_review\\_eng.pdf](https://gpr-soft.com/download/ge_software_review_eng.pdf)

[https://gpr-soft.com/download/ge\\_brochure\\_eng.pdf](https://gpr-soft.com/download/ge_brochure_eng.pdf)

Technical support:

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