УДК 528.063:528.42:550.3
DOI 10.33764/2618-981X-2023-1-2-242-249

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Automatization for geodetic support of 3D Transient Electomagnetic Survey

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Abstract: The article covers the technology of high-automatized geodetic support of transient electromagnetic survey. Transient electromagnetic method (TEM) is considered and the tasks of its geodetic support are given and analyzed. The specified module for RouteEditor software was designed directly for the tasks of geodetic support of transient electromagnetic survey. The article considers the module and highlights the main technological stages of its using. The conclusions on the proposed method of geodetic support were made. The considered technology of TEM geodetic support using RouteEditor reduces significantly the time spent on the Planning routine is due to the high-automatized solutions. It also provides the single software solution for the different tasks of TEM geodetic support. Moreover, the software detects errors in point names and positions could and filter them automatically, that makes the human-factor much lower.

Keywords: TEM, geophysics, geodetic support, planning, measurements control, automatization

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Автоматизация геодезического обеспечения электромагнитных исследований 3D-ЗСБ

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Аннотация: В статье предложен метод повышения автоматизации геодезического обеспечения геофизических исследований методом зондирования становлением электромагнитного поля в ближней зоне, также известного как ЗСБ. Рассмотрены базовые принципы геофизических работ методом ЗСБ, рассмотрены задачи геодезического обеспечения данных исследований. Разработан специализированный модуль для RouteEditor, решающий непосредственно задачи геодезического обеспечения геофизических работ методом ЗСБ. В статье рассмотрен данный модуль и технологические этапы его применения. Рассмотренная технология в значительной мере снижает временные затраты, возникающие на этапе проектирования работ, а также при выполнении дальнейшего полевого и камерального анализа геофизических исследований методом ЗСБ. Указанный эффект достигается за счет повышения автоматизации указанных технологических процессов. Также данная методика позволяет решать большинство задач геодезического обеспечения на базе единой программной платформы. Кроме того, предложенная методика анализа точности и качества, в частности, в именах пунктов, помогает избежать ошибок оператора, возникающих при анализе большого объема данных.

Ключевые слова: ЗСБ, геофизика, геодезическое обеспечение, проектирование, контроль измерений, автоматизация

Transient electromagnetic method

The transient electromagnetic method (TEM) alternately called time-domain EM (TDEM) or pulse EM (PEM) is a commonly-used, non-intrusive, geophysical method for obtaining subsurface resistivity-conductivity data. The depth of investigation can vary from 10s of meters to over 1000 meters [1-3]. TEM methods are used for an extremely broad range of applications in exploration, engineering, and environmental investigation.

The most common TEM method (see Fig.1), which is considered in the article, bases on using of a specialized transmitter to drive a time-varying current into a transmitter loop, usually an ungrounded loop of wire laid on the ground surface [4].

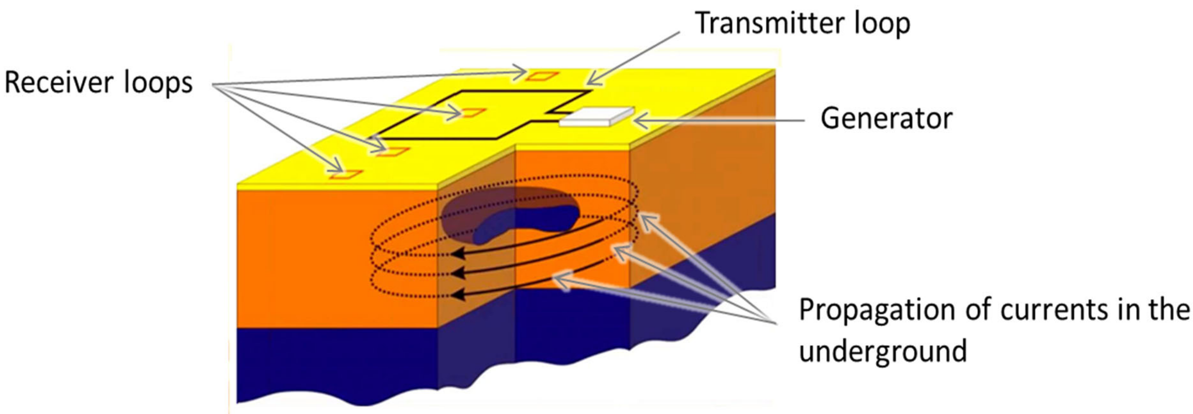


Fig. 1. Principles of TEM method

The transmitter loop generates an EM wave that propagates into the subsurface. As the EM energy encounters different subsurface materials, it induces eddy currents that generate secondary EM fields.

These secondary EM fields are picked up at the surface by a receiver loop or magnetic antenna and recorded as the induced energy diffuses into the earth. The rate of diffusion indicates the resistivity of the subsurface materials. The resulting survey data are used to predict the occurrence of raw materials or man-made objects under the surface of the area.

Geodetic support of transient electromagnetic survey

One of the most important parts of geological and geophysical surveys in general and TEM surveys in particular is geodetic support.

Geodetic support of TEM is a complex of techniques providing the solutions of topographic and geodetic issues as [5, 6]:

- Survey planning, including the location of transmitter loops, receivers and other details of the field deployment,
- The removal of designed points on the ground with a given accuracy,
- Quality and accuracy control during the field survey and the final data processing,

– The preparation of result data, including catalogs of coordinates and quality reports.

The objects of the planning are transmitter loops centers and their angular points and receiver loops centers (pickets).

Planning could be implemented with two consistent stages:

1) Placement of transmitter loop centers (usually using profile lines or by survey area borders),

2) Settings of the transmitter loops (including their angular points receiver loops positioning).

For the transmitter loop centers placement the algorithm of the placement must be defined. As a result the centers of the loops will be placed in the map. The settings of the transmitter loops define their size, orientation azimuths and other properties. The receiver loop centers (pickets) placement could be also considered as a part of the assignment of settings of the transmitter loops.

Classical TEM method has a single receiver loop in the center of the transmitter loop, but the most innovative 3D-TEM survey [1, 7-10] uses the multiply receiver loops. The placement of pickets could be implemented by one of the most common patterns, that showed in Fig. 2. But also by some reasons the placement could have non-standard template.

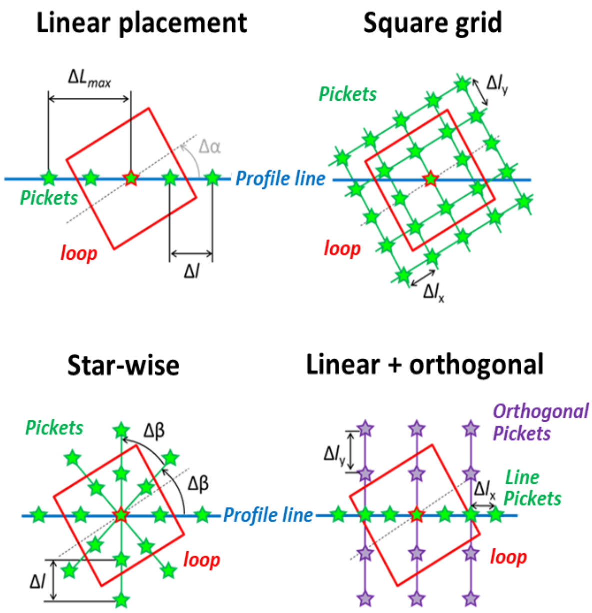


Fig. 2. The most common patterns of placement of the receiver loops for 3D-TEM

Fig. 2 uses the following variables:

Δl is a step distance between pickets,

ΔL_{max} is a maximum distance from the center of the transmitter loop allowed for the pickets,

$\Delta\alpha$ is an angle between a profile line and the transmitter loop orientation,

Δl_x and Δl_y are longitudinal and transverse steps between the adjacent pickets.

The next phase after the planning is field survey. It includes special geodetic operations directly in the survey area. These works are made with special staff using GNSS receivers (them class depends on the scale of survey, but navigational-class code GNSS receivers are sufficient in the most cases).

Before the field phase starts the planned points must be loaded into GNSS receivers. The geodetic support includes removal of the planning points on ground (border points of generator loops and centers of receiver loops) and operational control of quality and accuracy.

After the field phase, the measured data should be analyzed to check the accuracy and quality of the geodetic support. The resulting data must be presented as catalogs of coordinates in a format supported by the geophysical software for further processing. It is also good practice to output some textual and/or graphical data for technical reports.

Geodetic support of transient electromagnetic survey using RouteEdit utility

RouteEditor is an utility from RouteNav software package, which was designed as a navigational software for navigational support of aerial geophysics [11-13]. Nowadays it's being adapted for tasks of geodetic support of a wide circle of geological and geophysical methods [14].

Current version of RouteEditor includes a specialized module that was designed for geodetic support of TEM survey, including its planning and control phases.

The tools developed for the planning phase work in the following sequence:

- Source data preparing (coordinates of linear profiles points or the angular points of survey area),
- Planning placement of loop groups,
- Settings for each loop,
- Editing the resulting points independently,
- Export the resulting date into the formats of GIS and field facilities.

The tools developed for the field and post-field control work in two steps:

- Import the measured data for the analysis,
- Analysis reports and coordinates catalogs output.

Source data for the planning may be presented as coordinates of the points of survey area borders or line profiles (straight/compound). The data could be imported from the supported formats: text catalogs (*.txt, *.csv) or tables MS Excel, GPS Exchange *.gpx, Surfer *.bln. The profiles and survey area borders could be also created in the map or by the coordinates manually.

Source data may also include maps and satellite images that could be downloaded automatically, imported from OziExplorer *.map format or geo-referenced manually using Raster utility included with the software.

Placement of generator loops step could be implemented along the profile lines, within the survey area borders or manually in the map or by coordinates, Fig. 3.

Both methods of the placement have flexible settings (spacing between loops, patterns, indents from the start, azimuths for loops relevant to the profiles or independent, naming properties, common pickets placement configurations, etc.).

As a result of this phase the user has groups of planned transmitter loops. All the loops in the groups have the same properties. However, the program allows user to configure each loop independently.

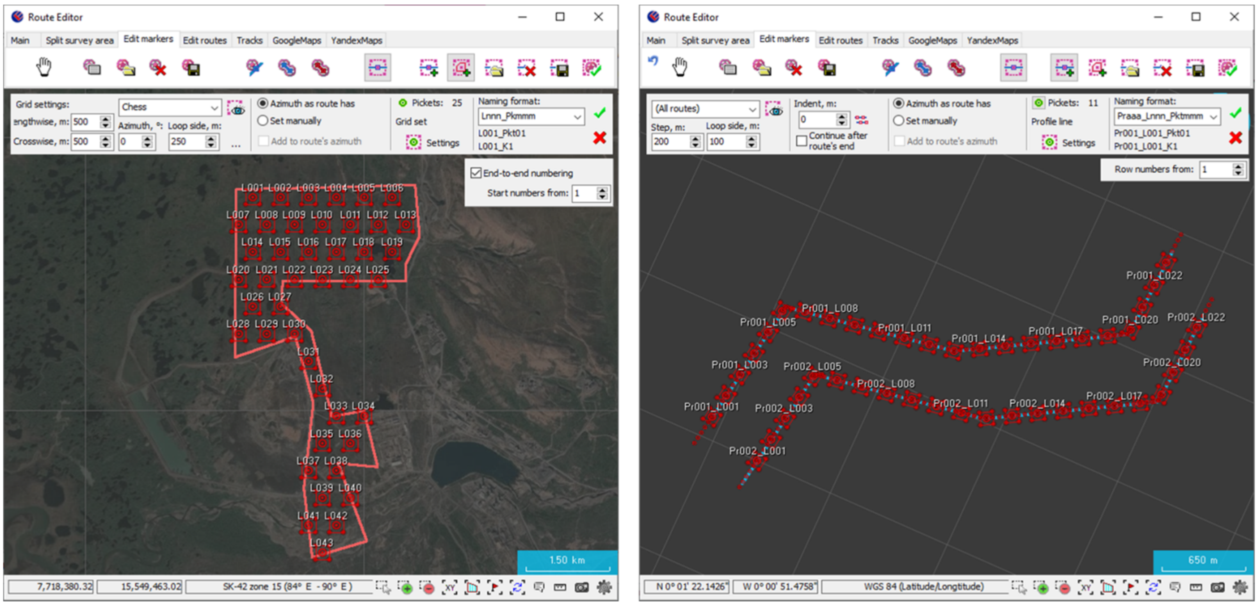


Fig. 3. Placement of generator loops in RouteEditor: within the borders of survey area (left) and by profile lines (right)

Each loop can have its size, shape and other parameters. Every loop could be replaced (by setting new coordinates or using drag-and-drop); its azimuth could be changed as well as configuration of pickets, Fig.4.

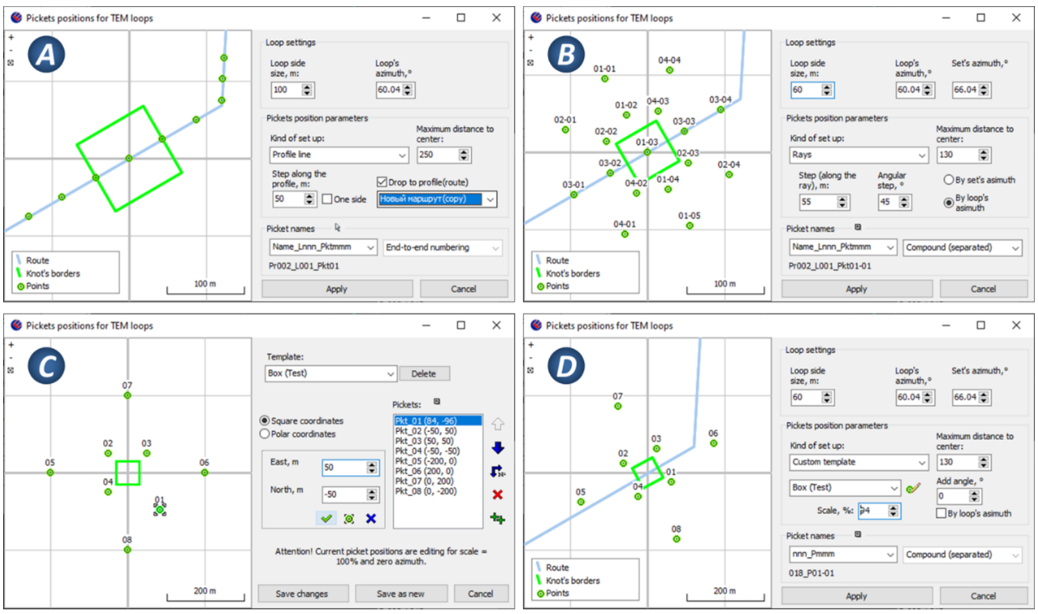


Fig. 4. Receiver loops (pickets) configuration examples: A) Projected to the profile; B) Star-wise (rays) template; C) Editing the user-defined manual template; D) Applying the user-defined manual template

The feature of RouteEditor is a support of standard picket templates with an ability for the user to create their own placement template.

The shape of the loop is also changeable. In most cases of TEM the loops are squares, but it their shape could be also changed to circular or rectangular, that is supported by the program.

The next step of planning is the convertation loop objects into a collection of points. In this mode the user has an opportunity to edit each point directly (add/delete/change coordinates and name, etc.). This stage is the final planning step before the data is being exported.

For the export there are several formats supported:

- Golden Software Surfer *.bln format, which is used in the Surfer editor for math and modeling,
- GPS eXchange *.gpx format, which supported by GNSS receivers as Garmin,
- EM-DataProcessor *.xyz/*.mxyz format for geophysical data processing,
- Custom text table *.txt for other purposes.

In the program the statistical report for the project is also available (including number of loops and pickets, their average size, density within the area, etc.).

After the planning and exporting plan data, the field survey phase follows. It includes the removal of planned points on the ground and the implementation of operational control.

Receiver loops must be positioned during the deployment. In most cases each receiver loop detector includes a processor block with an internal GNSS-receiver. The data, picked up by the receiver loops, could be presented by files which are contained both GNSS and geophysical measurements.

During the survey from hundreds to tens of thousands of such files must be downloaded from the facilities for processing. The probability of errors in coordinates, names and data availability increases with the number of the files. Threfore it is necessary to provide control for each day of the field survey as well as the final post-field control.

Huge amount of data could be imported to RouteEditor with the common or individual settings of import. Coordinates for each point are calculated as an average values using 3-sigma filter, Fig 5.

During the analysis of the imported data the following parameters could be estimated:

- Standard deviations for the measurements could be estimated for each imported file,
- Differences in coordinates between planned and measured points,
- Errors in names of measured points in comparison with the planned data (it implements by checking by names of the points and by the nearest coordinates.

As a result user has a report that includes all coordinates and estimation results, Fig. 6.

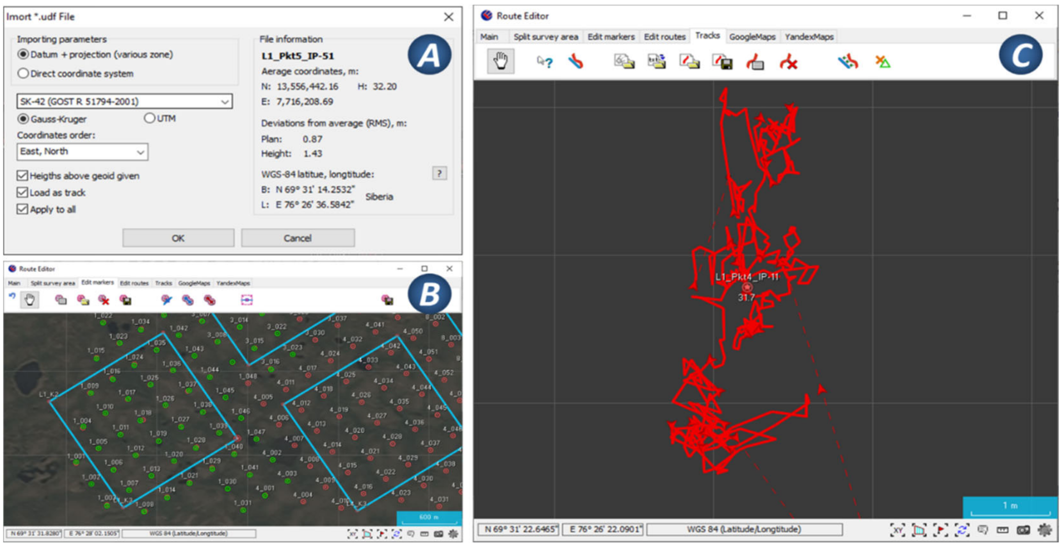
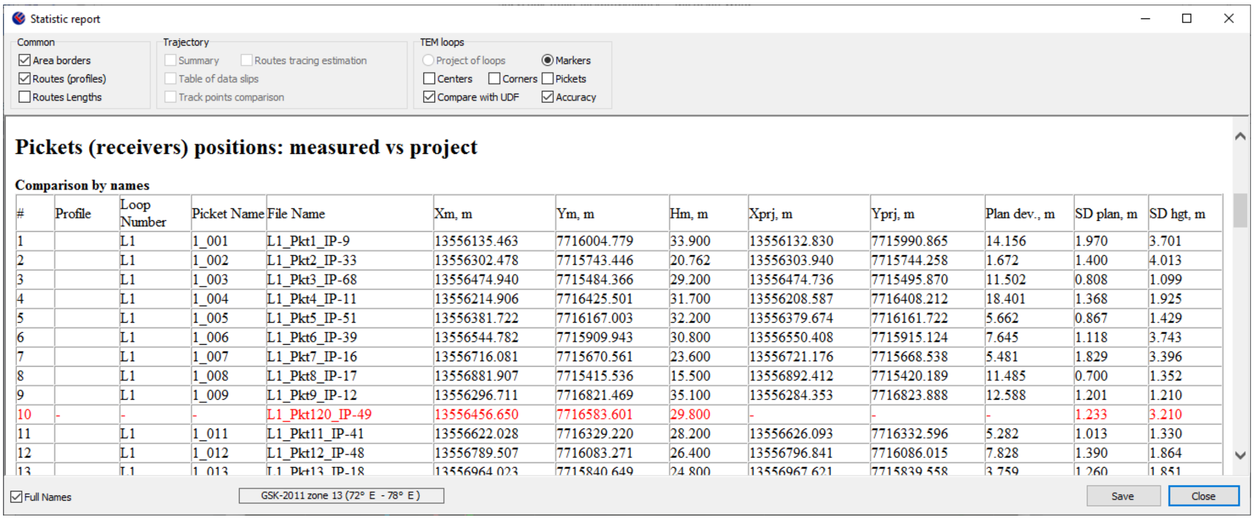


Fig. 5. Import the measured data from receiver loop facilities: A) Import settings; B) Visual comparison of planned and measured points coordinates; C) Measurements presented as a track



Pickets (receivers) positions: measured vs project

Comparison by names

#	Profile	Loop Number	Picket Name	File Name	Xm, m	Ym, m	Hm, m	Xprj, m	Yprj, m	Plan dev., m	SD plan, m	SD hgt, m
1		L1	1_001	L1_Pkt1_IP-9	13556135.463	7716004.779	33.900	13556132.830	7715990.865	14.156	1.970	3.701
2		L1	1_002	L1_Pkt2_IP-33	13556302.478	7715743.446	20.762	13556303.940	7715744.258	1.672	1.400	4.013
3		L1	1_003	L1_Pkt3_IP-68	13556474.940	7715484.366	29.200	13556474.736	7715495.870	11.502	0.808	1.099
4		L1	1_004	L1_Pkt4_IP-11	13556214.906	7716425.501	31.700	13556208.587	7716408.212	18.401	1.368	1.925
5		L1	1_005	L1_Pkt5_IP-51	13556381.722	7716167.003	32.200	13556379.674	7716161.722	5.662	0.867	1.429
6		L1	1_006	L1_Pkt6_IP-39	13556544.782	7715909.943	30.800	13556550.408	7715915.124	7.645	1.118	3.743
7		L1	1_007	L1_Pkt7_IP-16	13556716.081	7715670.561	23.600	13556721.176	7715668.538	5.481	1.829	3.396
8		L1	1_008	L1_Pkt8_IP-17	13556881.907	7715415.536	15.500	13556892.412	7715420.189	11.485	0.700	1.352
9		L1	1_009	L1_Pkt9_IP-12	13556296.711	7716821.469	35.100	13556284.353	7716823.888	12.588	1.201	1.210
10	-	-	-	L1_Pkt120_IP-49	13556456.650	7716583.601	29.800	-	-	-	1.233	3.210
11		L1	1_011	L1_Pkt11_IP-41	13556622.028	7716329.220	28.200	13556626.093	7716332.596	5.282	1.013	1.330
12		L1	1_012	L1_Pkt12_IP-48	13556789.507	7716083.271	26.400	13556796.841	7716086.015	7.828	1.390	1.864
13		L1	1_013	L1_Pkt13_IP-18	13556964.023	7715840.649	24.800	13556967.621	7715839.558	3.759	1.260	1.851

Fig. 6. Example of RouteEditor report on TEM survey geodetic support analysis

Conclusions

The developed functional of RouteEditor for TEM geodetic support provides:

– High-automatized planning of TEM survey,

– Export of the plan data to several formats that are necessary during the survey and geophysical processing,

– Operative and high-automatized field and post-field control of the measurements,

– Using the other features of RouteNav utilities:

– Support of plenty of coordinate systems and height systems,

– Support of raster maps and satellite images from geo-services for the planning,

– Flexible visualization tools.

The considered technology of TEM geodetic support reduces significantly the time spent on the Planning routine thanks to high-automatized algorithms, which were implemented. The technology also provides the single software solution for the different tasks of TEM geodetic support. Moreover, the software detects errors in point names and positions and filters them automatically, that reduces the operator errors possibility.

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