Aspects Concerning the Automation of Topo-Cadastral Works

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***Abstract**: The article presents the RTK method using the actual GPS technology. This GPS technology is a modern method of measuring, the main aspects followed in the article being the gathering of field data with the RTK method. In the case study the authors made a comparison between different GPS measuring methods and the use of total stations, too. Finally we present some conclusions and recommendations concerning the use of RTK method for cadastre in localities.*

1. Performing Measurements Using GPS Technology

In order to perform GPS measurements, the following operations have been completed: planning and design of the kinematic measurements, performing the kinematic measurements, and processing the kinematic measurements.

1.1. Planning and Design Kinematic Measurements

Some of the principles of static measurements are also valid for kinematic measurements. In the case of kinematic measurements, the fundamental condition that has to be respected is the continuous reading of signals sent by at least four (preferably five) satellites, both during stationing and during the periods of passing from one station to another.

The design of kinematic measurements was done within the office, based on "mission planning" programs, but it was seen that a new thorough recognition is necessary in the field, the lack of which would not allow performing real time kinematic measurements in an elegant, professional, efficient and time effective manner.

The planning of measurements was accomplished within the office, after a careful recognition of the field, of the available satellites, of the GPS type real time positioning equipment and of the GPS post-processing positioning equipment.

The measurements were performed outside and inside localities, in order to create an inventory of the lands owned by the State Domain Agency.

- The measurements outside localities have been performed in the Topolog commune in autumn (October).
- The observation plan for each location was designed within the office, based on the information gathered during the field recognition stage and taking into account that there were 3 GPS receivers available for measurements:
- The first criterion for design consisted in covering with points the required interest area and choosing the common points for the connection with the reference systems.
- The second criterion was the efficiency during measurements, especially the optimization of the time required for passing between the points and the time between the observation sessions.
- The third criterion consisted in stationing in at least two independent sessions of each benchmark and establishing at least two connections with neighboring points, in order to reach the required precision and confidence parameters.

The observation plan was drafted on the computer, using the MULTI SITE MISSION PLANNING software from Ashtech. We have created a project named "X.PRJ" which included all the points selected for GPS observations.

The observation program was based on:

- The approximate geographic coordinates and altitudes of the points, obtained from the 1:25 000 map sheets (or previously known);
- The recognition sheets drafted during the operation of field recognition for the points that offered an open window for the entire horizon, above the 15° elevation.
- The planning was done for this case for three receivers, such that the following conditions were fulfilled:
- At least four-five satellites being read simultaneously by the three receivers;
- The PDOP value should be under 5, as a measure of expected precision, imposed by the geometry of the satellite constellation;
- Minimal observation time between 20 seconds and 1 minute.

1.2. Performing Kinematic Measurements

We have determined the coordinates of the detail cadastral points in Topolog commune from Tulcea County using the kinematic measuring method, in real time, by means of three SERCEL types GPS receivers. These receivers have been used for real time measurement, determining beforehand the trans-computational coefficients between WGS-84 and Stereo 70 systems for that area. Using the Mobil.exe software that runs with the SERCEL software, the trans-computational coefficients of the WGS-84 system have been integrated in the Stereo 70 system, and therefore, the coordinates have been determined directly in the field in the Stereo 70 national projection.

This was possible because we used a HUSKY types controller, which is very easy to use. SERCEL receivers are equipped with 12-16 real time data transmission channels, in fact, for transmitting differential corrections.

During measurements, the purpose was to read at least five satellites, because in case the signal from one satellite is interrupted, we ensured receiving data from at least four satellites, which is enough for determining the coordinates. Even if during a measurement session the constellation changes, the measurements will not be compromised. It is not necessary to read the signals from the same satellites from the beginning until the end of the measurements.

In the case of kinematic measurements, it is important to correctly choose the route, in order to ensure continuous signal receiving. At least four satellites have to be visible at any time and from any point of the route. This requires parsing the selected route, before the beginning of measurements, in order to identify the obstacles that might impede properly receiving the signals from the satellites.

During field works, we faced various situations, which required different solutions, namely:

- For the points situated on the borders of sections or property bodies (in the coverage areas), (eccentric) “auxiliary points” have been surveyed on the alignment, from which we measured the distance to the point that had to be surveyed.
- For permanent buildings, the antenna was placed in (eccentric) “auxiliary points”, too, on the line of the front walls (on the extension), measuring each time the distances to the points of the building, using the measuring reel.
- In the case of buildings with stairs, their corners were used, together with a corner of the building (directly or as auxiliary point).
- In order to survey cadastral details within the property, we have surveyed points from some permanent elements, which were accessible, such as inspection chambers,

drinking fountains, corners of concrete fences, etc, which could be later used for surveying other details by means of intersections of distances.

In order to be able to perform comparisons, the chosen areas have been surveyed using total stations, by means of the known classical methods.

During the measurements, the following aspects required special attention:

- Pressing the button ROVE before moving the antenna into another point;
- Handling the antenna avoiding loosing the signals of the satellites in any moment;
- Placing the hands under the plane surface of the antennas during handling.

The RTK Method.

The method of real time kinematic measurements (RTK) has been used for detail cadastral surveys outside and inside Topolog commune from Tulcea County.

In these cases, too, the observation plan was designed within the office, using the same elements and respecting the same known criteria and conditions.

The following operations have been performed for accomplishing the measurements:

1. Preparing operations:

As preparing operations, we have performed the following:

- Synchronizing the clock of the receiver to the UTC time;
- Inserting the approximate coordinates of the station;
- Inserting auxiliary information: GPS day, session number, beginning and ending time, centering type (in our case, forced centering), antenna number, cable length, antenna height, the satellites specified to be monitored etc.

2. Preliminary operations:

As preliminary operations, we have performed the following:

- Horizontal setting and centering of the antenna on the pillar (maybe on trivet) and its bearing on N direction;
- Measuring the height of the antenna (in our case: direct vertical measuring, because of the forced centering);
- Connecting the antenna to the receiver, and the receiver to a power supply;
- Starting measurements by means of a switch and automatic recording;

3. Operations performed during recording:

During recording in a station, we have performed the following operations:

- Measuring meteorological data that presents interest;
- Filling in the observation sheet with data concerning the parameter of the given station;
- Changing batteries (the receiver chooses automatically the best power source).

4. Operations performed after recording:

- Switching off the receiver (stopping measurements);
- Measuring again the height of the antenna;
- Disassembling cables.

5. Downloading the data:

At the end of the daily observation session, the recorded data is downloaded from the internal memory of the GPS receiver into a computer and on disks. Data download is performed using a program included in the GPS software.

We have used 1:25000 scale maps for field recognition, in order to identify the triangulation points from the given area. In the close vicinity of the area of interest, we have identified several geodesic points.

The reference station from Topolog commune in Tulcea County was placed in an order II triangulation point, which was closest to the area where the cadastral measurements were going to be performed.

After performing initialization measurements, as described in section before, the coordinates of those points where inserted, using the micro-controller, beforehand inserting the parameters needed for trans-computing the coordinates from the WGS 84 system directly into the Stereo 70 system.

The SERCEL receivers that have been used are two frequency L1, L2, geodesic receivers, equipped with real time transmitting devices that use UHF waves, needed for the real time transmission of the differential corrections from the base station to the mobile receivers that are stationing in the detail points. We were stationing in each detail point, until the differential corrections transmitted by means of UHF waves have been stabilized, and therefore, the stationing time was of 30 seconds to 1 minute. The SERCEL receivers are equipped with software for recording X, Y coordinates in a file named RES, from where these coordinates can be accessed and processed.

1.3. Processing Kinematic Measurements

We have processed the GPS measurements taking into account the known formulas. At the end of the daily observation session, the recorded data was downloaded from the internal memory of the GPS receiver into a computer and on disks. Data download is accomplished using a program included in the GPS software.

Processing measurements was accomplished using different processing and adjustment software, such as: 3SPACK – for the data from the SERCEL receivers from Topolog, Tulcea County.

The 3Spack software (Satellite Survey Software Package) is a program that runs under Windows platforms, using windows and icons, processing only the observations from the Sercel receivers, and it can export data in RINEX format, too.

The data from inside and outside Topolog, Tulcea County, was processed using 3Spack software (Satellite Survey Software Package). In this case, the coordinates were determined directly in the Stereo 70 system, because the trans-computational parameters were inserted in advance, in order to transform directly the WGS 84 coordinates into stereo projection. The coordinates have been determined directly in the field, in real time.

The data in presented in tables, and at a close look, we can see that the precision of measurements using GPS technology is superior to that obtained using total stations, and that the precision is uniform in the case of GPS technology.

The tables present the coordinates in the Stereo 70 projection system, being determined using the classical method with the total station and using real time GPS technology (RTK), and the corresponding precisions, but the tables also present comparative data for the measurements performed outside Topolog, Tulcea County.

2. Comparative analysis between measuring methods using GPS technology and total stations technology

In order to carry on a comparative analysis, the areas mentioned above have been surveyed using total stations, too.

Outside Topolog commune from Tulcea County, the operations were performed as follows:

We have identified and surveyed the points from the characteristic details, first we have identified the fields marked by characteristic elements, such as: exploitation roads, irrigation channels, fences, etc, then we have identified and also measured the parcels included in the fields, according to the parcel plan.

Outside a locality, the fields are identified and measured first, and then the parcels that constitute the field. The area of the field should be equal to the sum of the areas of the parcels that constitute that field.

We have determined traverse points and from them, we have radiated the cadastral survey points. The number of traverse stations was 16, which was influenced by the actual conditions in the field, the lack of visibility between the stations and between the stations and the cadastral survey points.

The measured area was of approximately 900 ha and consisted of 10 fields, growing sunflower, corn, soy-bean, and so on.

The time needed for the cadastral surveys using the total station was of 4 days, working with a team of three people.

In Topolog commune, Tulcea County, the measurements were performed by a team of three people, using a Rec Elta 15 total station, two sticks with 2 Zeiss reflectors, and a Dacia 1310 car.

It should be mentioned here that the method for collecting the details for drafting the cadastral plan requires building a schema and assigning codes characteristic to the types of details.

In order to compare the time needed for survey, for each method, we have used the following relation:

T= T1+T2+T3, where

T1 – is the cumulated office time needed for drafting the survey project, approximated to ≈ 60 minutes for each method;

T3 – is the time needed in the office for processing the measured data and it is estimated at 30 minutes for GPS surveys and one day for total stations.

T2 – is the time needed for surveying the detail points, and it is approximated using the following relations:

For the GPS kinematic method:

$$T_2 = \frac{2(t_1 + t_2 + t_5)}{n} + \frac{t_{3(i)}}{m} + t_{4(i)}$$

$t_1 =$ 5 – 10 minutes – choosing the point for placing the reference station;

$t_2 =$ 10 – 15 minutes – initializing the reference station and the communication system;

$t_3 =$ 5 seconds – 1 minute – measuring the detail point;

$t_4 =$ 1 minute – processing the observations for the detail point;

$t_5 =$ 10 minutes – packing the reference station;

n = the total number of detail points;

m = the number of mobile receivers;

Thus, for the GPS method, the time is of 1.6 – 2 minutes for one detail point, and for the entire area we have: 2 minutes x number of points.

In the case of cadastral measurements outside Topolog, Tulcea County, we have: 1.6 minutes x 341 points = 545minutes / 60 ≅ 9 hours ≅ one day.

For surveys using the total station:

$$T_2 = \frac{2(t_1 + t_2 + t_5)}{n} + \frac{t_{3(i)}}{m} + t_{4(i)}$$

- performing the observations for one detail point, in which:

$t_1 =$ 10 – 30 minutes – field and point recognition;

$t_2 =$ 10 – 20 minutes – stationing in the station point, including installing the instrument;

$t_3 =$ 1 minute – aiming and measuring towards the detail point;

t_4 = 1 minute – processing the observations for the detail point;

t_5 = 10 minutes – packing the instrument and passing to another station;

n = the total number of detail points;

m = the number of reflectors;

For the case of cadastral measurements outside Topolog, Tulcea County, we have: 2 minutes x 341 points + [(t1 + t2) + 15] = 1432 minutes / 60 ≅ 24 hours ≅ 3 days.

From the aspects shown above, we can draw the following conclusions:

The value T_2 is smaller in the case of measurements using the GPS kinematic method, but this value is computed in the case of measuring the points from one station. This was done using the GPS technology, by means of the real time kinematic method (RTK), and the time needed to determine the 341 points from outside Topolog, Tulcea County, was 1 day, for a team of three people. This was possible because we have used a reference station in an order II geodesic point near Topolog, Tulcea County, from which we have performed the measurements towards the other cadastral survey points.

In the case of the measurements from Topolog commune, Tulcea County, we have measured over 900 ha from the total of near 15000 hectares that represent the area of the commune. The percentages representing the area are presented in the appendices.

The measurements performed inside the locality using GPS technology were successful, the detailed being surveyed in 65-80% of the cases, depending on the actual field conditions.

The measurements performed outside the locality in Topolog commune, Tulcea County, using GPS technology were 100% successful in what concerns the cadastral details surveyed in the actual field conditions. The cadastral details from outside the locality have been surveyed completely, because the field conditions were better than within the locality, and there were no obstacles in the way of the satellite signals.

In all three cases, the receivers used were geodesic class receivers on two wavelengths, which gives a better efficiency for cadastral surveys. Simple frequency receivers can also be used, but these have more strict limitations than those on L1, L2.

3. Conclusions

Based on the results obtained within this case study, we can establish the following conclusions and recommendations:

- The most recommended GPS methods, in what concerns precision and speed, for surveying cadastral details, are the post-processing "stop and go" kinematic method and the real time kinematic method (RTK).
- Using the network of permanent stations (which play the role of fix stations), brings great advantages, which materialize in increased surveying precision, reduced costs for labor and reduced working time in the field.
- We recommend using at least two mobile receivers in order to increase the efficiency of field works.
- In order to increase the precision of determining the surveyed point, we recommend determining two vectors from each detail point, preferably by parsing the points, with one mobile receiver, from one end of the area, and with the second mobile receiver, from the other end of the area, such that each point would be stationed twice, obtaining independent vectors and thus removing the errors that might be associated to the mobile receiver.
- We also recommend reinitializing the mobile receivers at the end of the kinematic measurements, as a precaution, for the case when the first initialization is not correct.

- Using GPS with total stations knows no restrictions, regardless of the type of the area, and the efficiency is increased both concerning precision and cost.
- The comparative analysis of using GPS and total stations in cadastral surveys recommends GPS methods, both because of precision and efficiency, with a ratio of approximately 3/1 on their part.
- Using GPS technology in cadastral surveys, with satellites from the NAVSTAR – GPS system would be greatly enhanced if we would also use the satellites of the GLONASS system or of the European GALILEO system, because the number of satellites that are visible from one station would be increased to 6-12, increasing certainty, precision and efficiency of surveys.

Table 1. Comparative analysis of precisions – Topolog commune, Tulcea County

	Determined with total stations		PRECISIONS	Determined with GPS		PRECISIONS
POINT	X(m)	Y(m)	st(m)	X(m)	Y(m)	st(m)
1	305877.769	781512.878	0.027	305877.777	781512.889	0.023
2	305872.005	781516.435	0.027	305872.025	781516.427	0.022
3	305868.086	781514.944	0.027	305868.095	781514.953	0.021
4	305877.769	781508.878	0.027	305877.755	781508.867	0.02
5	305882.398	781520.276	0.027	305882.387	781520.285	0.022
6	305886.398	781520.276	0.027	305886.372	781520.297	0.021
7	305876.634	781523.833	0.027	305876.621	781523.845	0.022
8	305876.634	781528.833	0.027	305876.641	781528.818	0.021
9	305841.266	781493.113	0.027	305841.278	781493.125	0.023
10	305842.817	781502.124	0.027	305842.802	781502.143	0.024

Table 2. Comparative analysis of coordinates – Topolog commune, Tulcea County

	Determined with total stations		Determined with GPS		Coordinate differences	
POINT	**X(m)**	**Y(m)**	**X(m)**	**Y(m)**	Δx (m)	Δy m)
1	305877.769	781512.878	305877.777	781512.889	-0.008	-0.011
2	305872.005	781516.435	305872.025	781516.427	-0.020	0.008
3	305868.086	781514.944	305868.095	781514.953	-0.009	-0.009
4	305877.769	781508.878	305877.755	781508.867	0.014	0.011
5	305882.398	781520.276	305882.387	781520.285	0.011	-0.009
6	305886.398	781520.276	305886.372	781520.297	0.026	-0.021
7	305876.634	781523.833	305876.621	781523.845	0.013	-0.012

8	305876.634	781528.833	305876.641	781528.818	-0.007	0.015
9	305841.266	781493.113	305841.278	781493.125	-0.012	-0.012
10	305842.817	781502.124	305842.802	781502.143	0.015	-0.019

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