Comparative analysis of the positioning accuracy through GNSS static and kinematic methods

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Abstract— Due to the ease of use of GNSS technologies, as well as the rapid processing of surveys, GNSS surveys find application in almost all areas of geodesy. The choice of GNSS survey technique for the realization of a geodetic service depends on the required accuracy, the time available for the completion of the project, the available equipment, etc. The purpose of this study is to compare the coordinates of points through static GNSS observations with a duration of 5 ÷ 25 min in the network with closed geometric figures, as well as kinematic observations with a duration of 5 min in the radial network depending of the baseline length and base reference stations TIR2 and/or DUR2.

Keywords — GNSS positioning, static and kinematic methods, radial and closed geometric figures network.

1. Introduction

GNSS satellite positioning systems (GPS, GLONASS, GALILEO ...), which are based on the known positions of satellites in space enable the determination of the position of points on the surface of the earth, sea or air. GNSS surveys find application in almost all areas of geodesy, due to the ease of use of GNSS equipment/receivers, as well as the rapid processing of surveys. The choice of GNSS survey technique for the realization of a geodetic service depends on the required accuracy, the time available for the completion of the project, the available equipment, etc. The main GNSS positioning methods, which are widely used around the globe, are Static (or Fast Static) and kinematic (classical or modern), which differ from [1]:

- The duration of static GNSS observations depends on the required accuracy, the apparent number of satellites, the geometry of the satellite distribution, and the length of the base line, while the duration of kinematic observations is short (usually 3 ÷ 10 sec).
- The results of static surveys/point coordinates are obtained after processing GNSS surveys in the office through special software, while the results of kinematic observations can be obtained in real time or after processing GNSS observations in the office.
- The accuracy of static settings varies at the level of 2 mm ÷ 2 cm, while the accuracy of kinematic settings varies 2 ÷ 4 cm.

2. Materials and Methods

In this study, for the static GNSS positions the radial network (Figure 1) is used, while for kinematic determinations the closed geometric figures network (Figure 2) [1].

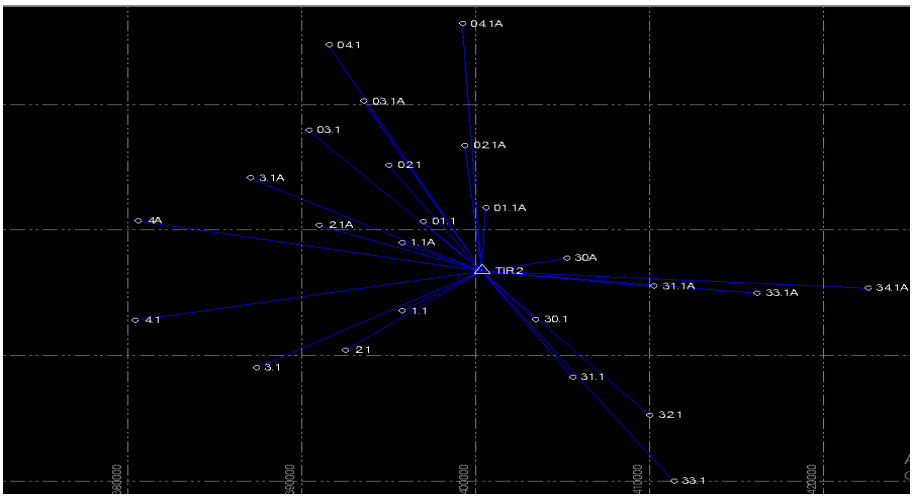

Fig. 1: Radial network [1]

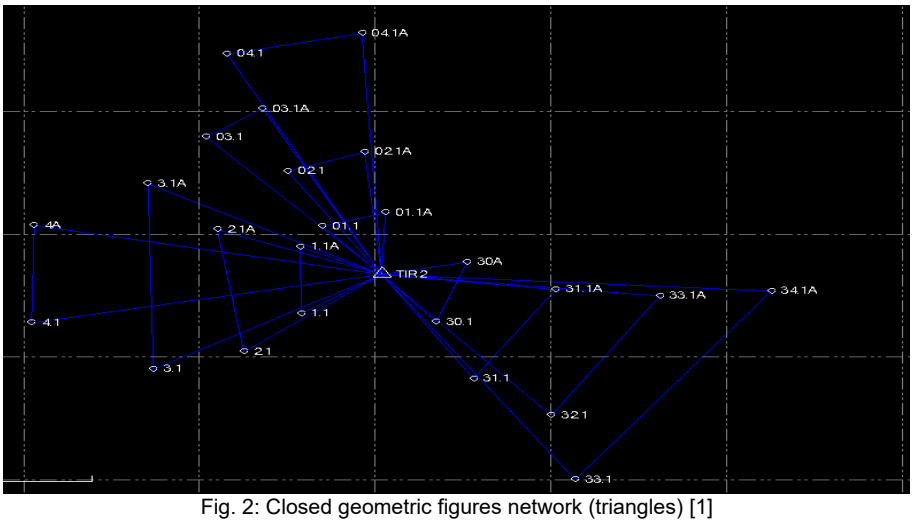

Fig. 2: Closed geometric figures network (triangles) [1]

Before going to the field to perform the GNSS surveys: (1) the technical design is prepared, (2) GNSS receivers are provided and inspected, (3) the vehicles are provided, (4) the necessary equipment for group communication is provided and (5) the working groups have been trained.

(1) In advance, on the map of scale of 1:10 000 is drawn the scheme of the network of points, which will be measured. Considering the Center of ALBPOS station in IPRO Tirana Office as a base point, four concentric circles have been built, respectively with a radius of 5 km, 10 km, 15 km and 20 km. The points are projected to be chosen at the intersections of the circles with the predetermined paths (Tirana – Durres, Tirana- Elbasan, Tirana- Lezha). After a detailed study of the scheme, the positions of the points in the orthophoto were determined, as well as the start and end time of the GNSS field observation session was planned.

Since the GNSS measurements will be performed by two working groups, at the same time and in order to form closed geometric figures, the measurements were planned to be performed in three campaigns:

- Campaign 1 (Figure 3, left), Group 1: Tirana - Durrës (secondary road parallel to the highway), Group 2: Tirana - Durrës (old road from Ndroqi).
- Campaign 2 (Figure 3, right), Group 1: Tirana - Lezha, Group 2: Tirana - 5 km Bathore, 10 km Qinam village, 15 Arrameras, 20 km Kruja.
- Campaign 3 (Figure 4): Group 1: Tirana - Vërri (from Linza), Group 2: Tirana - Elbasan (old road, from Krraba).

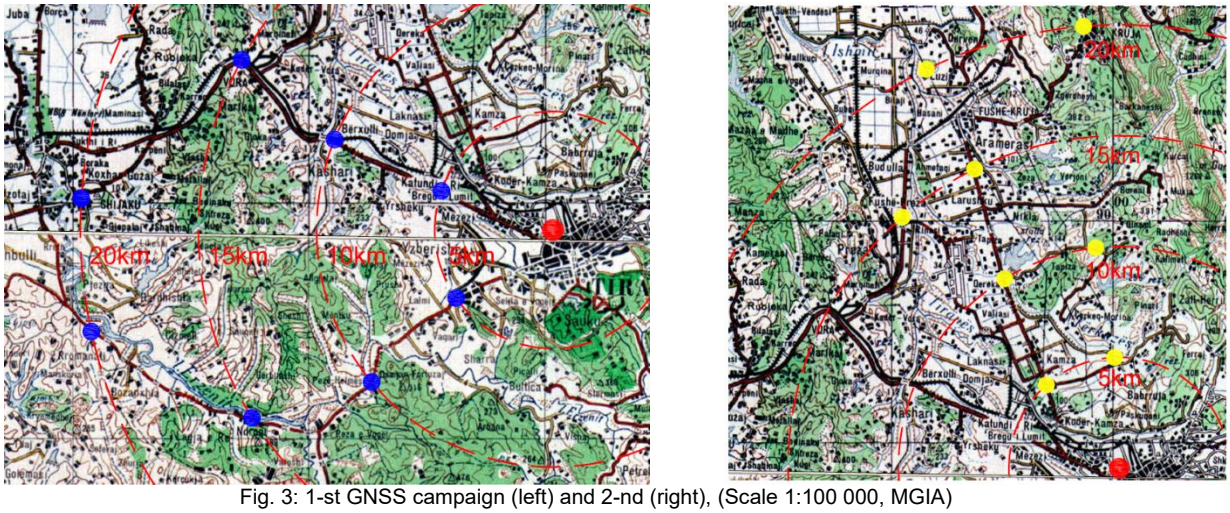

Fig. 3: 1-st GNSS campaign (left) and 2-nd (right), (Scale 1:100 000, MGIA)

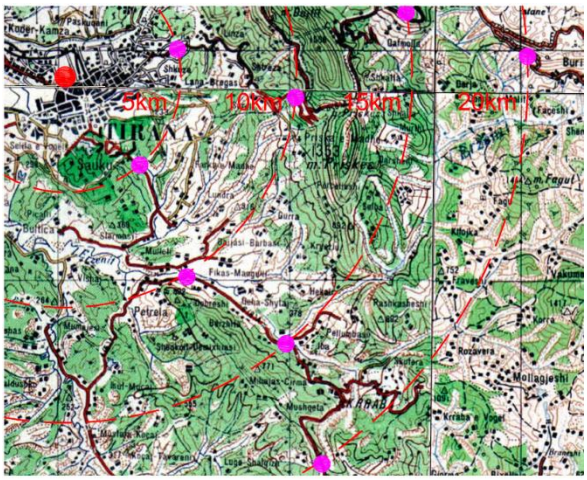

Fig. 4: 3-rd GNSS campaign (Scale 1:100 000, MGIA)

To find the predefined points in the field, the Maps.Me application was used, which was previously installed on the mobile phone.

(2) Trimble R8 Series 2 receivers are used as GNSS devices.

(3) Two vehicles were used to perform the field measurements: NISSAN MICRA and OPEL VECTRA.

(4) Mobile phones were used for communication between the two groups during the field measurement process.

(5) In order to avoid any surprise that could occur in the field, the staff has been trained (GNSS measurement skills testing sessions with different methods were performed, TSC2 configuration for receiver connection (Bluetooth) and SIM card configuration for RTK measurements).

2.1. Planning of the GNSS surveys

The GNSS observations were collected by using of Trimble R8 receiver with data collection every 5 seconds based on the ALBPOS reference stations TIR2 and/or DUR2. The duration of GNSS observations depending on the baseline length is shown in Tab. 1:

TABLE 1: THE DURATION OF GNSS OBSERVATIONS DEPENDING ON THE BASELINE AND METHOD

Method	Baseline length (km)	GNSS observation duration (min)
Static/ Fast-Static	5	5
	10	15
	15	25
	20	40
Kinematic	5	5
	10	5
	15	5
	20	5

2.2 Processing of GNSS field measurements

GNSS observations collected during the field measurement campaign were transferred from receivers to the computer (Figure 5), and the RINEX data of the reference stations TIR2 and DUR2 were downloaded from the ALBPOS.net website.

After the GNSS observations were checked in advance, the processing was performed using the TBC (Trimble Business Center) office software (Trimble Inc. PN 022543-256Q).

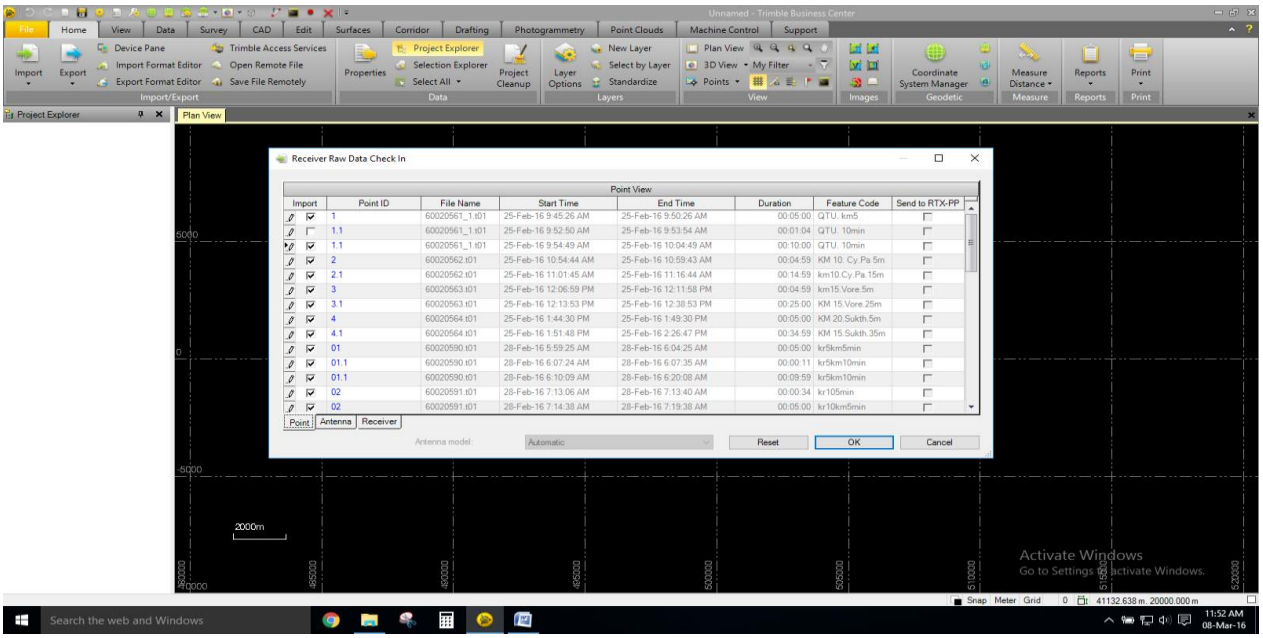

Fig. 5: Importing of the GNSS field observations to the PC

After the processing of the GNSS observations (Figure 6) based on the ALBPOS reference station TIR2 (Tirana) and the adjusting of the network (Figure 7), the coordinates of the points measured (N, E, h) with the static method are obtained on the Albanian modern reference (ETRS89, ETRF2000, GRS80, UTM, k_0 = 0.9996, λ_0 = 21º, reference, Epoka 2014.177), (Tab. 2, Tab. 3, Tab. 4).

Also, due to the control of the GNSS network, after the processing of the GNSS observations based on the ALBPOS reference station DUR2 (Durrës) and the adjusting of the network, the coordinates of the measured points were obtained on the Albanian modern reference (ETRS89, ETRF2000, GRS80, UTM, k_0 = 0.9996, λ_0 = 21º, reference, Epoch 2014.177), (Tab. 5, Tab. 6).

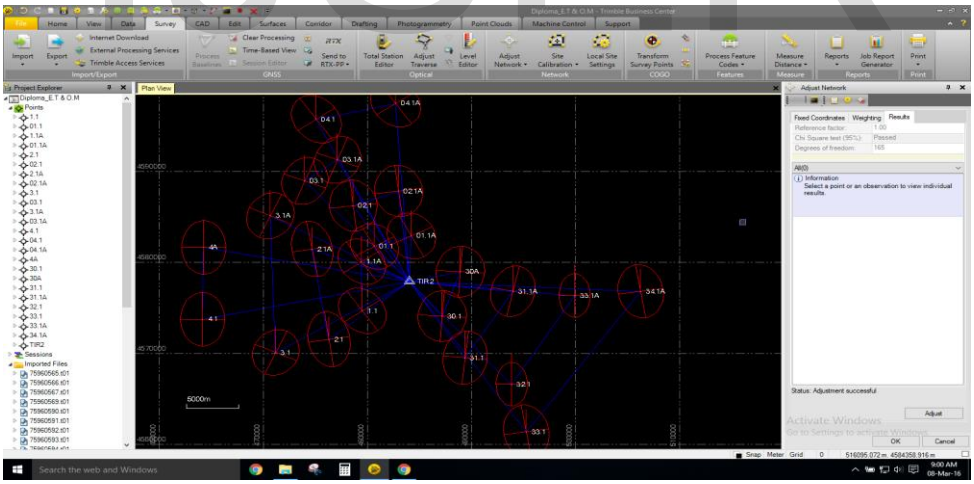

Fig. 6: Processing of GNSS observations based on the ALBPOS reference station TIR2

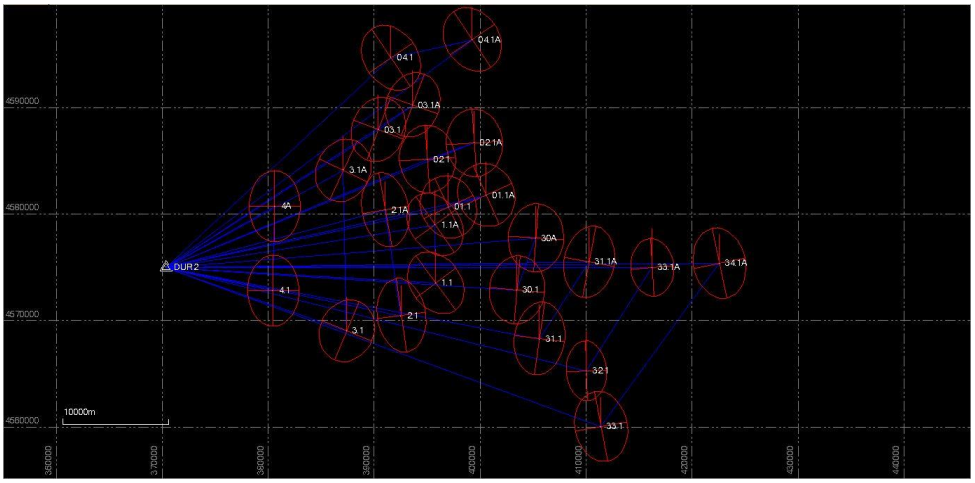

Fig. 7: The adjusting of the network based on the ALBPOS reference station TIR2

TABLE 2: COORDINATES IN REFERENCE ETRF2000, EPOKA 2014.177
(STATIC METOD – CLOSED GEOMETRIC FIGURES NETWORK - ALBPOS REFERENCE STATION TIR2)

Point	EUTM, GRS80	NUTM, GRS80	hGRS80	Location
1.1	395801.944	4573497.356	130.326	5 km Vaqarr
01.1	397033.640	4580615.464	100.652	5 km Kamëz
1.1A	395764.611	4578942.817	95.797	5 km QTU
01.1A	400604.812	4581717.125	136.197	5 km Bathore
30.1	403485.610	4572812.906	237.423	5 km Sauk
30A	405264.132	4577702.171	292.527	5 km Linzë
2.1	392541.124	4570398.976	118.332	10 km Pezë-Helmës
02.1	395033.265	4585097.629	78.738	10 km Tapizë
2.1A	391029.391	4580344.912	90.003	10 km City park
02.1A	399426.824	4586667.362	177.008	10 km Qinam
31.1	405614.949	4568215.049	202.755	10 km Mullet
31.1A	410301.647	4575463.910	623.448	10 km Surrel
3.1	387391.132	4568987.383	95.884	15 km Ndroq
03.1	390414.377	4587888.352	66.271	15 km Rinas
3.1A	387085.452	4584079.184	85.960	15 km Vorë
03.1A	393609.130	4590188.792	70.810	15 km Arramenas (Fushë Krujë)
32.1	410057.230	4565227.830	250.440	15 km Ibë e Poshtme
33.1A	416235.198	4574937.260	453.454	20 km Krrabë
4.1	380439.751	4572761.516	90.733	20 km Romanat
04.1	391590.028	4594649.126	57.053	20 km Derven (Fushë Krujë)
04.1A	399266.152	4596335.582	593.438	20 km Krujë
4A	380604.520	4580689.266	54.779	20 km Sukth
33.1	411419.696	4559996.213	794.845	15 km Derje
34.1A	422594.267	4575343.040	611.535	20 km Vërri

TABLE 3: COORDINATES IN REFERENCE ETRF2000, EPOKA 2014.177
(STATIC METOD– RADIAL NETWORK - ALBPOS REFERENCE STATION TIR2)

Point	EUTM, GRS80	NUTM, GRS80	hGRS80	Location
1.1	395801.944	4573497.356	130.326	5 km Vaqarr
01.1	397033.639	4580615.464	100.652	5 km Kamëz
1.1A	395764.611	4578942.817	95.797	5 km QTU
01.1A	400604.812	4581717.125	136.197	5 km Bathore
30.1	403485.61	4572812.906	237.424	5 km Sauk
30A	405264.132	4577702.171	292.527	5 km Linzë
2.1	392541.124	4570398.977	118.332	10 km Pezë-Helmës

02.1	395033.266	4585097.63	78.735	10 km Tapizë
2.1A	391029.392	4580344.91	90.003	10 km City park
02.1A	399426.824	4586667.362	177.009	10 km Qinam
31.1	405614.948	4568215.048	202.756	10 km Mullet
31.1A	410301.648	4575463.911	623.446	10 km Surrel
3.1	387391.132	4568987.383	95.884	15 km Ndroq
03.1	390414.376	4587888.351	66.274	15 km Rinas
3.1A	387085.452	4584079.184	85.96	15 km Vorë
03.1A	393609.131	4590188.793	70.807	15 km Arramenas (Fushë Krujë)
32.1	410057.229	4565227.83	250.439	15 km Ibë Poshtme
33.1A	416235.198	4574937.26	453.455	20 km Krrabë
4.1	380439.751	4572761.516	90.732	20 km Romanat
04.1	391590.026	4594649.127	57.054	20 km Derven (Fushë Krujë)
04.1A	399266.154	4596335.582	593.437	20 km Krujë
4A	380604.521	4580689.266	54.779	20 km Sukth
33.1	411419.696	4559996.213	794.845	15 km Derje
34.1A	422594.267	4575343.039	611.535	20 km Vërri

TABLE 4: COORDINATES IN REFERENCE ETRF2000, EPOKA 2014.177
(KINEMATIC METOD – ALBPOS REFERENCE STATION TIR2)

Point	EUTM, GRS80	NUTM, GRS80	hGRS80	Location
1.1	395801.949	4573497.352	130.338	5 km Vaqarr
01.1	397033.635	4580615.468	100.648	5 km Kamëz
1.1A	395764.609	4578942.825	95.801	5 km QTU
01.1A	400604.809	4581717.129	136.19	5 km Bathore
30.1	403485.609	4572812.899	237.43	5 km Sauk
30A	405264.135	4577702.177	292.536	5 km Linzë
2.1	-	-	-	10 km Pezë-Helmës
02.1	395033.259	4585097.623	78.727	10 km Tapizë
2.1A	391029.381	4580344.929	90	10 km City park
02.1A	399426.821	4586667.364	177.01	10 km Qinam
31.1	405614.951	4568215.054	202.774	10 km Mullet
31.1A	410301.655	4575463.9	623.482	10 km Surrel
3.1	-	-	-	15 km Ndroq
03.1	390414.371	4587888.354	66.271	15 km Rinas
3.1A	387085.455	4584079.201	85.984	15 km Vorë
03.1A	393609.128	4590188.802	70.806	15 km Arramenas (Fushë Krujë)
32.1	410057.229	4565227.83	250.451	15 km Ibë Poshtme
33.1A	416235.199	4574937.26	453.446	15 km Fshati Derje
4.1	-	-	-	20 km Romanat
04.1	391590.029	4594649.129	57.043	20 km Derven (Fushë Krujë)
04.1A	399266.16	4596335.601	593.473	20 km Krujë
4A	380604.508	4580689.263	54.796	20 km Sukth
33.1	411419.707	4559996.225	794.853	20 km Krrabë
34.1A	422594.275	4575343.052	611.518	20 km Vërri

TABLE 5: COORDINATES IN REFERENCE ETRF2000, EPOKA 2014.177
(STATIC METOD – CLOSED GEOMETRIC FIGURES NETWORK - ALBPOS REFERENCE STATION DUR2)

Point	EUTM, GRS80	NUTM, GRS80	hGRS80	Location
1.1	395801.932	4573497.357	130.324	5 km Vaqarr
01.1	397033.631	4580615.461	100.627	5 km Kamëz
1.1A	395764.599	4578942.82	95.793	5 km QTU
01.1A	400604.803	4581717.122	136.172	5 km Bathore
30.1	403485.604	4572812.906	237.395	5 km Sauk
30A	405264.128	4577702.175	292.498	5 km Linzë

2.1	392541.117	4570398.978	118.339	10 km Pezë-Helmës
02.1	395033.263	4585097.633	78.711	10 km Tapizë
2.1A	391029.382	4580344.916	90.009	10 km City park
02.1A	399426.822	4586667.366	176.983	10 km Qinam
31.1	405614.945	4568215.049	202.74	10 km Mullet
31.1A	410301.644	4575463.911	623.431	10 km Surrel
3.1	387391.123	4568987.379	95.904	15 km Ndroq
03.1	390414.371	4587888.346	66.253	15 km Rinas
3.1A	387085.444	4584079.181	85.978	15 km Vorë
03.1A	393609.125	4590188.785	70.792	15 km Arramenas (Fushë Krujë)
32.1	410057.222	4565227.829	250.428	15 km Ibë Poshtme
33.1A	416235.19	4574937.259	453.439	20 km Krrabë
4.1	380439.74	4572761.519	90.765	20 km Romanat
04.1	391590.023	4594649.131	57.042	20 km Derven (Fushë Krujë)
04.1A	399266.148	4596335.586	593.425	20 km Krujë
4A	380604.51	4580689.268	54.81	20 km Sukth
33.1	411419.694	4559996.209	794.846	15 km Derje
34.1A	422594.265	4575343.035	611.535	20 km Vërri

TABLE 6: COORDINATES IN REFERENCE ETRF2000, EPOKA 2014.177
(STATIC METOD– CLOSED GEOMETRIC FIGURES NETWORK - ALBPOS REFERENCE STATIONS TIR2 AND DUR2)

Point	E (UTM, GRS80)	N (UTM, GRS80)	H (GRS80)	Location
1.1	395801.941	4573497.355	130.325	5 km Vaqarr
01.1	397033.638	4580615.464	100.642	5 km Kamëz
1.1A	395764.608	4578942.819	95.795	5 km QTU
01.1A	400604.811	4581717.125	136.187	5 km Bathore
30.1	403485.61	4572812.905	237.414	5 km Sauk
30A	405264.134	4577702.173	292.517	5 km Linzë
2.1	392541.122	4570398.976	118.336	10 km Pezë-Helmës
02.1	395033.266	4585097.633	78.724	10 km Tapizë
2.1A	391029.388	4580344.915	90.006	10 km City park
02.1A	399426.826	4586667.366	176.996	10 km Qinam
31.1	405614.951	4568215.047	202.748	10 km Mullet
31.1A	410301.651	4575463.911	623.439	10 km Surrel
3.1	387391.128	4568987.38	95.894	15 km Ndroq
03.1	390414.375	4587888.351	66.262	15 km Rinas
3.1A	387085.448	4584079.184	85.969	15 km Vorë
03.1A	393609.129	4590188.792	70.8	15 km Arramenas (Fushë Krujë)
32.1	410057.231	4565227.827	250.434	15 km Ibë Poshtme
33.1A	416235.2	4574937.259	453.447	20 km Krrabë
4.1	380439.744	4572761.517	90.749	20 km Romanat
04.1	391590.026	4594649.133	57.048	20 km Derven (Fushë Krujë)
04.1A	399266.153	4596335.588	593.431	20 km Krujë
4A	380604.514	4580689.268	54.795	20 km Sukth
33.1	411419.7	4559996.208	794.845	15 km Derje
34.1A	422594.273	4575343.038	611.535	20 km Vërri

3. RESULTS

3.1 Comparison between the coordinates

Comparisons between coordinates of points (considering the positioning method (Static/Fast-Static or Kinematic), type of network (closed geometric figures or radial), baseline length from control ALBPOS reference station (5 km, 10 km, 15 km, 20 km)) are shown in following. Standard deviation in (N, E, h) is computed respectively:

$$\sigma(N)=SQRT([dNdN]/n),\ \sigma(E)=SQRT([dEdE]/n),\ \sigma(h)=SQRT([dhdh]/n)$$

where, n is number of points, (dN, dE, dh) are the differences between two kinds of coordinates.

Tables 7 ÷ 9 show the differences between the coordinates of all points of the network, while Tables 10 ÷ 12 show the differences for points at a distance of 5 km, Tables 13 ÷ 15 show the differences for points at a distance of 10 km, Tables 16 ÷ 18 show the differences for points at a distance of 15 km and Tables 19 ÷ 21 show the differences for points at a distance of 20 km.

TABLE 7: DIFFERENCES BETWEEN THE COORDINATES (TABLE 2 – TABLE 3; TABLE 2 – TABLE 4)

Pika	Tab. 2 – Tab. 3			Tab. 2 – Tab. 4		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
1.1	0	0	0	-0.005	0.004	-0.012
01.1	0.001	0	0	0.005	-0.004	0.004
1.1A	0	0	0	0.002	-0.008	-0.004
01.1A	0	0	0	0.003	-0.004	0.007
30.1	0	0	-0.001	0.001	0.007	-0.007
30A	0	0	0	-0.003	-0.006	-0.009
2.1	0	-0.001	0	-	-	-
02.1	-0.001	-0.001	0.003	0.006	0.006	0.011
2.1A	-0.001	0.002	0	0.01	-0.017	0.003
02.1A	0	0	-0.001	0.003	-0.002	-0.002
31.1	0.001	0.001	-0.001	-0.002	-0.005	-0.019
31.1A	-0.001	-0.001	0.002	-0.008	0.01	-0.034
3.1	0	0	0	-	-	-
03.1	0.001	0.001	-0.003	0.006	-0.002	0
3.1A	0	0	0	-0.003	-0.017	-0.024
03.1A	-0.001	-0.001	0.003	0.002	-0.01	0.004
32.1	0.001	0	0.001	0.001	0	-0.011
33.1A	0	0	-0.001	-0.001	0	0.008
4.1	0	0	0.001	-	-	-
04.1	0.002	-0.001	-0.001	-0.001	-0.003	0.01
04.1A	-0.002	0	0.001	-0.008	-0.019	-0.035
4A	-0.001	0	0	0.012	0.003	-0.017
33.1	0	0	0	-0.011	-0.012	-0.008
34.1A	0	0.001	0	-0.008	-0.012	0.017
σ(m)	8E-04	7E-04	1E-03	5.9E-03	9.0E-03	1.5E-02

TABLE 8: DIFFERENCES BETWEEN THE COORDINATES (TABLE 2 – TABLE 5; TABLE 2 – TABLE 6)

Pika	Tab. 2 – Tab. 5			Tab. 2 – Tab. 6		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
1.1	0.012	-0.001	0.002	0.003	0.001	0.001
01.1	0.009	0.003	0.025	0.002	0	0.01
1.1A	0.012	-0.003	0.004	0.003	-0.002	0.002
01.1A	0.009	0.003	0.025	0.001	0	0.01
30.1	0.006	0	0.028	0	0.001	0.009
30A	0.004	-0.004	0.029	-0.002	-0.002	0.01
2.1	0.007	-0.002	-0.007	0.002	0	-0.004
02.1	0.002	-0.004	0.027	-0.001	-0.004	0.014
2.1A	0.009	-0.004	-0.006	0.003	-0.003	-0.003
02.1A	0.002	-0.004	0.025	-0.002	-0.004	0.012
31.1	0.004	0	0.015	-0.002	0.002	0.007
31.1A	0.003	-0.001	0.017	-0.004	-0.001	0.009
3.1	0.009	0.004	-0.02	0.004	0.003	-0.01
03.1	0.006	0.006	0.018	0.002	0.001	0.009
3.1A	0.008	0.003	-0.018	0.004	0	-0.009
03.1A	0.005	0.007	0.018	0.001	0	0.01
32.1	0.008	0.001	0.012	-0.001	0.003	0.006
33.1A	0.008	0.001	0.015	-0.002	0.001	0.007
4.1	0.011	-0.003	-0.032	0.007	-0.001	-0.016

04.1	0.005	-0.005	0.011	0.002	-0.007	0.005
04.1A	0.004	-0.004	0.013	-0.001	-0.006	0.007
4A	0.01	-0.002	-0.031	0.006	-0.002	-0.016
33.1	0.002	0.004	-0.001	-0.004	0.005	0
34.1A	0.002	0.005	0	-0.006	0.002	0
σ(m)	7.3E-03	3.6E-03	1.9E-02	3.2E-03	2.9E-03	8.9E-03

TABLE 9: DIFFERENCES BETWEEN THE COORDINATES (TABLE 5 – TABLE 4; TABLE 6 – TABLE 4)

Pika	Tab. 5 – Tab. 4			Tab. 6 – Tab. 4		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
1.1	-0.017	0.005	-0.014	-0.008	0.003	-0.013
01.1	-0.004	-0.007	-0.021	0.003	-0.004	-0.006
1.1A	-0.010	-0.005	-0.008	-0.001	-0.006	-0.006
01.1A	-0.006	-0.007	-0.018	0.002	-0.004	-0.003
30.1	-0.005	0.007	-0.035	0.001	0.006	-0.016
30A	-0.007	-0.002	-0.038	-0.001	-0.004	-0.019
2.1	-	-	-	-	-	-
02.1	0.004	0.010	-0.016	0.007	0.010	-0.003
2.1A	0.001	-0.013	0.009	0.007	-0.014	0.006
02.1A	0.001	0.002	-0.027	0.005	0.002	-0.014
31.1	-0.006	-0.005	-0.034	0.000	-0.007	-0.026
31.1A	-0.011	0.011	-0.051	-0.004	0.011	-0.043
3.1	-	-	-	-	-	-
03.1	0.000	-0.008	-0.018	0.004	-0.003	-0.009
3.1A	-0.011	-0.020	-0.006	-0.007	-0.017	-0.015
03.1A	-0.003	-0.017	-0.014	0.001	-0.010	-0.006
32.1	-0.007	-0.001	-0.023	0.002	-0.003	-0.017
33.1A	-0.009	-0.001	-0.007	0.001	-0.001	0.001
4.1	-	-	-	-	-	-
04.1	-0.006	0.002	-0.001	-0.003	0.004	0.005
04.1A	-0.012	-0.015	-0.048	-0.007	-0.013	-0.042
4A	0.002	0.005	0.014	0.006	0.005	-0.001
33.1	-0.013	-0.016	-0.007	-0.007	-0.017	-0.008
34.1A	-0.010	-0.017	0.017	-0.002	-0.014	0.017
σ(m)	8.2E-03	1.0E-02	2.4E-02	4.6E-03	9.0E-03	1.7E-02

TABLE 10: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 5 KM (TABLE 2 – TABLE 4)

Pika	Tab. 2 – Tab. 4		
	dE(m)	dN (m)	dh (m)
1.1	-0.005	0.004	-0.012
01.1	0.005	-0.004	0.004
1.1A	0.002	-0.008	-0.004
01.1A	0.003	-0.004	0.007
30.1	0.001	0.007	-0.007
30A	-0.003	-0.006	-0.009
σ(m)	3.5E-03	5.7E-03	7.7E-03

TABLE 11: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 5 KM (TABLE 2 – TABLE 5; TABLE 2 – TABLE 6)

Pika	Tab. 2 – Tab. 5			Tab. 2 – Tab. 6		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
1.1	0.012	-0.001	0.002	0.003	0.001	0.001
01.1	0.009	0.003	0.025	0.002	0.000	0.010
1.1A	0.012	-0.003	0.004	0.003	-0.002	0.002

01.1A	0.009	0.003	0.025	0.001	0.000	0.010
30.1	0.006	0	0.028	0.000	0.001	0.009
30A	0.004	-0.004	0.029	-0.002	-0.002	0.010
σ(m)	9.1E-03	2.7E-03	2.2E-02	2.1E-03	1.3E-03	8.0E-03

TABLE 12: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 5 KM (TABLE 5 – TABLE 4; TABLE 6 – TABLE 4)

Pika	Tab. 5 – Tab. 4			Tab. 6 – Tab. 4		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
1.1	-0.017	0.005	-0.014	-0.008	0.003	-0.013
01.1	-0.004	-0.007	-0.021	0.003	-0.004	-0.006
1.1A	-0.010	-0.005	-0.008	-0.001	-0.006	-0.006
01.1A	-0.006	-0.007	-0.018	0.002	-0.004	-0.003
30.1	-0.005	0.007	-0.035	0.001	0.006	-0.016
30A	-0.007	-0.002	-0.038	-0.001	-0.004	-0.019
σ(m)	9.3E-03	5.8E-03	2.5E-02	3.7E-03	4.6E-03	1.2E-02

TAB. 13: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 10 KM (TABLE 2 – TABLE 4)

Pika	Tab. 2 – Tab. 4		
	dE(m)	dN (m)	dh (m)
2.1			
2.1	0.006	0.006	0.011
2.1A	0.010	-0.017	0.003
02.1A	0.003	-0.002	-0.002
31.1	-0.002	-0.005	-0.019
31.1A	-0.008	0.010	-0.034
σ(m)	6.5E-03	9.5E-03	1.8E-02

TABLE 14: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 10 KM (TABLE 2 – TABLE 5; TABLE 2 – TABLE 6)

Pika	Tab. 2 – Tab. 5			Tab. 2 – Tab. 6		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
2.1	0.007	-0.002	-0.007	0.002	0	-0.004
2.1	0.002	-0.004	0.027	-0.001	-0.004	0.014
2.1A	0.009	-0.004	-0.006	0.003	-0.003	-0.003
02.1A	0.002	-0.004	0.025	-0.002	-0.004	0.012
31.1	0.004	0	0.015	-0.002	0.002	0.007
31.1A	0.003	-0.001	0.017	-0.004	-0.001	0.009
σ(m)	5.2E-03	3.0E-03	1.8E-02	2.5E-03	2.8E-03	9.1E-03

TABLE 15: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 10 KM (TABLE 5 – TABLE 4; TABLE 6 – TABLE 4)

Pika	Tab. 5 – Tab. 4			Tab. 6 – Tab. 4		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
2.1						
2.1	0.004	0.010	-0.016	0.007	0.010	-0.003
2.1A	0.001	-0.013	0.009	0.007	-0.014	0.006
02.1A	0.001	0.002	-0.027	0.005	0.002	-0.014
31.1	-0.006	-0.005	-0.034	0.000	-0.007	-0.026
31.1A	-0.011	0.011	-0.051	-0.004	0.011	-0.043
σ(m)	5.9E-03	9.2E-03	3.1E-02	5.3E-03	9.7E-03	2.4E-02

TABLE 16: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 15 KM (TABLE 2 – TABLE 4)

Pika	Tab. 2 – Tab. 4

	dE(m)	dN (m)	dh (m)
3.1			
3.1	0.006	-0.002	0.000
3.1A	-0.003	-0.017	-0.024
03.1A	0.002	-0.010	0.004
32.1	0.001	0.000	-0.011
33.1	-0.011	-0.012	-0.008
σ(m)	5.8E-03	1.0E-02	1.2E-02

TABLE 17: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 15 KM (TABLE 2 – TABLE 5; TABLE 2 – TABLE 6)

Pika	Tab. 2 – Tab. 5			Tab. 2 – Tab. 6		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
3.1	0.009	0.004	-0.02	0.004	0.003	-0.01
3.1	0.006	0.006	0.018	0.002	0.001	0.009
3.1A	0.008	0.003	-0.018	0.004	0	-0.009
03.1A	0.005	0.007	0.018	0.001	0	0.01
32.1	0.008	0.001	0.012	-0.001	0.003	0.006
33.1	0.002	0.004	-0.001	-0.004	0.005	0
σ(m)	6.8E-03	4.6E-03	1.6E-02	3.0E-03	2.7E-03	8.1E-03

TABLE 18: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 15 KM (TABLE 5 – TABLE 4; TABLE 6 – TABLE 4)

Pika	Tab. 5 – Tab. 4			Tab. 6 – Tab. 4		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
3.1						
3.1	0.000	-0.008	-0.018	0.004	-0.003	-0.009
3.1A	-0.011	-0.020	-0.006	-0.007	-0.017	-0.015
03.1A	-0.003	-0.017	-0.014	0.001	-0.010	-0.006
32.1	-0.007	-0.001	-0.023	0.002	-0.003	-0.017
33.1	-0.013	-0.016	-0.007	-0.007	-0.017	-0.008
σ(m)	8.3E-03	1.4E-02	1.5E-02	4.9E-03	1.2E-02	1.2E-02

TABLE 19: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 20 KM (TABLE 2 – TABLE 4)

Pika	Tab. 2 – Tab. 4		
	dE(m)	dN (m)	dh (m)
33.1A	-0.001	0.000	0.008
4.1			
4.1	-0.001	-0.003	0.010
04.1A	-0.008	-0.019	-0.035
4A	0.012	0.003	-0.017
34.1A	-0.008	-0.012	0.017
σ(m)	7.4E-03	1.0E-02	2.0E-02

TABLE 20: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 20 KM (TABLE 2 – TABLE 5; TABLE 2 – TABLE 6)

Pika	Tab. 2 – Tab. 5			Tab. 2 – Tab. 6		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
33.1A	0.008	0.001	0.015	-0.002	0.001	0.007
4.1	0.011	-0.003	-0.032	0.007	-0.001	-0.016
4.1	0.005	-0.005	0.011	0.002	-0.007	0.005
04.1A	0.004	-0.004	0.013	-0.001	-0.006	0.007
4A	0.01	-0.002	-0.031	0.006	-0.002	-0.016

34.1A	0.002	0.005	0	-0.006	0.002	0
σ(m)	7.4E-03	3.7E-03	2.0E-02	4.7E-03	4.0E-03	1.0E-02

TABLE 21: DIFFERENCES BETWEEN THE COORDINATES OF POINTS AT A DISTANCE OF 20 KM (TABLE 5 – TABLE 4; TABLE 6 – TABLE 4)

Pika	Tab. 5 – Tab. 4			Tab. 6 – Tab. 4		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
33.1A	-0.009	-0.001	-0.007	0.001	-0.001	0.001
4.1						
4.1	-0.006	0.002	-0.001	-0.003	0.004	0.005
04.1A	-0.012	-0.015	-0.048	-0.007	-0.013	-0.042
4A	0.002	0.005	0.014	0.006	0.005	-0.001
34.1A	-0.010	-0.017	0.017	-0.002	-0.014	0.017
σ(m)	8.5E-03	1.0E-02	2.4E-02	4.4E-03	9.0E-03	2.0E-02

TABLE 22: DIFFERENCES BETWEEN THE COORDINATES OF POINTS DEPENDING OF BASELINE LENGTH, CHOSEN METHOD (STATIC/FAST-STATIC OR RTK), AND NUMBER OF CONTROL ALBPOS REFERENCE STATIONS

σ(m)	Tab. 2 – Tab. 4			Tab. 2 – Tab. 6			Tab. 6 – Tab. 4		
	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)	dE(m)	dN (m)	dh (m)
All points	5.9E-03	9.0E-03	1.5E-02	3.2E-03	2.9E-03	8.9E-03	4.6E-03	9.0E-03	1.7E-02
5 km	3.5E-03	5.7E-03	7.7E-03	2.1E-03	1.3E-03	8.0E-03	3.7E-03	4.6E-03	1.2E-02
10 km	6.5E-03	9.5E-03	1.8E-02	2.5E-03	2.8E-03	9.1E-03	5.3E-03	9.7E-03	2.4E-02
15 km	5.8E-03	1.0E-02	1.2E-02	3.0E-03	2.7E-03	8.1E-03	4.9E-03	1.2E-02	1.2E-02
20 km	7.4E-03	1.0E-02	2.0E-02	4.7E-03	4.0E-03	1.0E-02	4.4E-03	9.0E-03	2.0E-02

4. CONCLUSIONS

1. From the comparison of the coordinates of the points determined by the Static method in the network with closed geometric figures and in the radial network with base station TIR2 (Tab. 7), we see that σN = ± 0.0008 m, σE = ± 0.0007 m and σh = 0.001 m, which means that at a distance of up to 20 km regardless of the shape of the selected network, the changes in the coordinates of the points are almost 1 mm.

2. From the comparison of the coordinates of the points determined by the Static and RTK methods with reference station TIR2 (Tab. 7), we see that σN = ± 0.006 m, σE = ± 0.009 m and σh = ± 0.015 m, which means that at a distance of up to 20 km regardless of the method chosen (Static or RTK), the changes in the coordinates of the points are small. At points with height up to 300 m the differences vary ±1 mm ÷ ±1 cm in (N, E, h), while at points above 500 m, such as points 31.1A, Surrel and 04.1A, Kruja differences in h vary ± 3.5 cm.

3. From the comparison of the coordinates of the points determined by the Static method refered ALBPOS station TIR2 and DUR2 (Tab. 8), we see that σN = ± 0.0073 m, σE = ± 0.0036 m and σh = ± 0.019 m, which means that at a distance of up to 20 km regardless of the selected ALBPOS reference station, the changes in (N, E) are at the level of mm level, while the changes in h vary ÷ ± 2 cm.

4. From the comparison of the coordinates of the points determined by the Static method, with reference station TIR2 and with two reference stations TIR2 and DUR2 (Tab. 8), we see that σN = ± 0.0032 m, σE = ± 0.0029 m and σh = ± 0.0089 m, which means that at a distance of up to 20 km regardless of the number of selected reference stations, the changes in (N, E, h) are at the level of mm.

5. References

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