Performance of DGPS correction distribution using cellular phone

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Abstract

The GPS-GSM system may be applied in numerous branches of state economy, service sector as well as in surveying projects as an inexpensive and highly reliable system providing near real time positioning at 1m level of accuracy. DGPS corrections generated by the permanent base station could fulfill the needs of system users all over a medium size European country wherever the GSM signal is receivable.

1. Introduction

Positioning using DGPS corrections provides in near real time position with an accuracy from a few metres to a sub-metre level. Low cost, high efficiency and achievable accuracy of the technique make it attractive for a wide spectrum of users. The role of DGPS has not been lowered by removing selective availability from GPS signals in May 2000. Experiments show that single point positioning with no selective availability provides reliable positioning at the accuracy level of 10-15 m.

A permanent DGPS base station operates in Borowa Gora since April 1998. The Ashtech G-12 receiver is linked via splitter to the Ashtech Dorne Margolin choke ring antenna of BOGO permanent GPS station of EUREF network. The RTCM 104 message with DGPS corrections is transmitted via a NAVI-GSM module and a cellular phone with a modem.

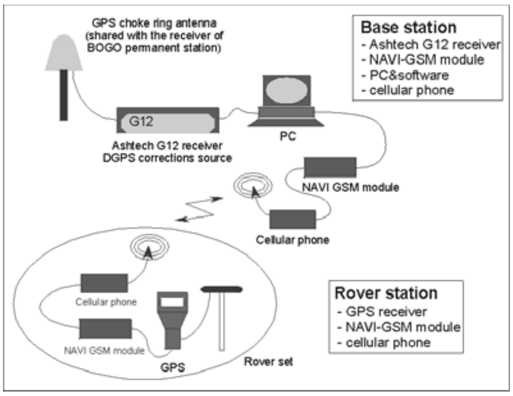

Fig. 1: Operational system of DGPS NAVI-GSM at Borowa Gora

The system is automatically controlled by a PC with NAVI-GSM software (CISAK et al., 1999). Roving GPS receiver operating in the system is equipped with a similar NAVI-GSM module and a cellular phone with a modem (Fig. 1).

Within the framework of the following project the use of GSM cellular phone network for distribution of DGPS corrections was investigated. In particular the use of BOGO permanent GPS station at Borowa Gora as a distributor of DGPS corrections was analysed. Different experiments were conducted to determine the usefulness of the system for a variety of potential users and accessibility to DGPS corrections in different regions.

2. Field Tests

The performance of DGPS with NAVI GSM has been first tested at the Institute of Geodesy and Cartography by conducting a multiple survey at a single point in 1999. The Ashtech Z12 GPS receiver equipped with DGPS mode and geodetic antenna located on the roof of the building of the Institute of Geodesy and Cartography in Warsaw was recording GPS signals at 1 s rate over 22 hours. DGPS – GSM survey was carried out by the operator in at least one hour intervals. An example of the record of single point positioning with circled DGPS – GSM data over 1 h interval is shown in Fig. 2.

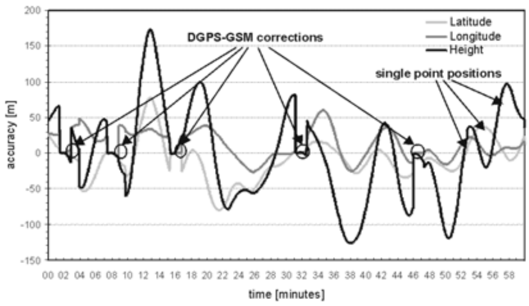

Fig. 2: Single point GPS data and DGPS NAVI- GSM data

The areas circled in Fig. 1 correspond to DGPS NAVI-GSM positioning within the sequence of single point GPS positioning. Zoomed images of three of those areas are shown in Fig. 3.

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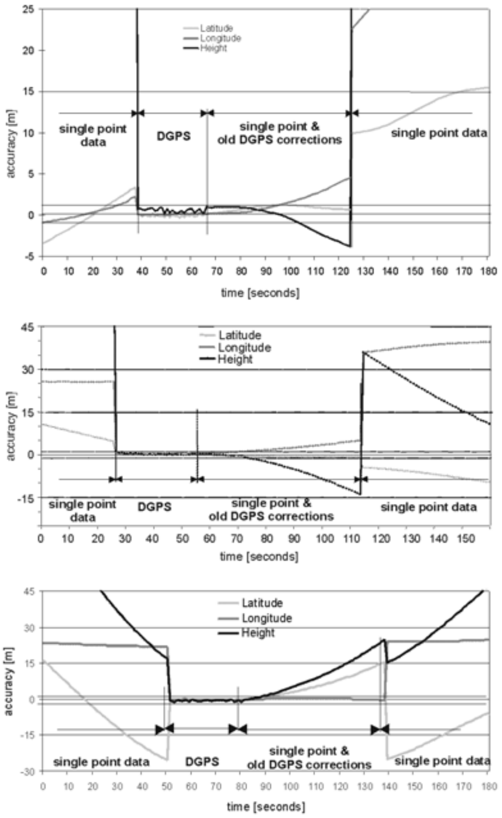

Fig. 3: DGPS positioning against single point GPS positioning

The results of DGPS-GSM survey are given in Tab. 1.

Distribution of the differences between the positions obtained from DGPS-GSM measurements and the static solution as the ground truth is shown in Fig. 4.

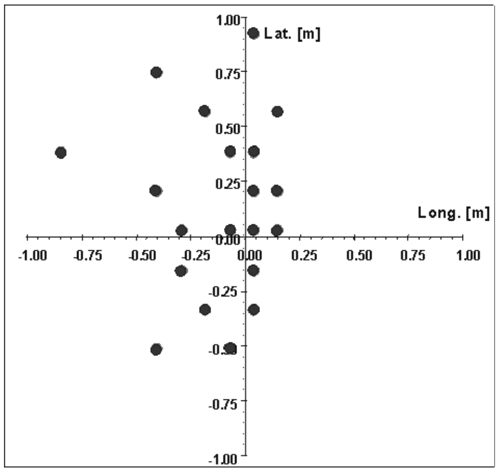

Fig. 4. Differences between the positions obtained from DGPS-GSM measurements and the ground truth

The following tests were conducted using the Warsaw DGPS Test Network (Fig. 5). Positions of 10 points of the network as well as of seven 1st order geodetic control points were determined using static GPS survey.

Tab. 1:Sequence of positions obtained from DGPS NAVI-GSM survey at a single point

Time [hh:mm]	ϕ 52 [min]	λ 21 [min]	H [m]	PDOP	No of sat.	Differences as compared with static solution [m]	[m]	[m]
17:50								
18:00	No manually recorded data. Data recorded only in the receiver memory.							
18:07								
18:15								
18:30	14.0128	00.8228	169.5	3	6	0.02	0.15	0.72
18:45	14.0125	00.8226	167.5	3	5	-0.52	-0.07	-1.23
19:05	14.0125	00.8223	168.5	2	7	-0.52	-0.40	-0.23
20:00	14.0127	00.8224	168.4	2	7	-0.16	-0.29	-0.33
20:15	14.0130	00.8227	169.2	3	6	0.38	0.04	0.47
21:03	14.0128	00.8227	168.6	1	8	0.02	0.04	-0.13
21:49	14.0129	00.8223	168.5	2	6	0.20	-0.40	-0.23
22:04	14.0129	00.8227	168.7	2	6	0.20	0.04	-0.03
22:30	14.0129	00.8227	168.6	2	7	0.20	0.04	-0.13
00:50	14.0128	00.8228	169.0	2	6	0.02	0.15	0.27
01:40	14.0128	00.8226	169.8	2	6	0.02	-0.07	1.07
02:45	14.0132	00.8223	169.6	3	5	0.74	-0.40	0.87
03:08	14.0130	00.8219	168.6	1	7	0.38	-0.84	-0.13
04:22	14.0130	00.8226	169.3	2	6	0.38	-0.07	0.57
05:05	14.0133	00.8227	168.7	1	8	0.92	0.04	-0.03
06:17	14.0126	00.8227	168.6	3	6	-0.34	0.04	-0.13
07:00	14.0126	00.8225	168.0	1	8	-0.34	-0.18	-0.73
07:58	14.0128	00.8224	169.0	1	10	0.02	-0.29	0.27
08:59	14.0131	00.8225	168.7	2	8	0.56	-0.18	-0.03
10:00	14.0127	00.8227	169.9	2	7	-0.16	0.04	1.17
11:00	14.0129	00.8228	169.9	2	7	0.20	0.15	1.17
12:00	14.0131	00.8228	169.4	1	8	0.56	0.15	0.67
13:00	14.0128	00.8227	168.4	1	8	0.02	0.04	-0.33
14:00	14.0128	00.8224	167.7	2	7	0.02	-0.29	-1.03
14:10	14.0128	00.8227	168.7	2	7	0.02	0.04	-0.03

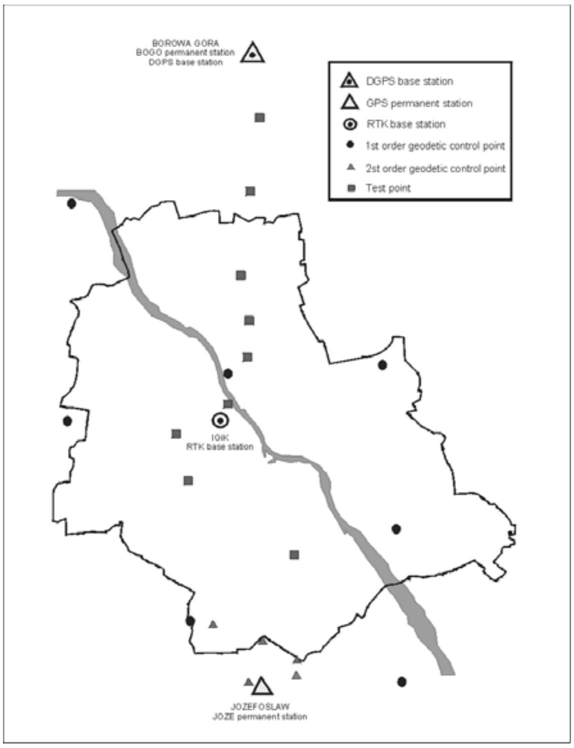

Fig. 5. Warsaw DGPS Test Network

Coordinates obtained from DGPS survey with Ashtech Reliance C/A receiver (with phase smoothing) were compared with the corresponding ones from static GPS positioning (Tab. 2). Tab. 2 shows also the results of DGPS positioning against the catalogue positions of the points of 2nd order control.

Multiple DGPS survey with Ashtech Reliance C/A receiver was conducted at one of the stations of the Operational Calibration Baseline at Warsaw. Comparison of consecutive DGPS solutions with the solution derived from static GPS survey as a ground truth shows the discrepancies in centimetres in latitude, longitude and height within the intervals: (-106,6), (-33,1), (-183,68) respectively.

The experiments indicate that the accuracy of DGPS positioning is not influenced by a length of the distance from the base station within 50 km range. Similarly to a static survey the DGPS survey is affected by obstructions (number of tracked satellites, PDOP). The quality of DGPS positioning does not depend on the strength of GSM signal. This makes the system particularly useful in urban areas.

DGPS with NAVI GSM was further tested at 29 points of POLREF network (POLREF – 0-order geodetic control established as a densification of EUREF network in Poland). Fig. 6 shows the map of POLREF stations with circled stations surveyed with DGPS and a DGPS base station.

Tab. 2. Results of survey at Warsaw DGPS Test Network

DGPS positioning vs. static GPS positioning for the points of the Test Network

Point	$Lat_{DGPS-GSM}$ [° ' "]	Lat_{stat} ["]	ΔLat [m]	$Lon_{DGPS-GSM}$ [° ' "]	Lon_{stat} ["]	ΔLon [m]	$H_{DGPS-GSM}$ [m]	H_{stat} [m]	ΔH [m]
IGIK	52 14 00.77	00.77	**0.22**	21 00 49.36	49.36	**0.04**	168.83	168.660	**0.17**
1	52 14 59.79	59.78	**0.62**	21 01 02.52	02.53	**0.14**	115.95	116.279	**-0.33**
2	52 16 40.28	40.30	**-0.75**	21 01 41.57	41.58	**0.09**	114.74	114.271	**0.47**
3	52 18 01.65	01.63	**0.67**	21 01 55.08	55.05	**-0.66**	113.93	113.674	**0.26**
4	52 19 41.18	41.19	**-0.19**	21 01 45.10	45.12	**0.35**	116.70	116.730	**-0.03**
5	52 22 43.48	43.50	**-0.77**	21 01 44.61	44.61	**-0.02**	113.85	114.111	**-0.26**
6	52 26 52.35	52.33	**0.52**	21 00 18.14	18.17	**0.45**	111.97	111.703	**0.27**
7	52 14 02.55	02.56	**-0.23**	20 59 48.27	48.25	**-0.44**	144.42	145.593	**-1.17**
8	52 12 39.79	39.79	**0.08**	20 59 45.01	45.02	**0.14**	143.05	143.359	**-0.31**
9	52 08 57.79	57.78	**0.27**	21 03 33.24	33.21	**-0.53**	135.89	135.616	**0.27**

DGPS positioning vs. static GPS positioning for the points of the 1st order geodetic control

Point	$Lat_{DGPS-GSM}$ [° ' "]	Lat_{stat} ["]	ΔLat [m]	$Lon_{DGPS-GSM}$ [° ' "]	Lon_{stat} ["]	ΔLon [m]	$H_{DGPS-GSM}$ [m]	H_{stat} [m]	ΔH [m]
4230005	52 22 27.27	27.29	**-0.79**	20 52 11.16	11.17	**0.18**	110.20	111.290	**-1.09**
4210015	52 14 20.59	20.56	**0.93**	20 52 42.46	42.45	**-0.23**	137.50	137.532	**-0.03**
3130009	52 06 56.68	56.68	**-0.16**	20 59 14.34	14.36	**0.32**	140.83	140.247	**0.58**
2240001	52 03 18.18	18.17	**0.30**	21 09 45.56	45.56	**-0.06**	143.42	144.205	**-0.79**
2220008	52 10 26.26	26.25	**0.20**	21 09 52.86	52.86	**0.03**	118.25	118.681	**-0.43**
1210006	52 16 21.34	21.37	**-1.00**	21 09 16.10	16.07	**-0.51**	122.25	123.480	**-1.23**
4110020	52 16 18.52	18.51	**0.35**	21 00 39.79	39.86	**1.26**	115.65	115.442	**0.21**

DGPS positioning vs. catalogue positions for the points of 2nd order geodetic control

Point	$Lat_{DGPS-GSM}$ [° ' "]	Lat_{cat} ["]	ΔLat [m]	$Lon_{DGPS-GSM}$ [° ' "]	Lon_{cat} ["]	ΔLon [m]	$H_{DGPS-GSM}$ [m]	H_{cat} [m]	ΔH [m]
758	52 07 17.37	17.38	**-0.20**	21 00 01.55	01.56	**0.17**	135.97	136.225	**-0.25**
762	52 06 29.19	29.19	**-0.16**	21 02 14.74	14.72	**-0.35**	134.05	133.595	**0.46**
763	52 06 23.13	23.15	**-0.50**	21 03 17.74	17.75	**0.11**	138.75	139.675	**-0.93**
769	52 05 48.58	48.58	**-0.01**	21 01 50.55	50.55	**-0.06**	140.45	141.385	**-0.94**
850	52 05 26.19	26.21	**-0.83**	21 03 14.39	14.41	**0.29**	136.60	138.135	**-1.54**

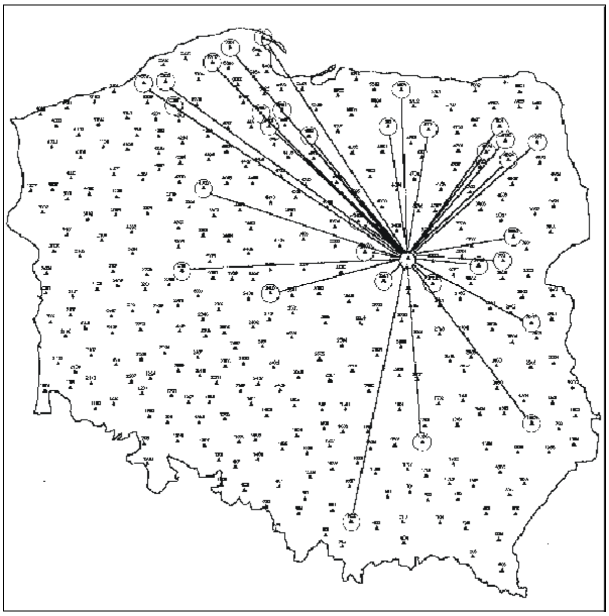

Fig. 6. Stations of POLREF network surveyed with DGPS

Differences between the coordinates obtained from DGPS positioning with Ashtech Reliance C/A receiver and the respective catalogue coordinates of POLREF network points are given in Tab. 3. The graph of the computed differences is shown in Fig. 7 in the order of growing distance from DGPS reference station at Borowa Gora.

The results of the experiment does not indicate any significant evidence of dependence of the accuracy of DGPS positioning on the distance from the base station within the range up to 400 km.

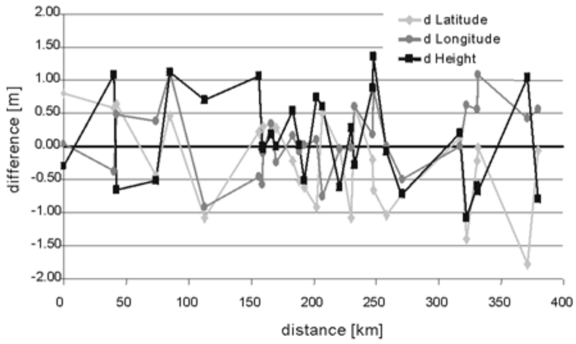

Fig. 7. DGPS determined positions vs catalogue positions of 29 POLREF network points

The usefulness of DGPS with NAVI GSM for map updating was tested in sub-urban area south of Warsaw. About 100 sites identified on the map in scale 1:10 000 including control points in the area were surveyed with DGPS using the Ashtech Reliance C/A receiver. Differences between the horizontal coordinates obtained from DGPS measurements of 26 points and the ground truth are given in Fig. 8.

Tab. 3: Comparison of DGPS positioning with coordinates of POLREF stations

Distance [km]	Point Number	Location	Δ Lat [m]	ΔLong [m]	Δ H [m]
0.2	217	BOROWA GÓRA	**0.80**	**0.04**	**-0.30**
40.0	3601	BIALUTY	**0.58**	**-0.39**	**1.07**
42.1	3704	KOBIERNE	**0.63**	**0.47**	**-0.67**
74.0	3604	JEZEWO	**-0.45**	**0.38**	**-0.52**
85.1	3802	KARLUSIN	**0.46**	**1.12**	**1.12**
112.8	3801	SADY	**-1.09**	**-0.92**	**0.70**
156.5	4701	UZRANKI	**0.22**	**-0.46**	**1.06**
158.9	4803	ELZBIECIN	**-0.08**	**-0.58**	**0.00**
159.6	302	LAMKÓWKO	**0.31**	**-0.10**	**-0.05**
166.1	2902	HORODYSZCZE	**0.35**	**0.34**	**0.18**
170.2	3408	KRWONY	**0.29**	**-0.23**	**0.00**
183.1	4802	KROSZEWO	**-0.22**	**0.17**	**0.53**
188.7	4502	OBRZYNOWO	**-0.52**	**-0.08**	**0.02**
192.5	303	MASZE	**-0.62**	**0.02**	**-0.52**
202.2	5603	ROSKAJMY	**-0.93**	**0.10**	**0.73**
207.2	2406	JASIEN	**0.50**	**-0.76**	**0.61**
221.0	1705	SZCZEKA	**-0.04**	**-0.03**	**-0.63**
230.0	4402	WYSOKA	**-1.08**	**-0.03**	**0.28**
232.9	5401	GNISZEWO	**0.60**	**0.60**	**-0.28**
247.1	1903	WIEPRZEC	**-0.19**	**0.18**	**0.87**
247.5	5408	KLESZCZEWO	**-0.66**	**0.87**	**1.36**
258.1	4306	KRACZKI	**-1.04**	**0.00**	**-0.08**
270.6	216	BOROWIEC	**-0.73**	**-0.50**	**-0.71**
317.2	301	ROZEWIE	**0.14**	**0.00**	**0.20**
322.5	602	SPYRKOWA G	**-1.40**	**0.62**	**-1.07**
330.9	5301	ROSZCZYCE	**-0.22**	**0.56**	**-0.60**
331.5	5302	LOJEWO	**-0.01**	**1.07**	**-0.69**
370.8	307	STUDNICA	**-1.79**	**0.41**	**1.05**
379.7	5204	LABUSZ	**-0.06**	**0.56**	**-0.80**

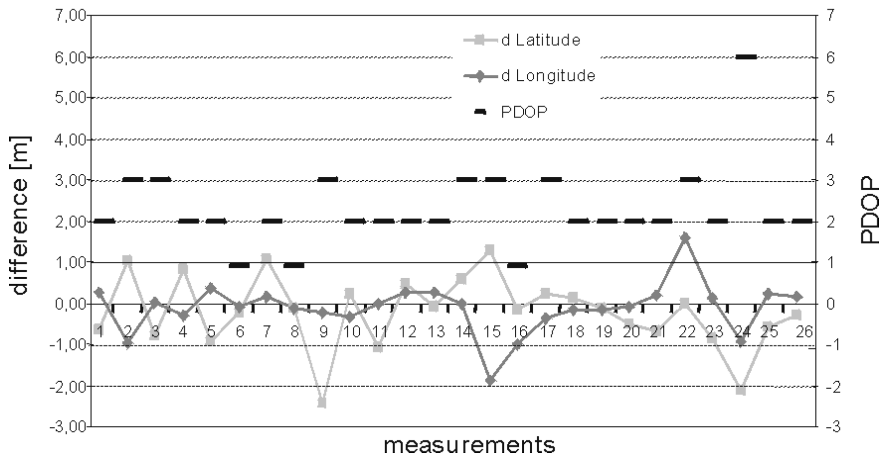

Fig. 8.Differences between DGPS measurements and the ground truth

Accuracy of height determination with DGPS NAVI-GSM using the Ashtech Reliance C/A receiver was tested in the experiment in which the coastline of the lake at the water level was surveyed (Fig. 9).

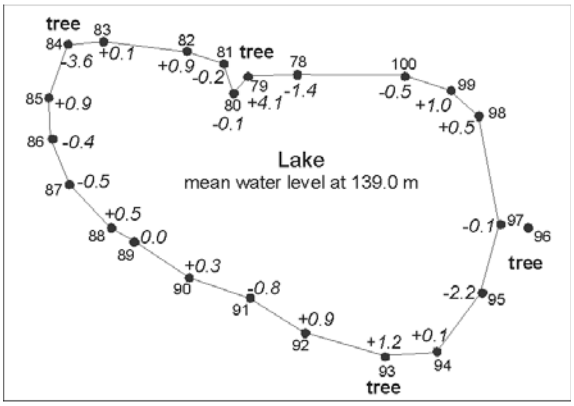

Fig. 9. Surveyed points of the coastline of the lake

Differences between heights measured with DGPS and the mean water level indicated in Fig. 9 besides point numbers are given in Fig. 10.

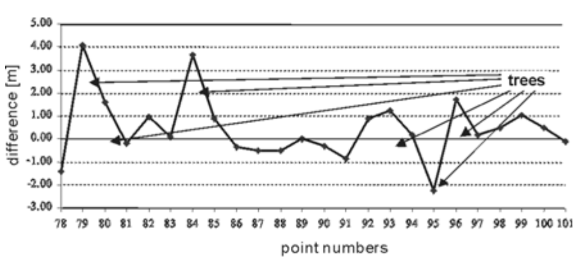

Fig. 10. Differences between DGPS measured heights and the mean water level

3. Conclusions

Surveying tests show that DGPS with NAVI GSM is an effective and reliable positioning system. Its performance in terms of accuracy substantially depends on the number of satellites and their geometrical configuration (PDOP). Obstructions and multipath effect deteriorate the results of DGPS surveying.

Low cost equipment is sufficient to provide positioning with accuracy required by most of users. The cost of positioning is proportional to the number of surveyed points. Actual cost of positioning of a single point depends on the phone rate; it is at the level of ¼ $US and it could be reduced in future.

In terms of accuracy of positioning DGPS with NAVI GSM is superior with respect to satellite DGPS systems. Positioning accuracy of DGPS with NAVI GSM at 1 m level can be achieved independently of the distance from base station in the range up to 400 km.

The access to DGPS with NAVI GSM depends on the accessibility of GSM, that has growing up tendency. Presently it corresponds to 80% of area of Poland, mainly urbanized areas.

DGPS with NAVI GSM seems to be mainly suitable for static positioning. It can be widely applied for GIS, LIS, in communal services, highway services, etc. It can also be used for some surveying tasks, e.g. map updating.

Acknowledgments

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