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Laboratory Testing of an IGTS Device Supporting GPS-RTK Systems

1. Introduction

A GPRS technology provides constant communication between the base station and mobile units in GPS RT measurements. Besides, this technology spurs the development of new navigation and survey techniques [1], as outlined in further sections.

Thanks to the small size of data to be transmitted (which is of major importance in terms of costs of GSM operators) the GPRS technique proves to be an excellent medium for transmission of GPS-RTK corrections (Fig. 1). Another benefit of GPRS

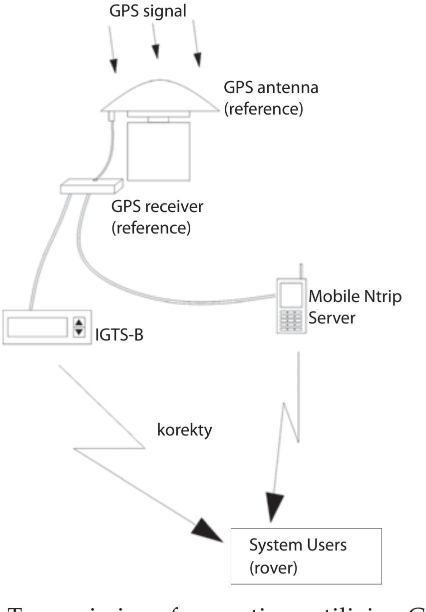

Fig. 1. Transmission of corrections utilizing GPRS

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is that RTK systems are not range-restricted, as it is often the case when modems are employed. Measurements can be taken at any point within the range of any GSM operator. In present day conditions that means nearly the whole area of our country.

One of the solutions available thanks to cellular phones and GPRS transmission involves the relay of data to a "caster" computer, utilising an IGTS-B device or applications: IGTS-B or mobile NtripServer) and then to the system users via IGTS-R or mobile Ntrip and mobile NtripPro applications [1–4]. Corrections can be now received even at large distances from the reference stations (30–40 km), with the centimetre level of accuracy.

2. IGTS/IGTS-R – specifications

IGTS-R a mobile unit of GSM/GPRS [2, 3] (Fig. 2) enables the reception of RTK or DGPS corrections from:

– base stations which transmit the corrections via the Internet;
– mobile/field base stations relaying the corrections via GSM/GPRS;
– casters Ntrip (for example: Euref IP);
– correction distribution systems (VRS, FKP).

Fig. 2. IGTS device by INS

An IGTS-R device has a lighted display and four keys. This interface enables the full configuration and control of operating parameters. The display shows the current status of the device, for example a corrections counter.

All configuration parameters are stored in the memory and no additional support is required. When the power is off, IGTS-R is able to process previously saved information and automatically compiles GPRS connections to the selected GSM operator's network. The user has to select the operating parameters and to activate the corrections transfer. Data transmission (for which the user is charged) begins at the user's request and might be interrupted any time without breaking the GPRS connection. When the device is switched off, the user is logged out of the GSM operator network and a GPRS session is over.

IGTS-R can receive differential corrections generated by distributions systems of corrections for area via the Ntrip protocol. Approximate coordinates of the control area are required in order to generate a virtual reference stations or surface correction FKP and these can be transferred by IGTS-R as a NMEA message of the GGA type. Received differential corrections are transmitted to the receiver via a serial port RS-232. The device can fully configure the serial port, so in this solution IGTS-R can interact with any GPS receiver equipped with a serial port and capable of differential corrections reception. The automatic operation mode is available too – when the power is on, the device automatically logs to the operator's network, compiles the connections with the selected server and begins to receive corrections from the selected station. In this mode of operation the user configures the device each time, and actually has to just switch it on and off.

IGTS-R has it an in-built power supply. An integrated, in-built set of batteries ensures minimum 12 hours of continuous operation. An external power source, such as the power supply of the GPS receiver, is another option. The whole device is placed inside a rugged, water-proof and shock-resistant housing 110 × 100 × 40 mm.

This module was extensively tested, which is outlined in further sections.

3. Methodology

Tests were run to explore the potential applications of an IGTS-R device (Fig. 3) and to evaluate its operational performance in various GPS functions.

The following experimental procedure was applied:

1. The test program involved several measurement cycles. To test functionality and stability of the device, tests were run in various hardware and software configurations.
2. All tests were conducted using the RTK technology. The following system configurations were considered:
   – IGTS-R directly connected to a GPS rover *via* a serial port,
   – IGTS-R connected to a radio modem, the same radio modem was connected to a GPS rover.
3. Corrections were mostly acquired from the KRAW station, AGH-UST, Kraków. In order to check the quality of positioning control, attempts were made to collect the corrections from other stations as well: ZYWI (Żywiec) and KATO (Katowice). In the case of corrections from ZYWI and KATO stations, the accuracy was ensured on the level of 20–60 cm, depending on the distance from the control station. This issue was not inquired any further.

Fig. 3. IGTS-R with a connected radio modem during the tests

The notion was confirmed that DGPS correction is possible for available GPS receiver.

Recording of position control data utilises the Ashtech Evaluate software (Fig. 4)

Tests were run on two control points with forced centring. Observations were taken in two versions: with simultaneous observations on the two points and with independent position control of these points.

Two experiments were run simultaneously:

– to determine the stability of a single point positioning;
– to find the accuracy of determining a vector on the basis of point coordinates obtained from a RTK system.

Standard measurement procedure applied in the present study is as follows:

– an rod-mounted antenna and an IGTS-R device are connected to a GPS receiver to collect the corrections;
– each measurement procedure takes one hour, divided into several (2–5) sessions;
– measurements are monitored using a terminal of the Ashtech Evaluate program and saved to a file[1] to be further processed using the UTM file Stats.

[1] Data are saved to a file with an extension log, i.e. "logfile" in which NMEA data were recorded.

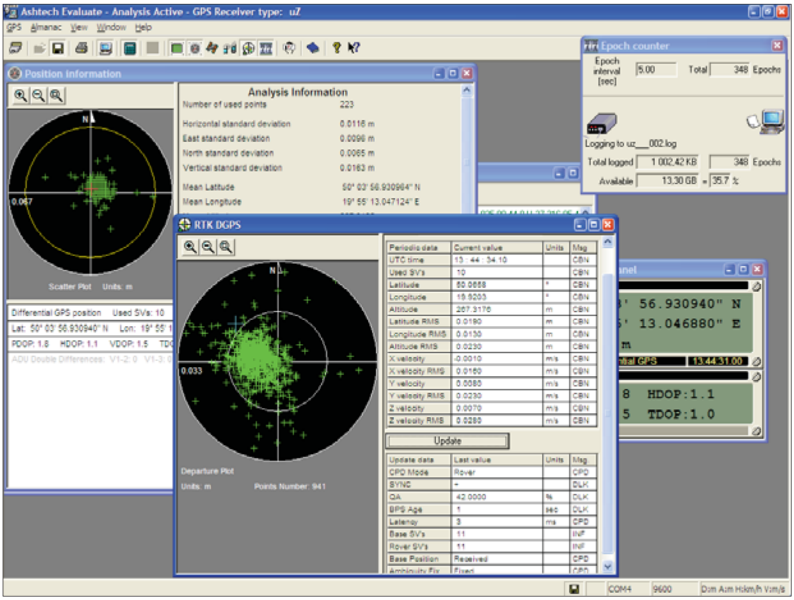

Fig. 4. Ashtech Evaluate program used in RTK GPS surveys

4. Statistical treatment of data

Laboratory test data are handled using the UTM file Stats application [2], written for the purpose of the present study (Fig. 5).

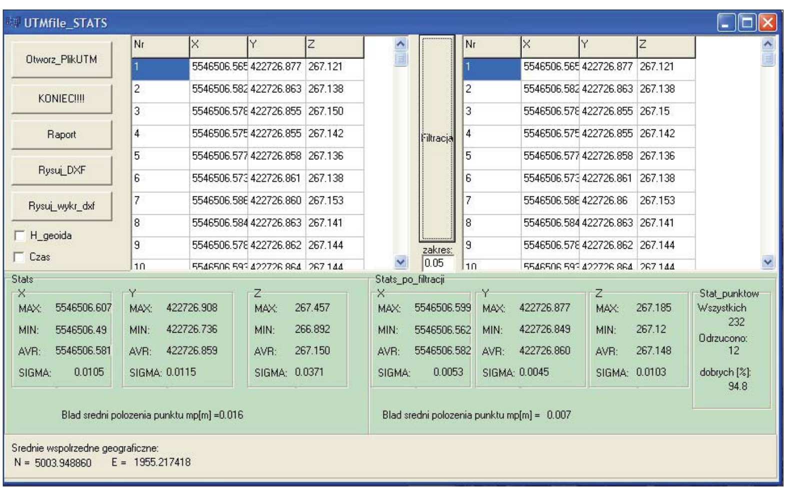

Fig. 5. Application UTMfile Stats; author: P. Chełpa

Basing on the file containing NMEA[2] codes, the application shall generate:

a) written report (text) on the test results, including:
   – compilation of coordinates from each measuring epoch;
   – statistical data: extreme values, mean values, standard deviation before and after data filtration[3];
   – mean geographical coordinates of a control point;
b) graphic file containing the plot of coordinate deviations from the mean value against PDOP [4] (Fig. 6);
c) scattering of coordinates in relation to the error of point's mean position and a circle depicting the maximal distance of a point from the mean value, before and after data filtering (Fig. 6);
d) histograms of deviations of thus obtained coordinates and ranges from the mean value. These are plots for the coordinate *X*, *Y*, *Z* and the values of distance from the mean value (Fig. 6).

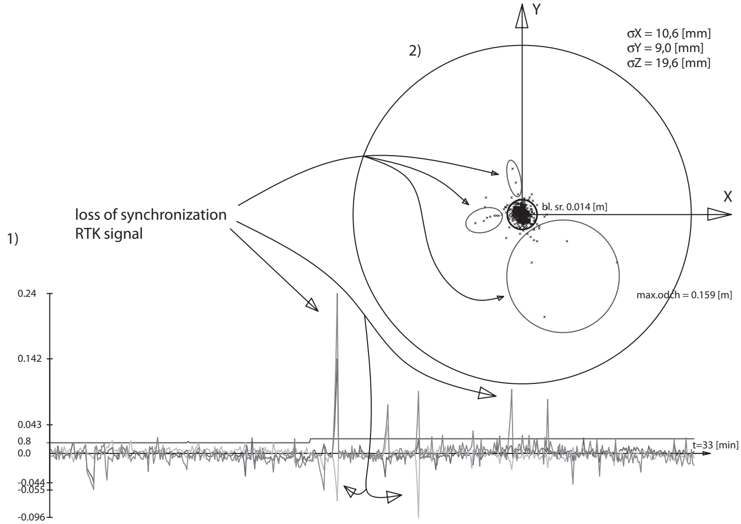

Fig. 6. Plots in UTM file Stats

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[2] NMEA – National Marine Electronics Association, a specification defining the methods of communication between the Navy's electronic devices.

[3] Filtration in the UTM file Stats involves the rejection of coordinates that differ from the mean value by a specified quantity, related to position control quality RTK→ and defined by the parameter RMS.

[4] PDOP – Position Dilution of Precision – "diluting" the accuracy in position control – the ratio of receiver position error to that involved in a satellite position, indicating when a constellation of satellites ensures the most accurate result as the PDOP value during the observation should be less than 3.

The purpose of the applied data filtering is to reject the coordinates that differ too much from the mean value, which is chiefly due to disruptions and interruptions in the corrections transfer in the course of continuous data recording. These lead to further discrepancies in statistical analysis and do not correctly emulate the measurements. Statistical handling of data before and after filtration well portrays this process (Figs 7, 8).

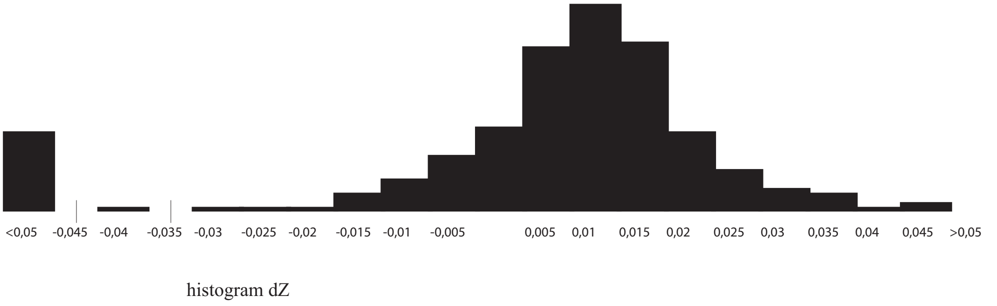

Fig. 7. Histogram for coordinate *Y* difference before data filtration (laboratory measurement no 8; 27.03.2006)

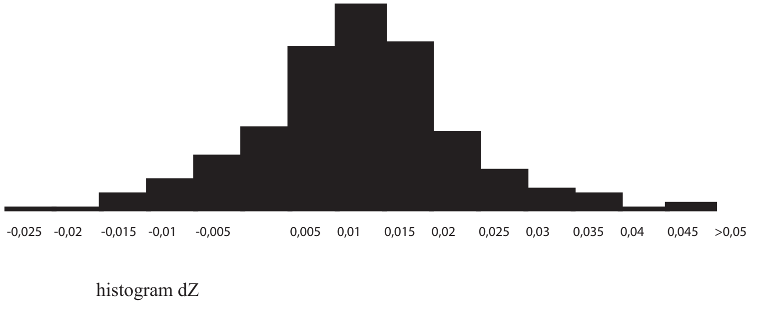

Fig. 8. Histogram for coordinate *Y* difference after data filtration (laboratory measurement no 8; 27.03.2006)

5. Discussion of results

Laboratory test data supported by statistical analysis and 'low-pass' filtering are compiled in tables 1 and 2, showing the accuracy of positioning systems, timing (Tab. 1) and compiled base length obtained from a GPS-RTK system (Tab. 2). It is readily apparent (Tab. 1) that the mean a ccuracy would remain on the level ± 1 cm →, which agrees well with the established facts (Fig. 9).

It is worthwhile to mention that prolongation of positioning time does not significantly affect the accuracy levels (Tab. 1).

6. Conclusion

Laboratory test data lead us to the following conclusions:

– Long-term covering of a single point does not affect the positioning accuracy as it does not depend on time (Tab. 1).

– Assuming the RTK system where the results (coordinates) are obtained on the current basis and the small distance from the reference station KRAW (being a major factor controlling the accuracy), it is uncertain whether the sub-centimetre level of accuracy can be ensured in conventional measurements.

– Laboratory test data agree well with the objectives and specifications of the RTK technology, the application of the device IGTS-R does not affect accuracy or quality of transferred corrections, so its use is fully justified.

– IGTS allows for enhancing the distance between the control point and reference station (in relation to radio modems).

– Compared to DARC-type solutions (RDS radio subcarrier) which require the support of public or commercial radio stations, IGTS allows a more individual approach to data transmission.

– The device can interact with any GPS receiver available on the market (*via* a serial port RS232) in system configurations.

– One has to bear in mind that application of a IGTS device reduces the number of surveyors in a team. One person is able to operate the device in RTK surveys, at the same time handling the receiver antenna and the IGTS device connected to the GPS receiver.

– Evident drawbacks of the device include periodic interruptions in RTK corrections transfer when we lose the "fix" solution, through these interruptions are rather rare.

A IGTS device manufactured by INS is an excellent solution for geodetic and surveying companies. Its benefits include easy adjustment to the customer's needs, reception and transfer of corrections from the operator's base station or *via* ASG-PL (Ntrip and VRS).

Among the state-of-the art. technologies, IGTS-R ranks as an excellent device enabling data transmission and system configurations tailored to the specific needs.

Table 1. Measuring epochs and accuracy of GPS positioning

Date of Measure	Epochs of measuring		RMS of point positioning [mm]
	all	for computing.	
S1-13.02	484	474	±9
S1-13.03_3	35	31	±11
S1-13.03_4	56	54	±7
S1-13.03_5	232	220	±7
S1-27.03_10	127	127	±7
S1-27.03_11	8	8	±12
S2-13.03_6	157	151	±7
S2-13.03_7	13	13	±4
S2-27.03_8	225	203	±11

Table 2. Distances between poles 1 and 2 obtained from laboratory measurement data

No.	Start Point 1	End Point 2	Distance [m]	Bearing [g]
1	S1-13.02	S2-13.03_6	3.512	23.0289
2	S1-13.02	S2-13.03_7	3.511	23.0587
3	S1-13.02	S2-27.03_8	3.512	22.6852
4	S1-13.03_3	S2-13.03_6	3.509	23.6511
5	S1-13.03_3	S2-13.03_7	3.508	23.6812
6	S1-13.03_3	S2-27.03_8	3.509	23.3073
7	S1-13.03_4	S2-13.03_6	3.517	23.5817
8	S1-13.03_4	S2-13.03_7	3.515	23.6117
9	S1-13.03_4	S2-27.03_8	3.516	23.2385
10	S1-13.03_5	S2-13.03_6	3.518	23.592
11	S1-13.03_5	S2-13.03_7	3.516	23.622
12	S1-13.03_5	S2-27.03_8	3.517	23.2489
13	S1-27.03_10	S2-13.03_6	3.509	23.5534
14	S1-27.03_10	S2-13.03_7	3.508	23.5835

Table 2 cd.

No.	Start Point , 1	End Point 2	Distance [m]	Bearing [g]
15	S1-27.03_10	S2-27.03_8	3.509	23.2096
16	S1-27.03_11	S2-13.03_6	3.516	23.4673
17	S1-27.03_11	S2-13.03_7	3.515	23.4973
18	S1-27.03_11	S2-27.03_8	3.515	23.1241
		Statistics:		
		Mean	3.513	
		Max	3.518	
		Min	3.508	
		Std dev.	3.6 [mm]	

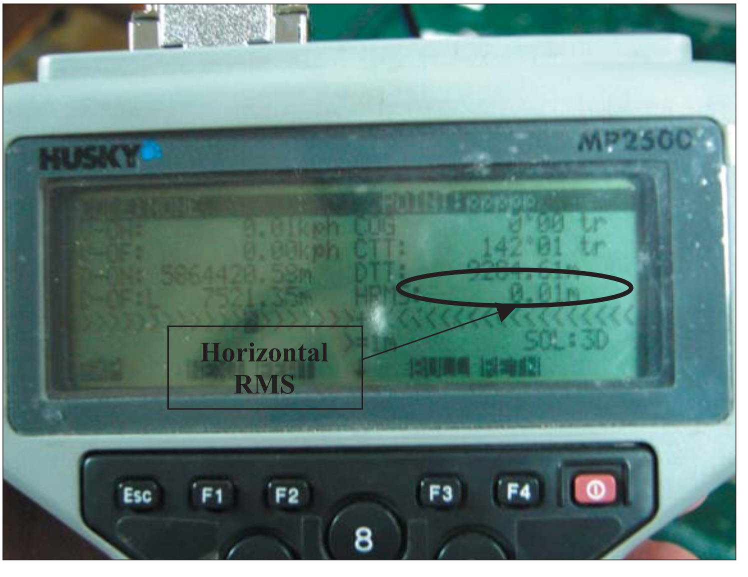

Fig. 9. Controller display during the acquisition of RTK corrections

References

[1] Lipecki T.: *The Modern Technologies of DGPS and RTK Corrections Transfer.* Geomatics and Environmental Engineering, Vol. 1, No. 3, 2007.

[2] Chełpa P.: *Wykorzystanie transmisji GPRS do przesyłania korekt RTK na przykładzie urządzenia IGTS firmy INS.* AGH, Kraków (thesis, promoter T. Lipecki).

[3] Source materials of INS Corp.

[4] Protokół Ntrip – Ntrip Protocol: http://igs.ifag.de/index_ntrip.htm.