

## Estimation of GPS Receiver Parameters with Re-reference System and Signal Simulator

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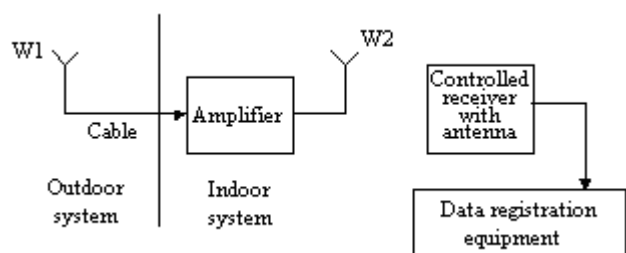
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### Introduction

The manufacturing of Satellite Systems Users' Devices is being actively advanced all over the world. It is necessary to have special testing equipment and software in order to verify that Devices' Parameters comply to the information specified by manufacturer. This article describes testing results with using Satellites Signal Re-reference System and GPS Signal Simulator STR4500. There were different brand devices used for verification. The measurements of parameters were implemented both in static and dynamic modes. Verification with use of Signal Simulator was implemented in room environments with metallized glass, as well as in the SAC3 camera, which does not reflect electromagnetic waves. Testing results had shown, that functionality of users' devices can be verified by using Re-reference system, however in order to verify dynamic parameters, it is necessary to use satellite signal simulator. The precision of verification increases, when SAC3 camera is used.

### Precision estimation of users' devices by using the Re-reference system

In order to implement testing of the satellites system users' devices in the laboratory environments it is necessary to set up Re-reference system, which would allow receiving the satellite signals in room environments. We have used the system, which was included in satellite system training package GPS-101. Its diagram is shown in Fig.1, but its outdoor and indoor locations in Fig. 2 and Fig. 3, respectively.



**Fig. 1.** Re-reference system for GPS receiver functionality estimation



**Fig. 2.** Receiving antenna of Re-reference system



**Fig. 3.** Indoor antenna of Re-reference system

To use the Re-reference system for the precision estimation of users' devices, it was necessary to determine exact coordinates of receiving antenna's location. It was achieved by using high-precision satellite receiver "Topcon" with local differential correction in the post-processing mode. The results of measurements are shown in Table 1. These results are in WGS84 BLH coordinates frame format. The error of measurements does not exceed 2 cm in flat and 6 cm for height.

**Table 1.** Exact coordinates of receiving antenna

Latitude (B)	Longitude (L)	Height, m
56°56'28.816275"	24°09'20.842871"	30.419

In order to test users' devices it was necessary to create software for data collection, processing and visualization. Users' Devices provide data in the NMEA-0183 protocol format. For data recording in the text file from the software Visual GPS was being used. The software provides the visualization of experiment's results and text file's recording with testing results.

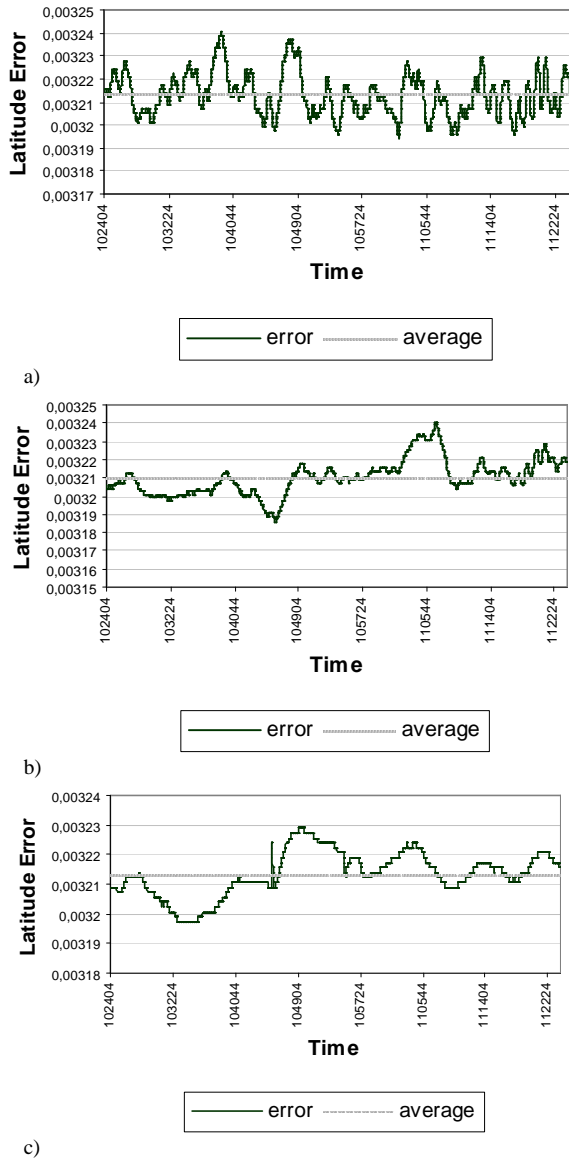


Fig. 4. Results for latitude measurements of users' devices with Re-reference system: a) GPS-101, b) eTrex, c) Holux

The initial processing of obtained frames was made by special software written in C++ language. The main purpose of given software was to simplify text file's reading and formatting, so that it can be processed with use of electronic tables and other tools. There are different tools, which can be used for graphic representation: MS Excel, MathCad and MatLab software.

There are different users' devices, which were verified in static mode using the Re-reference system: GPS-101, eTrex, Holux and others. Verification was made for all users' devices simultaneously. Measurements were one hour long and its' latitude results for all devices are shown in Fig.4. Histogram with latitude measurements' distribution for eTrex device is shown in Fig.5. Table 2

illustrates generalized results for all coordinates of Average Errors (AE) and Root Mean Squared Errors (RMSE), which were calculated by using standard formulas [3].

As we can see from generalized results, the errors' average values have the greatest contribution, and these average errors are similar for all devices. That means, this errors occur during the time of signal distribution, and thus, they depend on satellites' location and do not depend on features of the tested devices. Therefore, it is necessary to compare these results with standard device's data in order to test users' devices with the Re-reference system. This will help in determining the average errors, which depend on satellites' location and signal distribution.

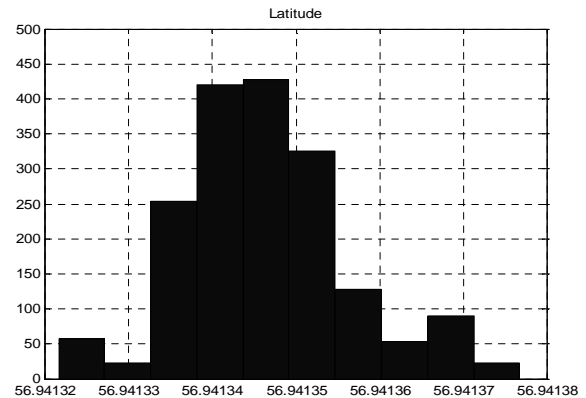


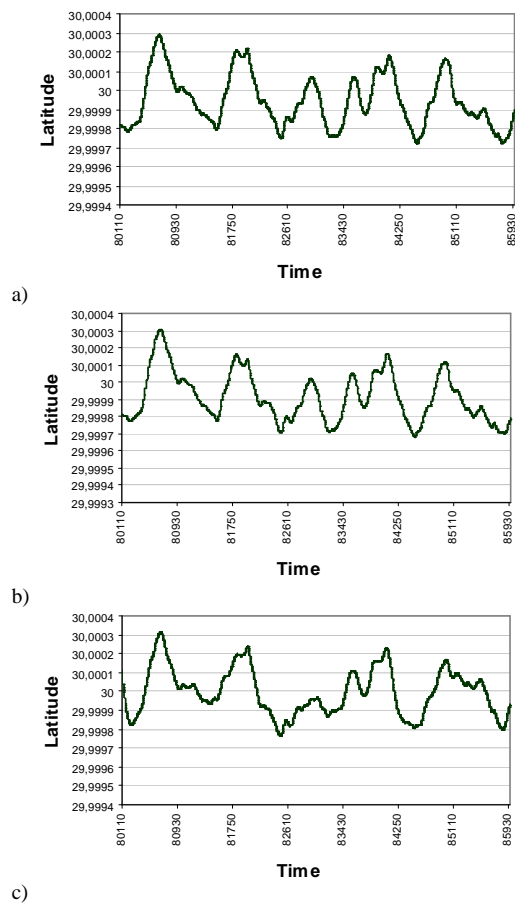
Fig. 5. Histogram of latitude measurements' distribution for eTrex user device

Table 2. Experiment results for testing of users' devices with Re-reference system

Users' devices	GPS-101	eTrex	Holux
Latitude average error, deg.	0.00321296	0.003210281	0.003213503
Longitude average error, deg.	0.002314055	0.002318604	0.002319762
Height average error, m	1.3442152	2.40617379	1.52068415
Latitude RMSE, deg.	0.00000930	0.000009742	0.000007692
Longitude RMSE, deg.	0.000011540	0.000008080	0.000014519
Height RMSE, m	1.9459467	2.353677231	1.762545651

#### Precision estimation of users' devices in static mode by using signal simulator STR4500

Users' devices, which were mentioned above, were used in this experiment. Simulated signals correspond to user's location at coordinates  $B = 30,0000^\circ$ ,  $L = 90,0000^\circ$ ,  $H = 0$  m, and simulation time matches 2000, May 17. Testing occurred in the laboratory with metallized windows, by using signal simulator STR4500, its parameters are available in [2]. First of all, there were tests of "cold start" time in these experiments, because it was necessary for the devices to renew the entire almanac information in order to move from previous measurements of 2007 year condition to simulated conditions, both in the meaning of time and satellites' location. The "cold start" time can exceed the normal conditions' start time by 5 till 10 times and it changes few minutes till tens of minutes.



**Fig. 6.** Results for latitude testing of users' devices with STR4500 in static mode: a) GPS-101, b) eTrex, c) Holux

Fig. 6 shows results of measurements, which were obtained during one hour static simulation. The same way it was done before, there are shown measurements of only one coordinate (this case, latitude). Table 3 illustrates generalized results of average errors and root mean squared errors for all coordinates.

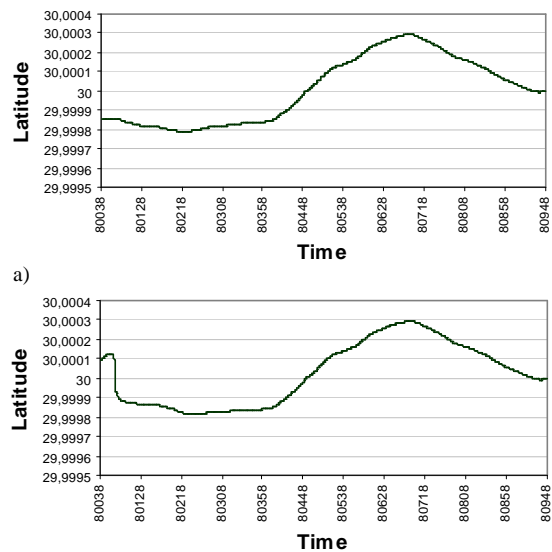
As we can see from diagrams in Fig. 6, the measurements' random errors are mutually connected (there is a cross-correlation). The values of average errors are considerably less, and that means there are no distribution effects in this case, so all errors are dependent on the tested devices only.

**Table 3.** Experiment results for testing of users' devices with signal simulator in static mode

Users' devices	GPS-101	eTrex	Holux
Latitude average error, deg.	-0.000054793	-0.000085901	-0.000002986
Longitude average error, deg.	-0.000029951	-0.000030842	-0.000036873
Height average error, m	4.3715340909	-4.272954546	11.197045455
Latitude RMSE, deg.	0.000138085	0.000142971	0.00012507
Longitude RMSE, deg.	0.00013387	0.00013881	0.00013646
Height RMSE, m	37.34909119	31.6865593	33.04554719

### Precision estimation of users' devices by using signal simulator STR4500 in static mode in the SAC3

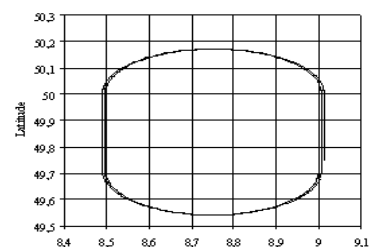
To compare measurements in the room with metallized windows and measurements in reflectionless camera SAC3, there were made measurements in both places with equal simulation conditions. In both cases, measurements were correlated at the great extent (Fig.7). Therefore, we can see the possibility to make the precision estimation of users' devices in laboratory with metallized windows. If there is necessity to determine the sensitivity of receiver, it is advised to make measurements in reflectionless camera, since in laboratory environments the intensity of signal is being amplified because of the reflections.



**Fig. 7:** Results for latitude testing with GPS-101 in: a) laboratory, b) SAC3

### Precision estimation of user's devices by using signal simulator STR4500 in dynamic mode

GPS satellite system signals of simulator STR4500 were used for simulation in dynamic mode, when users' devices move along its rout with variable speed (Fig.8). The height changes in the mobile object scenario and height measurements' errors are shown in Fig.9. As we can see, height changes four times for 100 m during scenario. The changes of single coordinate (latitude in this case) in scenario and measurements' errors for latitude are shown in Fig.10. The errors' plots in (Fig.9 b) and (Fig.10 b) show, that all tested users' devices: GPS-101, eTrex, Holux have dynamic errors. These errors are proportional to the acceleration and that proves there is one integrator used in the tracking system of tested users' devices.



**Fig. 8.** Mobile object route scenario

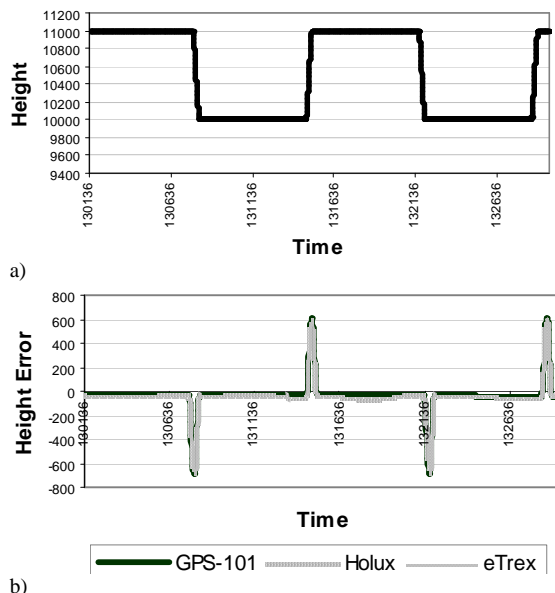


Fig. 9. Mobile object height: a) scenario, b) measurements' errors

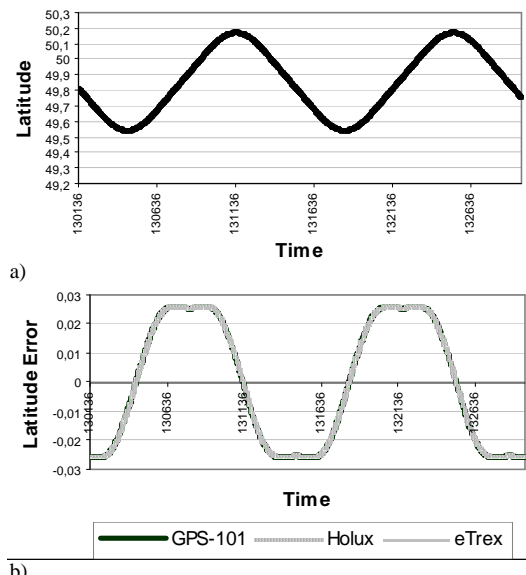


Fig. 10. Mobile object latitude: a) scenario b) measurements' errors

A. Kluga, J. Kluga, V. Semjonova, E. Grabs. Estimation of GPS Receiver Parameters with Re-reference System and Signal Simulator // *Electronics and Electrical Engineering*. – Kaunas: Technologija, 2008. – No. 5(85). – P. 69–72.

Results of satellite system users' devices testing using the Re-reference system and signal simulator CTR4500 are presented. Testing was made in the laboratory with metallized windows and in reflectionless camera SAC3. Testing results have shown the possibility to use Re-reference system with receiver in static mode for precision estimation, and to define dynamic errors in laboratory with metallized windows using the satellites system signal simulator. Ill. 10, bibl. 3 (in English, summaries in English, Russian and Lithuanian).

A. Клуга, Я. Клуга, В. Семенова, Э. Граб. Определение параметров GPS приемников с использованием Re-reference системы и имитатора сигналов // *Электроника и электротехника*. – Каунас: Технология, 2008. – № 5(85). – С. 69–72.

Рассмотрены результаты тестирования аппаратуры потребителя спутниковой навигационной системы с помощью системы создания вторичного поля (Re-reference) и с помощью имитатора сигналов CTR4500. Тестирование проводилось в лаборатории с металлизированными окнами и в безэховой камере SAC3. Результаты тестирования показали возможность использования для оценки точности Re-reference систему с контрольным приемником в статическом режиме, а также определить динамические погрешности в лаборатории с металлизированными окнами применяя имитатор сигналов спутниковой системы. Ил. 10, библи. 3 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Kluga, J. Kluga, V. Semjonova, E. Grabs. GPS imtuvo parametru analizė naudojant antrinį lauką sukuriančią sistemą ir signalo imitatorių // *Elektronika ir elektrotechnika*. – Kaunas: Technologija, 2008. – Nr. 5(85). – P. 69–72.

Pateikti palydovinės sistemos vartotojo įrangos testavimo rezultatai, gauti naudojant antrinį lauką sukuriančią sistemą (angl. Re-reference) ir signalo imitatorių CTR4500. Eksperimentai atlikti laboratorijoje su metalizuotais langais ir neatspindinčiaja kamera SAC3. Rezultatai rodo, jog tokią sistemą statine veika galima naudoti tikslumui įvertinti ir dinaminėms paklaidoms nustatyti laboratorinėmis sąlygomis. Il. 10, bibl. 3 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).

## Conclusion

This article reveals results of experiments for errors of satellite systems users' devices, which were determined by using the Re-reference system and signal simulator STR4500. Testing was made in laboratory with metallized windows, as well as in special reflectionless camera SAC3. The results have shown the possibility to test satellites' devices in laboratory environments with metallized windows. Furthermore, the obtained results showed the possibility to test users' devices by using the Re-reference system and standard device. There are interesting results, which were obtained in the dynamic mode. They show significant dynamic errors for widely used common users' devices.

## References

1. Hay C. Standardized GPS Simulation Scenarios for SPS Receiver Testing // Position, Location, And Navigation Symposium. – 2006. – IEEE/ION, April 25-27, 2006. – P. 1080–1085.
2. Kluga A., Kulikovs M., Semjonova V., Zelenkovs A. GPS user devices parameter control methods // RTU 48 International scientific conference reports. – Riga 2007 October 12, section "Telecommunication and electronic".
3. John R. Taylor. An Introduction to Error Analysis. – Mill Valley, California: University Science Books. 1982.

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