Scientific Proceedings of RTU. Series 7. Telecommunications and Electronics, 2007 vol.7

GPS user devices parameter control methods

A.Kluga[1], M.Kulikovs[2], V.Semjonova[3], A Zelenkovs[4]
[1]Department of Transport electronics and telematics, Riga Technical University,
Lomonosova iela 1, V korpuss, LV-1019, Riga, LATVIA,E-mail: ansis.kluga@rtu.lv
[2]Department of Transport electronics and telematics, Riga Technical University,
Lomonosova iela 1, V korpuss LV-1019, Riga, LATVIA, E-Mail: mike@dimir.lv
[3]Department of Transport electronics and telematics, Riga Technical University,
Lomonosova iela 1, V korpuss LV-1019, Riga, LATVIA, E-Mail: veronika_semjonova@inbox.lv
[4]Department of Transport electronics and telematics, Riga Technical University,
Lomonosova iela 1, V korpuss LV-1019, Riga, LATVIA, E-Mail: Alberts.Zelenkovs@rtu.lv

Wide assortment of GPS user devices is manufactured nowadays. How to verify that parameter of the real device corresponds to parameters that manufacture shows? How to verify that parameters have not been changed during the operation time? The last one is very important for aviation GPS systems, which must be verified before the flight, because the values of parameter change between repair works. This work analyses GPS user devices parameters control methods.

Keywords: Global Positioning System, functionality control, parameter control, receiver test.

I. INTRODUCTION

Signal of the GPS satellites can be received in the static and in the dynamic mode. The static mode in general is used for mapping. The dynamic mode can be used for moving object navigation. Wide GPS are used for route control of the vehicles (where maximal speed is 150 – 200km/h). At the same time it can be used for high-speed transport systems, for instance aircraft, where the speed can vary from 200 till 3000 km/h.

GPS system control has two steps: first is functionality control and second is parameter control. Functionality control includes control of satellite's signal receiving, processing of the information and indication in all modes (mapping, rout planning and other).

All methods of GPS receiver parameters control can be divided into two groups: first is method, which imitates constant user place and satellite situation or signals. Second group is systems, which allow imitated satellite signals in all positions of the world. These systems can be also used in aviation training systems. Systems' structures and control algorithms are described in this work.

II. GPS receiver's functionality control

Functionality control can be released in place where satellite signals are received, but we recommend to use re-reference system (Fig.1) for this purposes. Outdoor antenna W1 is put on the top of the building in Lomonosova str., 1, bloc V, Riga . Fig.2), where all satellites are visible in azimuth 0-360°. Cable connects outdoor antenna with indoor system, which includes signal transmitting antenna W2 and signal amplifier. Amplifier compensates signal loses in the cable. Receiver functionality control is possible in the room, where transmitting antenna is placed. If necessary, results of the control can be registered using computer based registration system. A receiver is connected with registration computer based on protocol NMEA 0183 using COM port [1]. Estimation of GPS receiver's functionality control with re-reference system shows, that this method is very good if repeated results of the control are not necessary, because the position of visible satellites is different.

We used re-reference system manufacture by GPS NETWORKING INC for functionality control. System consists of the outdoor antenna L1GPSA-N (Fig.2), NRRKAMP amplifier and indoor transmitting antenna L1 RRKPA-S (Fig.3). Antennas were connected with 30 m long low loss cable. Reference signal of visible satellites was strong in all points of room (64 m^2) and can be received also outside the room. Basing on the Fig. 4 we can conclude, that the outdoor antenna has good position for receiving signals from visible satellites (Fig.4).

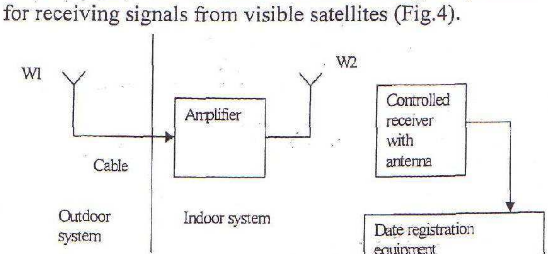

Fig. 1. Re-reference system for GPS receiver functionality control

Within the framework, described in the paper, practical experiments were made. The detection of signal by two handheld GPS receivers: GARMIN GPS 72 and GARMIN eTrex were implemented. The experiments were executed in the room with the screened windows, where GPS receiver's antenna system was set. The results of GPS accuracy (in the meters) are: 4,7 m - GARMIN GPS 72 and 6,9 m - GARMIN eTrex. The middle accuracy of the received coordinates of the position in twenty points of the room does not exceed acceptable GPS accuracy, which is set by GARMIN producer (GPS accuracy for determining position is less than 15 m for GARMIN GPS 72 and GARMIN eTrex).

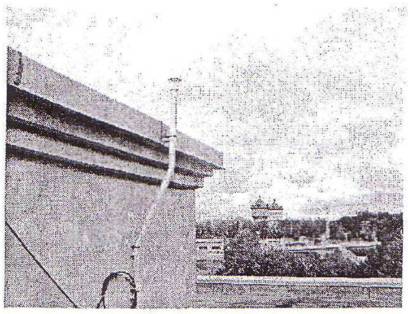

Fig. 2. Receiver antenna of re-reference system

Re-reference system can be used to determine some parameters of GPS receivers also. For example, precision of the position determination in static mode can be implemented. For this purpose the position of antenna W1 can be determined with middle square error (MSE) (σ), that is less than:

$$\sigma \leq 0{,}4\, \sigma_e \,, \qquad (1)$$

where σ_e is MSE of testing device. The equation (1) can be correct for all coordinates (x, y, z) or longitude, latitude and height. The determination of the position of the W1 antenna is implemented with geodesic equipment or very high accuracy geodesic GPS receiver with phase measurement and local area augmentation system working in post processing mode.

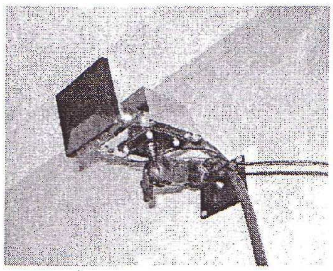

Fig. 3. Indoor antenna of re-reference system

Errors of position determination for testing GPS receiver also depend on satellite disposition and can vary in time. If testing time is more than one rotation cycle of satellites (for GPS system 12 hours), then middle mean error (MME) and middle square error (MSE) of testing GPS receiver can be determined correctly.

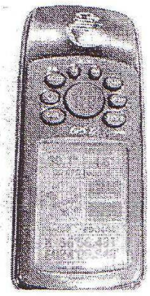

Fig. 4. Visible satellites and receiver signals

III. GPS receiver parameter control in static mode with signal simulator

When repeatable results of control are necessary, satellite signal simulator is used. Simulator provides generation of signal delays for some constant position of satellites and a user position, which allows to estimate receiver place determination precision. Simulator also provides verification of receiver sensitivity, changing RF signal power level. For determination of simulated signal level changing step, expression (1) can be used. Level step 1 dB is widely used, for example GPS-101-2 simulator for aviation devise provides adjustable RF output level from -85 to -145 dBm in 1 dB steps [2].

The GPS-101-2 has the following functional capabilities:

- Generates GPS signals on the L1 channel (1575.42 MHz) frequency.
- Provides adjustable RF output level from -85 to -145 dBm in 1 dB steps (to verify system and/or receiver sensitivity).
- Offsets Doppler frequency as selected (no shift, -4 or +4 kHz).
- Simulates one of 32 global positioning satellites or one of five ground stations by transmission the selected phase modulated C/A code (Gold Code) signal identifying the particular satellite or ground station.
- Provides selectable preset 50 Hz NAV data test patterns.
- Allows uploading and downloading of almanac data.
- Provides adjustable date and time. (The GPS-101-2 has the current date and time [UTC] loaded initially at the factory).
- Operates on battery power for approximately six hours.

Static signal simulator can be connected with estimated receiver using a cable, but most popular is the way, when antennas of transmitting and receiving units (UUT) are used. (Fig.5). The control of receiver's sensitivity can be implemented in the best way in the room with screened windows. In this situation real navigation satellite signals won't be received.

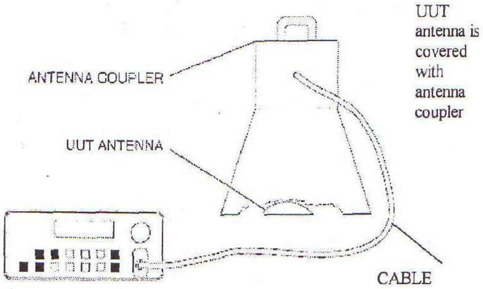

Fig. 5. GPS receiver functionality control with static signal simulator and antenna coupler

IV. GPS receiver parameter control in dynamic mode

In the dynamic mode the GPS satellite signal generator with computer management should be used. Control system provides following estimation modes:

Static control of receiver parameters (place determination precision, sensitivity);

Dynamic control parameters, when the velocity of a vehicle changes;

Different scenarios can be used for transport device trajectory imitation;

All experiments of control can be repeated with same satellite situation;

Results of control can be saved.

The structure of the system for dynamic GPS receiver control system with transmitting antenna is shown in (Fig.6). When a controlled receiver doesn't have an antenna, the GPS signal simulator is connected with receiver using a cable.

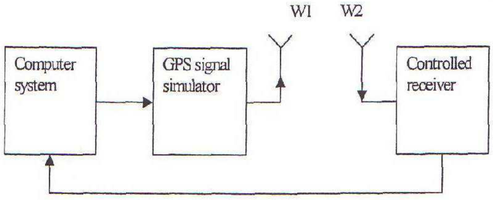

Fig. 6. GPS receiver parameters dynamic control system

Very important part of GPS receiver parameters control is estimation of scenarios. It can be typical scenario including static and dynamic motion parts and special scenario for estimation of parameters in critical modes of work. Same of scenario are described in the work [4].

Some scenarios for GPS receivers control in static and dynamic mode are suggested in the papers. First the measurement errors in static mode for many positions on the world of receiver location can be estimated. We offered the method how to determinate location of the receiver: it is necessary to take random numbers of latitude between (-90°) and (+90°), choose random numbers of longitude between (-180°) and (+180°) and pick-up a random numbers of the height between 0 to 10 km. More than 30 experiments ($n \geq 30$) should be done. Precision of every coordinate can be estimated by MME (M_x) and MSE (σ_x).

It is very important to find error of Doppler frequency shifts or velocity measurements in user device in the dynamic mode. For this purpose the movement with constant velocity can be modelled. We offer the movement with constant velocity from one of points where static errors were determinate. Velocity value can be taken as a random number in range of $-V_{max}$ till $+V_{max}$ for all direction of coordinates (φ, λ and H). V_{max} is maximum value of velocity to verify GPS receiver. Velocity measurement errors of GPS receiver also can be estimated by MME (M_v) and MSE (σ_v) values.

The parameters of receiver loop distance and velocity measurement devices estimate modelling mode with constant or changing acceleration. For this purpose we offer three scenarios. The first scenario is like velocity error measurement. From the one of point where static errors were determined receivers movement is modelled with constant acceleration. Accelerations value can be taken as a random number in range of $-a_{max}$ till $+a_{max}$ for all direction of coordinates (φ, λ and H). Acceleration measurement errors of GPS receiver also can be estimated by MME (M_a) and MSE (σ_a) values.

The second scenario is suitable for dynamic parameter determination of loop measurement devices where receiver moves with constant velocity and then modelling break of receiving satellite signals, how it is show in Fig.7. a) from time t_1 till time t_2. This scenario permits to estimate velocity determination error and use determined value of velocity to coordinate location in case of satellite signal absence. In practice this case takes place when transport move throw tunnels.

Last scenario, which we offer, is movement with short time acceleration. In practice this GPS receiver's working mode is in action when aircraft changes course, when vehicle begins to move and so on. GPS receiver control with this scenario gives the information about navigation data processing algorithms used in receiver:

The Kalman filter,

The adaptive filter.

If the complex information processing is used in GPS receiver, then special imitators can be used. They imitate autonomous systems (inertial navigation, odometer) output or input signals.

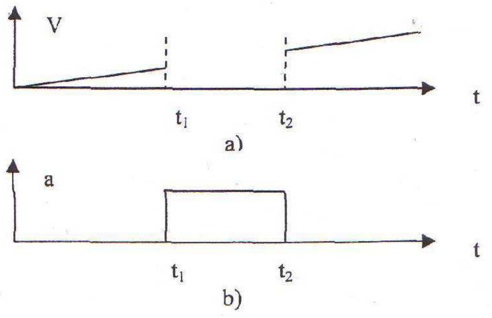

Fig. 7. GPS receiver parameters dynamic control scenario: a) with satellite signal break, b) with short time acceleration modelling

V. GPS receiver's special parameter control

Modern GPS receivers are equipped with special algorithms to decrease or compensate multipath signal receiving, ionospheric and tropospheric signal delays and other special errors of GPS system. To estimate GPS receivers signal processing algorithms, signal modelling can include special system errors generation. For estimation of the ability to compensate these special errors by receivers, we offer imitate these errors in static mode after estimation of receivers precision in this mode.

Multipath, ionospheric and tropospheric errors values can be calculated using formulas, which are shown in [5].

For the same types of GPS receivers, for example aviation, it is very important to have an ability to signalize about Satellite failures, data errors and ephemeris errors. For this purpose satellite signal imitator is able to work in these special modes.

For GPS signal generator devices of Spirent company (Great Britain) can be used, for example, Spirent STR4500 [3], Spirent GSS7790 or devices of WelNavigate, Inc. (USA), for example, GPS test equipment GS-100 (GS-100W). For GLONASS system signal generation can be used CH-3802, CH-3803 («КБ НАВИС», Russia) [6]. We used for signal simulation generator STR4500. This device imitates 12 satellite signals on frequency L1 (1575.42 MHz) and provides following error imitation [3]:

- Multipath (multiple types)
- Terrain Obscuration
- Reception Antenna Gain patterns
- Antenna site lever arm and associated effects
- Ionospheric delay
- Tropospheric delay
- Satellite failures and data errors
- Ephemeris errors
- Wave effects for ships

Imitated signals precision is following:

Pseudorange ± 0.1 m (MSE) including interchannel bias

Pseudorange rate ± 0.01 m/s (MSE)

Pseudorange acceleration ± 0.005 m/s2 (MSE over >1s)

Pseudorange jerk ± 0.02 m/s3 (MSE over >1s)

Satellite signal level step 1.0dB per channel nominal level +/- 15dB

Carrier Frequency +8Hz to +158Hz at L1 after 1 year (absolute)

Master Clock Stability $+1 \times 10^{-8}$ over temp range.

VI. Conclusions

We describe some methods for GPS receiver functionality and parameters control in this work. We recommend re–reference system for functionality control, but for parameters control we recommend signal imitation system, which provides dynamic control with various scenarios and GPS system special operation modes, for example, testing system Spirent STR4500.

References

[1] GPS-101. Global Positioning System Technology Trainer. Graymark International, Inc., 2004.

[2] Global Positioning Simulator GPS-101-2. Operation manual. Published by Aeroflex, 2004.

[3] STR4500 multi-channel GPS/SBAS simulator. Product specification. Spirent company, June 2007.

[4] В.В. Куршин. Тестирование GPS / WAAS / ГЛОНАСС алгоритмов. Электронный журнал - Труды МАИ, №12, июль 2003: www.mai.ru/projects/mai_works/articles/num12

[5] Parkinson, B., et al., Global Positioning System: Theory and Applications, Vol. I and II, Washington, D.C.: American Institute of Aeronautics and Astronautics, 1996.

[6] О.А. Борсук, М.Ю. Медведев. Имитатор сигналов спутниковых навигационных систем ГЛОНАСС и GPS СН-3803: www.navis.ru/content/img/public/2004/10/img/Pub1.pdf