# TIME TRANSFER UNIT ON THE BASE OF THE 16-CHANNEL GPS/GLONASS RECEIVER

P. Bogdanov, V.Moskvin, N.Novikov, I.Galichina, M.Soshin, A. Feoktistov

Rissian Institute of Radionavigation and Time
193124, 2 Rastrelli sq., St.Petersburg, Russia, e-mail: office@rirt.ru

## ABSTRACT

This paper presents the brief description of construction and operation principles of the Time Transfer Unit on the base of the 16-channel GPS/GLONASS receiver K-161B type, designed in the Russian Institute of Radionavigation and Time, as well as the results of its tests.

## 1. INTRODUCTION

The use of the multi-channel receivers is one of the methods to increase the comparison accuracy of the remote clocks using GPS and GLONASS signals [1]. But its realization in Russia was limited for a long time because of the lack of these receivers.

The Time Transfer Unit on the base of the 16-channel GPS/GLONASS receiver was made in the Russian Institute of Radionavigation and Time (RIRT). It provides the determination of the offset between the local clock and GPS-time and GLONASS-time for the following estimation of the time offset between the remote clocks.

The basic performances of the designed Time Transfer Unit and its construction and operation principles, as well as the preliminary testing results of the unit are presented in this paper.

## 2. BRIEF DESCRIPTION OF THE TIME TRANSFER UNIT

The Time Transfer Unit is intended for determination of the offset between the local clock and GPS-time and GLONASS-time to determine the mutual offset between the remote clocks, as well as for forming the output 1 pps pulse signal synchronized relative to the national Universal Time Coordinated of Russia UTC(SU).

The Time Transfer Unit should provide:

- the parallel receiving and processing of the navigational signals from 16 GPS and GLONASS satellites in L1 frequency band;
- the determination of the offset between local clock and GLONASS-time with the error no more than 35 ns (rms) and GPS-time with the error no more than 20 ns (rms) if Selective Availability (SA) mode is switched off and 200 ns (rms) if SA mode is switched on;
- the determination of the mutual offset between the remote clocks with the error no more than 5 ns (rms) if the distance between clocks is up to 100 km and with the error no more than 10 ns (rms) at large (up to 6000 km) distances;
- forming the comparison results in the structure recommended by Time Section of Bureau International des Poids and Measures (BIPM).

The error of the synchronization accuracy of the output 1 pps pulse signal relative to UTC(SU) should be no more than 50 ns (rms).

The Time Transfer Unit consists of the antenna box, the main amplifier, the comparison device, PC and installation kit including the antenna cable of length up to 60 m, the communication cable between the comparison device and PC and the feeding cable for the comparison device. PC is included in the complete set according to the customer's instruction. The view of the Time Transfer Unit is given in Figure 1.

Figure 1. The view of the Time Transfer Unit

The active type of the antenna with the built-in amplifier is used as the antenna box. The main amplifier is intended for additional amplification of the received signals if the damping in the antenna cable is more than 11,5 dB. The input of the main amplifier is connected to the output of the antenna box, and the output of the main amplifier is connected to the antenna cable.

The comparison device includes the following main blocks: 16-channels GPS/GLONASS receiver K-161B type (RCV), the time interval counter (TIC), the crystal oscillator (CO), RS-232 interface module (IM) and the microcontroller (MC). The block-diagram of the comparison device is given in Figure 2.

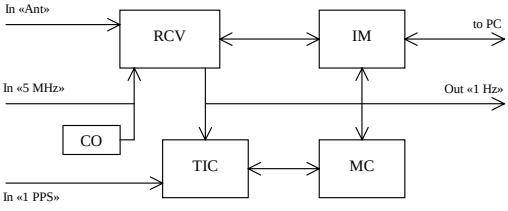


Figure 2. The block-diagram of the comparison device

The receiver provides the searching and tracking of the GPS and GLONASS signals, selection of the service information from the received signals, the measurement of radionavigational parameters (pseudo-range and pseudo-range rate), the calculation of navigational parameters (coordinates of the antenna), the formation of the 1 pps pulse signal of the internal time scale, which can be synchronized relative to one of the reference time scales: GLONASS-time, GPS-time, UTC(SU) or UTC(USNO), the reception of command messages and the forming of the output messages through RS-232C communication port. The time interval counter provides the measurement of the offset between the 1 pps signals of the receiver and the local clock for the subsequent accounting while determining the offset between the local clock and GPS-time and GLONASS-time. The crystal oscillator is intended to check of unit's operation in an autonomous mode.

The power supply of the comparison device is the alternating current 220 V 50 Hz, the power consumption – no more than 30 VA. The overall dimensions – 225x75x210 mms, the weight – 1,5 kg.
PC is intended to form and give out the control signals to the comparison device, to receive the measurements and other information from the comparison device, and to process, store, display and record the information on FD. IBM-compatible PC with the following minimal system parameters may be used: CPU type – Pentium, CPU clock rate – not less than 200 MHz, RAM – not less than 32 Mbytes, HDD – not less than 3,2 Gbytes, and operational system – Windows 95/98/NT.

The special software provides the input of the initial data for the unit's operation to the comparison device, control and monitoring of the comparison device's blocks, reception and processing of the information from the comparison device and forming the comparison results in the given format.

The operational mode of the Time Transfer Unit is continuous. The prepare time is no more than 30 minutes.

The initial data for the unit's operation includes the information concerning the user and equipment, the values of the signal delays in the antenna channel (the antenna, the main amplifier and the antenna cable), in the receiver and in the cable from the local clock to the comparison device, the known coordinates of the antenna and the current date and time.

The determination of the GPS and GLONASS signals delays in the antenna box, in the main amplifier and in the receiver for subsequent accounting are made during their manufacturing. The special test bench equipment including the GPS/GLONASS signals simulator is used for calibration of the devices. The summary error of the absolute signal delay determination is about 10 ns. The additional measurement of the delay correction for each GLONASS frequency is made with the error no more than 1 ns.

## 3. PROCEDURES FOR MEASUREMENTS AND THEIR PROCESSING

Each pseudo-range measurement is formed in the receiver by integration of the received signal in the interval of 1 second. The result of the pseudo-range measurement is characterized by the Modified Julian Date (MJD) and hours, minutes and seconds in the Universal Time Coordinated (UTC).

The primary processing of the pseudo-range measurements is made by square interpolation of each 15 not overlapped single measurements [2]. Then the following corrections, estimated for the same time, are added:

- the propagation delay of the satellite signal computed on the base of the known coordinates of the user and ephemerides transmitted from the satellite;
- the Sagnac correction;
- the ionospheric correection;
- the tropospheric correction;
- L1 - L2 correction;
- the internal signal delay in the receiver;
- the signal delays in the antenna channel and in the cable from the local clock to the comparison device;
- the value of the offset between satellite time scale and GLONASS-time or GPS-time, calculated on the basis of the time-frequency corrections transmitted from the satellite.

All parameters and constants, necessary for measurements processing, correspond to those given in the GPS and GLONASS Interface Control Documents.

During subsequent processing of the measurements results are formed as separate 13 minutes tracks in accordance with BIPM GPS and GLONASS international common-view schedules for time and frequency comparisons. For each track the linear smoothing of the following data is executed:

- the results of the offset between the internal receiver time scale and the satellite time scale. The smoothing results are presented as the estimations of the offset between the time scales at the middle of the track and the rate of the offset;
- the results of the offset between the internal receiver time scale and GLONASS-time or GPS-time. The smoothing results are presented as the estimations of the offset between the time scales at the middle of the track, the rate of the offset and root-mean–square value (rms) of the measurements;
- the correction of the computed ionospheric delay. The results are presented as the estimations of the ionospheric delay at the middle of the track and the rate of the delay;
- the correction of the computed tropospheric delay. The results are presented as the estimations of the tropospheric delay at the middle of the track and the rate of the delay.

Then the value of the offset between the internal time scale of the receiver and the local clock is added to the estimations of the offsets between the internal receiver time scale and satellite time scales, GLONASS-time and GPS-time. The obtained values are estimations of the offset between the local clock and the satellite time scale, GLONASS-time and GPS-time.

## 4. TIME TRANSFER UNIT TEST RESULTS

The estimations of the accuracy characteristics of the Time Transfer Unit was made during 10 days interval. These estimations were obtained on the basis of the method of least squares interpolation and linear model for time differences with one day average.

The estimations of time comparison accuracy of the RIRT's Secondary Time/Frequency Reference (STFR) with GLONASS-time and GPS-time are given in Table 1.

Table 1. The estimations of time comparison accuracy of the RIRT's STFR with GLONASS-time and GPS-time.

| Receiver type | Uncertainty (rms), ns | | |
|---|---|---|---|
| | GLONASS | | GPS |
| | one satellite | all satellites | |
| TTU(1) | 23–37 | 15–21 | 6–10 |
| TTU(2) | 25–33 | 14–17 | 5–9 |
| TTU(3) | 28–34 | 8–14 | 5–10 |

The estimations of instrumental accuracy of the mutual clocks comparisons using the Time Transfer Units are given in Table 2.

Table 2. The estimations of instrumental accuracy of the mutual clocks comparisons.

| Receiver type | Uncertainty (rms), ns | | | |
|---|---|---|---|---|
| | GLONASS | | GPS | GLONASS +GPS |
| | one satellite | all satellites | | |
| TTU(1) – TTU(2) | 2,4–3,5 | 2,2–3,7 | 2,7-3.1 | 3,5–4.1 |
| TTU(1) – TTU(3) | 2,7–3,4 | 2,4–3,7 | 2,6-3,3 | 3,2–3,8 |
| TTU(2) – TTU(3) | 2,3–3,7 | 2,7–3,4 | 2,5-3.0 | 3,0–3,5 |

The presented results confirm realization of the given requirements to the Time Transfer Unit and the possibility of time comparison with error no more than 5 ns (rms) if the distance between clocks is up to 100 km and no more than 10 ns at large distances.

## 5. CONCLUSION

The Time Transfer Unit on the base of the 16-channel GLONASS and GPS receiver K-161B type designed in RIRT provides the GLONASS and GPS measurements and their processing in accordance with the Technical Directives for Standardization of GPS and GLONASS time transfer and possibility of time and frequency comparisons in "all-in-view" mode.

The testing of the unit shown the following results:

- the determination error of the offset between the local clock and GLONASS-time is no more than 35 ns, and GPS-time is about 10 ns;
- the instrumental error of the time comparisons is about 3 ns via GLONASS and GPS signals separately and about 5 ns via GLONASS and GPS signals simultaneously.

## REFERENCES

[1]. Lewandowski W., Azoubib J., de Jong G., Nawrocki J., Danaher J. A New Approach to International Satellite Time and Frequency Comparisons: "All-in-View" Multichannel GPS+GLONASS Observations. Proc. ION GPS-97, 1997.
[2]. Allan D. W. and Thomas C. Technical Directives for Standardization of GPS Time Receiver Software. Metrologia, 31, 1994.