RESULTS OF RIRT'S COMPARISONS VIA GLONASS SIGNALS

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Abstract

At present using the signals of satellite navigation system for comparisons of remote clocks in common-view mode is the most popular and precise method. But its practical realization in Russia via GLONASS signals was suspended for many years due to lack of automated receiving system. This paper describes the experimental operation of automated system for receiving of GLONASS signals in the Russian Institute of Radionavigation and Time, St.Petersburg. The results of the time scale comparisons are presented for the period from the beginning of 1996 to the end of 1998.

INTRODUCTION

In late 1993 in Russian Institute of Radionavigation and Time (RIRT) timing receiver named ASN-16-02 was developed on the base of its own serial GLONASS ASN-16 receiver. It meets the requirements of Bureau International des Poids and Mesures (BIPM) Time Section [1]. To obtain the execution of measurements and their processing automatically the interface between receiver and personal computer (PC) was held. This set of devices was named as Receiving and Data Processing System (RDPS).

At the same time many platforms of the Russian State Time and Frequency Service (STFS) continue to use for GLONASS time comparisons the serial ASN-16 receiver with additional time interval measurer of the difference between receiver's internal time scale (TS) and user's clock. To provide the execution of measurements and their processing automatically using RDPS in this case, development of the additional interface module and software was required. The developed system is successfully maintained in the structure of the Secondary Time/Frequency Reference of RIRT, providing GLONASS common-view time comparisons and data exchange with other laboratories.

The present paper describes principles of construction and operation of the Receiving and Data Processing System on the basis of ASN-16 type receiver, as well as results of its application.

DESCRIPTION OF RECEIVING AND DATA PROCESSING SYSTEM

Modified Receiving and Data Processing System on the basis of ASN-16 type receiver provides:

- forming the current plan of measurements execution on the basis of schedules received from BIPM and STFS;
- carrying out measurements sessions according to current plan;
- statistical processing of measurements for various variants and conditions;
- forming information for data exchange with other users in the STFS and BIPM format;
- displaying GLONASS state;
- forming an additional information about presence of satellites in visible zone for given user or network of users;
- graphic displaying of measurements processing results and other information; monitoring of receiver operation.

The system consists of GLONASS receiver ASN-16 or ASN-16-02 type, timing intervals measurer (TIM), IBM - compatible PC, interface module (IM1) for connection with the receiver and interface module (IM2) for connection with TIM both installed in PC, and software of the system. Block diagram of the system is given in Figure 1, the view of the system - in Figure 2. Main specifications of the system are given in Table 1.

When ASN-16 unit is used, the value of the offset between the internal TS of the receiver and UTC (SU) - ΔT_{RCVR} is determined in the receiver and then given out to PC. Simultaneously the signal of the receiver's internal TS is sent to start input of TIM, and the signal from the user's clock is sent tc stop input of TIM. The value of the offset between the internal TS of the receiver and the user's clock - ΔT_{TIM}, is measured by means of TIM and then transfers to PC. During subsequent processing of results in PC the value of measured offset between the user's clock and UTC(SU) is defined: $\Delta T_{REF} = \Delta T_{RCVR} + \Delta T_{TIM}$.

When ASN-16-02 unit is used the value of the offset between the user's clock and UTC(SU) — $\Delta T_{RCVR} = \Delta T_{REF}$, is determined in the receiver directly and then given out in PC. In this case TIM is used only for monitoring of receiver's internal TS generation and user's clock.

Data exchange with other users provides the reception of BIPM and STFS schedules, measurement results from other laboratories in BIPM or STFS format, as well as forming measurements results in given format.

The software of the system is realized in MS DOS operational system version 5.0 using the computer languages such as Clipper 5.01 and Borland C ++ 3.0

PROCEDURES FOR MEASUREMENTS PLANNING, PERFORMING AND PROCESSING

Forming of current plans of measurement execution is produced on the basis of BIPM schedule, issued two times a year, and STFS schedule, issued two times a month. The BIPM schedule foresees the execution about 89 measurements sessions per day of 13-minute duration of each one. However the number of sessions executing in RIRT decreases to 25-35 per day because of features of ASN-16 receiver's operation. The STFS schedule foresees the execution four sessions per day only.

Planning of measurements sessions for independent operating mode of user is also possible, for example, several sessions for each satellite over each visible zone, for described time instants, etc. In this case forming of plan is executed on the basis of GLONASS almanac. Receiving of almanac is carried out once a week or after getting a message from GLONASS Coordination Scientific Information Center (CSIC) concerning system status change.

Execution of measurement sessions according to the current plan is produced in automatic mode completely. The execution of sessions directly by operator is also possible by set of appropriate mode.

The primary processing of measurements is executed in receiver. As GLONASS navigation message does not include model parameters of ionosphere and troposphere, the ionosphere and troposphere delays are computed using parameters stored autonomously in the receiver. Internal delay is determined by means of calibration of the receiver before each session.

Secondary measurement processing is realized totally by PC and is connected with getting session estimates for time offset of user's clock against UTC(SU) and GLONASS time, as well as estimates averaged over 1 day or for any other time interval. For computation of session estimates an averaging procedure can be chosen from following alternatives: linear approximation, square approximation or combined algorithm given by BIPM (square approximation of pseudorange measurements over 15-second sections with subsequent linear approximation over all session interval). Estimates with averaging over 1 day or over desired time interval are computed using all the session estimates, for the chosen satellite or for certain elevation angle.

RESULTS OF TIME COMPARISONS

List of laboratories, which observe GLONASS according to the STFS and BIPM schedules is given in Table 2.

The results of accuracy estimation of the laboratory's clock comparisons relative UTC(SU) and GLONASS time in the "direct synchronization" mode and the results of accuracy estimation of GLONASS common view comparisons between RIRT and other laboratories are given in Table 3. These results are the minimum and maximum values obtained on the basis of the method of least squares interpolation and linear model for time differences with one month averaging.

The presented data show that the average value of the accuracy determination of the offset between laboratory's clock and UTC(SU) or GLONASS time in the "direct synchronization" mode is 33 ns (discrepancy from 20 to 48 ns). The average values of the clock comparison accuracy in the GLONASS common-view mode are 17 ns (discrepancy from 11 to 28 ns) for Russian laboratories and RIRT and 13 ns (discrepancy from 9 to 19 ns) for foreign laboratories and RIRT. These results correspond to the tentative uncertainty estimations for "direct synchronization" mode and common-view mode well enough [2,3]. They show also that the comparison accuracy for Russian laboratories are worse than the one for foreign laboratories. It can be explained by great ground antenna coordinate uncertainties, as well as using of non-effective models for account of ionosphere and troposphere delays in ASN-16 type receivers.

The increase of time comparison accuracy using this system can be achieved by standardization and subsequent realization of BIPM requirements to GLONASS time receivers and to processing procedures [4]:

- the use of standard formulas and parameters for calculation of ionosphere and troposphere corrections;
- the use of ground antenna coordinates of GLONASS receivers expressed in the International Earth Rotation Service (ITRF) in Cartesian x, y, z form and their transformations in PZ-90 frame system using standard formulas and parameters adopted by all manufactures, or use of transformation of broadcast ephemeredes from PZ-90 into ITRF according to a standardized set of formulas and parameters;
- the stabilization of receiver's antenna temperature.

CONCLUSION

The automated Receiving and Data Processing System on the basis of ASN-16 type receiver developed in RIRT provides GLONASS common-view time comparisons in accordance with BIPM and STFS schedules and data exchange with other Russian and foreign laboratories.

The results of data processing show that the average value of the accuracy determination of the offset between user's clock relative UTC(SU) and GLONASS time is about 35 ns (rms) in "direct synchronization" mode. The average value of the accuracy of the remote clocks comparisons is about 15 ns (rms).

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ACKNOWLEDGEMENTS

The authors express the thanks to the colleagues in RIRT, which are engaged by execution and processing of measurements, as well as colleagues from other laboratories for given data.

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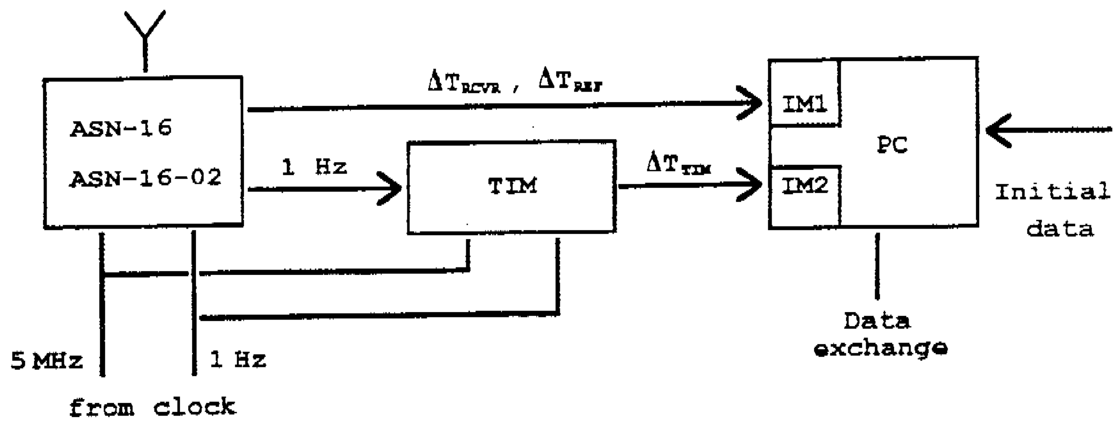

Figure 1. The block diagram of the Receiving and Data Processing System

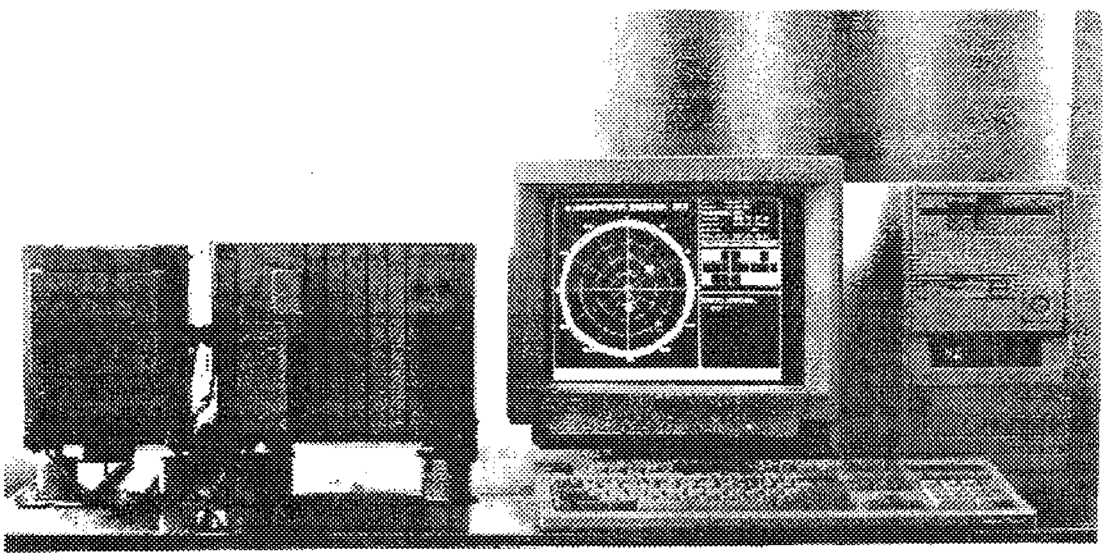

Figure 2. The view of the Receiving and Data Processing System

Table 1. Specifications for Receiving and Data Processing System on the basis of ASN-16 type receiver

Parameter	Value
Code operation	C/A
Operation frequency, MHz	1600
Measurements accuracy of pseudorange, m	0,5
Measurement time, s	1
Data output rate, s	2
Error of determination of the offset between user's clock and UTC(SU), ns	50
Error of determination of the offset between remote clocks, ns	20
Continuous operating not less than, hour	24
Power supply of the receiver (DC), V	27
Power consumption, W	150
Weigh, kg	27

Table 2. Laboratories observe GLONASS according to STFS and BIPM schedules

Laboratory	Equipment
1. Laboratories observe CLONASS, according to STFS schedule:	
SU (Mendeleevo, Russia)	ASN-16
ACSC (Moskow region, Russia)	ASN-16
IRK (Irkutsk, Russia)	ASN-16
KHAB (Khabarovsk, Russia)	ASN-16
NSK (Novosibirsk, Russia)	ASN-16
RIRT (St.Petersburg, Russia)	ASN-16-02
KHAR (Kharkov, Ukraine)	ASN-16
2. Laboratiries observe CLONASS, according to BIPM schedule:	
VSL (Delft, Netherlands)	R-100/40T
DLR (Oberpfaffenhofen, Germany)	R-100/10
RIRT (St.Petersburg, Russia)	ASN-16-02
BIRM (Beijing, China)	R-100/30
LDS (Leeds, UK)	ISN-RX1
NIST (Boulder, Colorado, USA)	R-100/30

Table 3. Results of accuracy estimation of clock comparisons

Laboratory	Uncertainty (rms), ns		
	UTC(i)-UTC(SU)	UTC(i)-GLONASS	UTC(i)-UTC(RIRT)
SU	21-48	21-33	11-19
ACSC	30-42	28-42	15-26
IRK	20-39	20-34	12-21
KHAB	21-41	20-32	16-28
NSK	25-38	24-34	11-23
RIRT	26-40	25-34	—
KHAR	22-45	21-37	11-24
VSL	27-40	26-33	9-14
DLR	29-43	29-37	11-13
BIRM	28-39	27-35	14-19
LDS	27-44	28-42	20-33
NIST	29-38	27-33	11-17