ACTIVITIES ON DEVELOPMENT AND IMPROVEMENT FOR SYSTEM OF TIME/FREQUENCY SUPPORT

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1. ABSTRACT

In this paper describes the activities of the Russian Institute of Radionavigation and Time (RIRT). RIRT is a leading organization in the field of development of systems and equipment for time/frequency support (TFS) in behalf of a national economy, science and defense.

Actually in RIRT the activities on two major systems are in progress:

- to a State System of Common Time and Standard Frequencies (SSCTSF);
- to a synchronization system to Global Navigation Satellite System GLONASS.

2. THE BRIEF HISTORICAL REFERENCE TO GLONASS SYSTEM CREATION

The beginning of activities on creation of a global navigational satellite system (GLONASS) falls into to middle of 70th years, when the accomplished researches in the field of mid-orbital satellite radionavigation systems.

Originally system was intended for a determination of coordinates and components of air users vector speed. However during creation of a system the field of application was expanded in a part with purpose of a position determination, movement arguments and precision time of marine, air and overland users [1].

Activities on creation GLONASS have started under the decision of the government in 1979. In 1982 successful launched the first satellite from which the stage of improvement and tests of principles of functioning of system began was held. In 1985 the second stage of expansion of system began based on satellite with improved accuracy and performance. In 1991 GLONASS flight-testing were successfully finished. Results of tests are published in [2]. In 1993 the system is accepted in operation and in 1995 full expansion of an orbital grouping of system include 24 satellites is completed.

The basic executors of system were:

- Research-and-production association of the applied mechanics (Krasnoyarsk) - the developer of system as whole, including satellites and the control software of satellite;
- The Russian scientific research institute of space instrument construction (Moscow) - the developer of a control and monitoring subsystems of onboard satellite equipment and the equipment of navigating users;
- The Russian institute of radionavigation and time (Saint-Petersburg) - the developer of system of synchronization, ground and onboard time/frequency standards and the users navigation kit.

RIRT function in creation and GLONASS improvement of synchronization system, navigation and time users kit is given in [2], regarding creation of onboard time/frequency standards - in [3] and regarding creation of quantum frequency standards - in [4].

3. GLONASS: CURRENT STATE AND DIRECTIONS OF IMPROVEMENT

Serious social and economic conditions in the country have resulted to that at present in orbital grouping of GLONASS are limited satellites number.

Despite of available difficulties and problems, GLONASS keeps a high priority in the Russian space program. In last decisions of the Government of the Russian Federation the complex of the actions directed on maintenance of GLONASS functioning and its further improvement is determined. Further development GLONASS is allied to creation of new satellites, with improvement accuracy and performance, with expansion of functionalities of system, adding of new measuring and computing means, improvement of algorithms and a quality of monitoring and managements of system functioning, creation of the navigating and time users kit of next generation.

For this purpose in RIRT the following activities are in progress:

- Creation of an onboard time and frequencies reference on the base of cesium atom-beam frequency standard with diurnal instability 1· 10-13 and with improved reliability and performance;
- Accuracy improving forming of time/frequency information which is uploading to a satellite board for users support;
- Creation of next generation units for the navigational and temporal problems solution for overland, air and space users.

4. BRIEF HISTORICAL REFERENCE TO CREATION OF STATE SYSTEM OF COMMON TIME AND STANDARD FREQUENCIES

The accelerated development of a missilery in the beginning of 50th years was resulted in necessity of means creation for range measurement, velocity and for diagnostic of onboard satellites systems. The accuracy results of observation and telemetries received from territorial diverse land measuring points (LMP) depending by error of time synchronization of measuring means. On the initial stage of a missilery the control and the measurements implemented basically on the track of a fissile flight segment of a rocket and the number of monitoring stations limited by polygon territory. Therefore one of technological tasks in 1957 assigned to institute was creation of synchronization and common time units for radio engineering complexes. Further long time of satellites activity on orbits and control of parameters of orbits have demanded expansion of a monitoring points network land and marine basing, that has resulted in necessity of creation of a System of common time of high accuracy (SCT HA). In 1973 there was a governmental order about creation SCT HA, where by the head executor was determined RIRT and in 1975 the system was accepted in force.

With appearance of satellite navigation system, increasing of requirements to accuracy and reliability of means, expansion of application fields in different areas of science and engineering the necessity of creation of common time/frequency network of the country has appeared. In a result in 1978 there was a decision about creation SSCTSF. The head executor is RIRT. In 1990 SSCTSF with limitations was accepted in force.

In detail history of creation and development of common time system of country and RIRT function in this process is published in [5].

5. CURRENT STATE AND IMPROVMENT CONCEPT OF STATE SYSTEM OF COMMON TIME AND STANDARD FREQUENCIES

State system of common time and standard frequencies (SSCTSF) is intended for maintenance by signals of standard frequencies, correct time and information on rotational variables of the Earth (RVE) of complexes and systems of defense, national economic and scientific assigning, and also metrology frequency/time maintenance of military forces and national economy of country. Actually for creation of perspective systems and complexes passes a stage of improvement system in the increase accuracy and performance. The basics principles of means improvement are following:

- Modular approach of hardware of different assigning and accuracy categories;
- Maximum automation of control procedures and monitoring;
- Possibility of adaptation output signals to the users requirements;
- Usage of actual element base;
- Reliability augmentation, resource, maintenance of reliability;
- Optimum combination hardware and software;
- Technology improvement, minimization of tuning activities;
- Power saving. Minimizing of units dimensions, cost of manufacturing.

In this paper the data about units of next generation designed by RIRT and which one on our view can be interesting to users operating in the meanings time/frequency methods and information.

The receiving points of system of common time, quantum frequency standards, comparison unit of high-stable time and frequencies references, conducted small-sized rubidium frequency standard and built-in single-board synchronization module.

6. RECEIVING STATIONS OF SYSTEN OF COMMON TIME

Receiving stations (RS) of system of common time are intended for formation and issue to users the signals of standard frequencies and time scale bound to UTC (SU). Depending on accuracy RS are divided into four accuracy categories. Basic performances of ground standing receiving stations (GSRS) of four accuracy categories documented n the table 1.

Output signals: 5 MHz and 1 MHz (sinusoidal); clock signals from 1 MHz to 1/300 Hz (pulsing); time scale by interface RS232.

The grid of output signals under the nomenclature, quantity of outputs and parameters can be adapted to the customer requirements.

Performances: lifetime is 15 years; specified life 100000 hours.

Table 1. Basic performances of GSRS of four accuracy categories

Performance	Accuracy categories			
	GSRS 1	GSRS 2	GSRS 3	GSRS 4
Root-mean-square frequency error per day	$1 \cdot 10^{-14}$	$1 \cdot 10^{-13}$	$2 \cdot 10^{-12}$	$1 \cdot 10^{-10}$
Synchronization error of time scale relative UTC (SU)	(5-10) ns	(50-100) ns	(50-100)ns	(0,2-0,5) mcs
Error of autonomous time scale keeping per month	(50-100) ns	(0,5–1) mcs	(20–40) mcs	1 ms, less

Receiving stations include following in dependence of accuracy categories:

- Modifications of base synchronization unit (BSU), including reserved time keepers, units of synchronizations on signals GLONASS/GPS, on signals LW and SLW stations, reserved power sources, crystal oscillator (CO) and rubidium frequency standards (RFS);
- Antenna-feeder system of synchronization unit via SRNS signals (AFS SRNS);
- Antenna-feeder system of synchronization unit via LW stations signals (AFS LW);
- Antenna-feeder system of synchronization unit via SLW stations signals (AFS SLW);
- Signals formation block (SFB);
- Quantum frequency standard based on atom-beam tube (QFS ABT);
- Group hydrogenous frequency standard (GHFS);
- Synchronization unit via GLONASS/GPS signals (SU GLONASS/GPS);
- Synchronization unit via TV signals (SU TV);

Table 2. GSRS base complete set structure of 1- 4 accuracy categories

Accuracy category GSRS CTS	BSU	SFB	SU GLONASS/ GPS	SU TV	CO	RFS	QFS ABT	GHFS
GSRS-1	BSU1	1	1	1	-	-	-	1
GSRS-2	BSU2	1	1		-	1	1	-
GSRS-3	BSU3	1	-		1	1	-	-
GSRS-4	BSU4	1	-		2	-	-	-

7. GROUND QUANTUM FREQUENCY STANDARDS FOR STATE COMMON TIME AND REFERNCES FREQUENCIES SYSTEM

RIRT experience during 40 years published in [4]. The modern quantum frequency standards performances describes in Table 3.

Table 3. The modern quantum frequency standards performances

Performance	Rubidium frequency standard RFS 2001	Cesium frequency standard «Fianit»
1. Frequency simulation error, (r.u).	$\pm 5 \cdot 10^{-11}$	$\pm 5 \cdot 10^{-12}$
2. Frequency instability, r.u. at measurement time: 1 sec 100 sec 1000 sec 1 hr 1 day	 $2 \cdot 10^{-11}$ $5 \cdot 10^{-12}$ $2{,}5 \cdot 10^{-12}$ — —	 $2 \cdot 10^{-11}$ $3 \cdot 10^{-12}$ — $5 \cdot 10^{-13}$ $1 \cdot 10^{-13}$
3. Frequency drift, r.u. for a month	$2 \cdot 10^{-11}$	—
4. Frequency simulation error from actuation to actuation, r.u	$2{,}5 \cdot 10^{-11}$	$5 \cdot 10^{-13}$
5. Frequency alteration step, r.u.	$1{,}39 \cdot 10^{-12}$	$1{,}5 \cdot 10^{-13}$
6. Discrete attenuation components in band 20 kHz of output signal specter, dB	-100	-95
7. Time for ready to normal mode, hrs	0,5	4,0
8. Temperature frequency factor, r.u/grad	$2 \cdot 10^{-12}$	$1 \cdot 10^{-13}$
9. Frequency magnetic offset, r.u/oersted, no more than	$5 \cdot 10^{-12}$	$1 \cdot 10^{-13}$
10. Power supply voltage, V	24 (DC)	220 (AC) 27 (DC)
11. Consumed power, VA	15	75 (AC) 55 (DC)
12. Weight, kg	2	36
13. Overall dimensions, mm	90×100×140	600×480×155
14. Lifetime, years	10	10
15. Specified life, hrs	100000	100000

8. SYNCHRONISATION UNIT OF HIGH STABILITY TIME AND FREQUENCY REFERENCES

Synchronization unit provide high-precisions comparisons of remote time scales high-stability time and frequency references. Provision of cross-comparisons of time scales n-references, by installing on each a unit set. Output information from comparison unit transmitting by interfaces RS 232 to PC for further processing.

Synchronization unit include: synchronization unit; antenna-feeder system, PC IBM compatible, data gathering software, posterior processing software.

Basic performances

- Input signals from time and frequency reference: 5Mhz and 1MHz.
- Comparison error of time scales for distance between standards no more than 100 km: 3 – 5 ns;
- Comparisons error of time scales for distance between standards
- more 100 km: no more than 10ns;
- Synchronization error of time scale of time and frequency reference to time scale
- UTC (SU) in direct comparison mode:50 – 100 ns;
- Power supply voltage:220V 50Hz (AC), 27V (DC);
- Overall dimensions of time transfer unit, mm: 200x200x80.

9. CONDUCTED SMALL-SIZED RUBIDIUM FREQUENCY STANDARD

Is intended for issue to a customer of a high-stable signal by frequency 5МГц, controlled on frequency by a signal of navigational space systems GLONASS/GPS.

Structure

- Small-sized rubidium frequency standard RFS 2001;
- Frequency synchronization unit on signals SRNS GLONASS/GPS;
- Data processing and mode operation controller

Basic performances

- Output signal 5MHz, real amplitude value: 0.5 – 1, V;
- Frequency error in operational mode: $5{\cdot}10^{-12}$;
- Relative root mean square frequency error:
  Measurement time 1sec: $1{\cdot}10^{-11}$;
  Measurement times 100sec: $5{\cdot}10^{-12}$;
- Power supply voltage: 220V, 50Hz;
- Volume: 4L.;
- Lifetime: 15 years;
- Specified life: 50000 hrs.

10. BUILDED SINGLE-BOARD SYNCHRONIZATION MODULE

Is intended for forming and issue to users signals of synchronizations and time scale bound to space navigation systems GLONASS/GPS to time scale UTC (SU). Have 2 modes: synchronization mode (basic mode) and autonomous mode (absence signals from receiver-measurer).

Structure

- Receiver-measurer SRNS GLONASS/GPS;
- Timekeeper based on thermo stable crystal oscillator;
- Data processing and mode operation controller.

Base performances

- Base output signals:
  5MHz (amplitude - 0.5V, form - sinusoidal);
  1Hz (amplitude 3 – 5V, form – pulse, 2 out);
- Synchronization errors, less than 100 ns;
- Power supplies voltage: +5V, ± 12 V;
- Time scale, control and diagnostic by interface RS 232;
- Lifetime 15 years;
- Specified life 50000hrs.

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