State Scientific Center
of the Russian
Federation

VNIIFTRI

National Research Institute for
Physical-Technical and Radio Engineering Measurements

Time-frequency and metrological assurance complexes development for GLONASS system

(United Nations/Russian Federation
Workshop on Applications of Global Navigation Satellite Systems)
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General requirements for GLONASS time-frequency assurance complex for 2016-2020

Requirements	Basic requirements for 2011	Planned values								
		2012	2013	2014	2015	2016	2017	2018	2019	2020
User GLONASS time uncertainty access due to the space segment	5 ns					2 ns				1 ns
RMS (UTC(SU) – GLO system time)	120 ns					20 ns				4 ns
RMS (UTC– UTC(SU))	10 ns					7 ns				3 ns

Current state of GLONASS time-frequency assurance complex

Requirements	Basic requirements for 2011	Planned values								
		2012	2013	2014	2015	2016	2017	2018	2019	2020
User GLONASS time uncertainty access due to the space segment	5 ns					2 ns				1 ns
RMS (UTC(SU) – GLO system time)	120 ns					20 ns				4 ns
RMS (UTC– UTC(SU))	10 ns					7 ns				3 ns

GLONASS synchronizer based on active H-maser ensemble:

1) Allan deviation $\sigma_y(\tau) \leq 2\times10^{-15}$ τ = 1 day
2) H-maser frequency drift $\leq 5\times10^{-16}$/day

Developing on land GLONASS system time scale and GLONASS time synchronization means
I stage (2016)
II stage (2020)

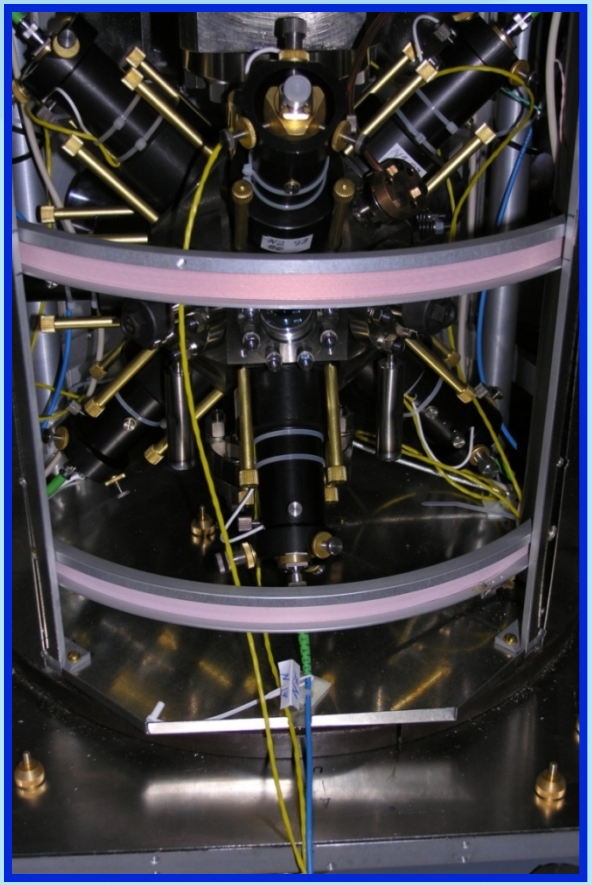
National Time and Frequency Standard ГЭТ1-2012:

- CS fountain standards;
- H-maser time keeping ensemble;
- Two way satellite time and frequency transfer system;
- GNSS based time transfer system;

1) Time unit accuracy $\leq 5\times10^{-16}$;
2) Allan deviation $\sigma_y(\tau) \leq 1\times10^{-15}$ $10 \leq \tau \leq 30$ days.

National Standard of Time and Frequency

Metrological Cs Fountain Standard CsFO2



Uncertainty **5·E-16**

	SYRTE-F01	SYRTE-F02	SYRTE-F0M	NIST-F1	PTB-CsF1	IEN-CsF1	NPL-CsF1
Uncertainty	7.2	6.5	7.7	3.3	9	16	10

in units ·E-16

Two-Way Satellite Time and Frequency Transfer equipment of the National Time, Frequency and ERP determination Service
(time scale difference estimate uncertainty
± 2 ns for the distances up to thousands km)

Mobile system

Stationary system

UTC - UTC(SU) ≤ 7 ns

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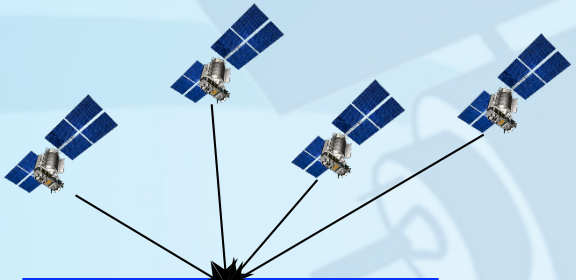
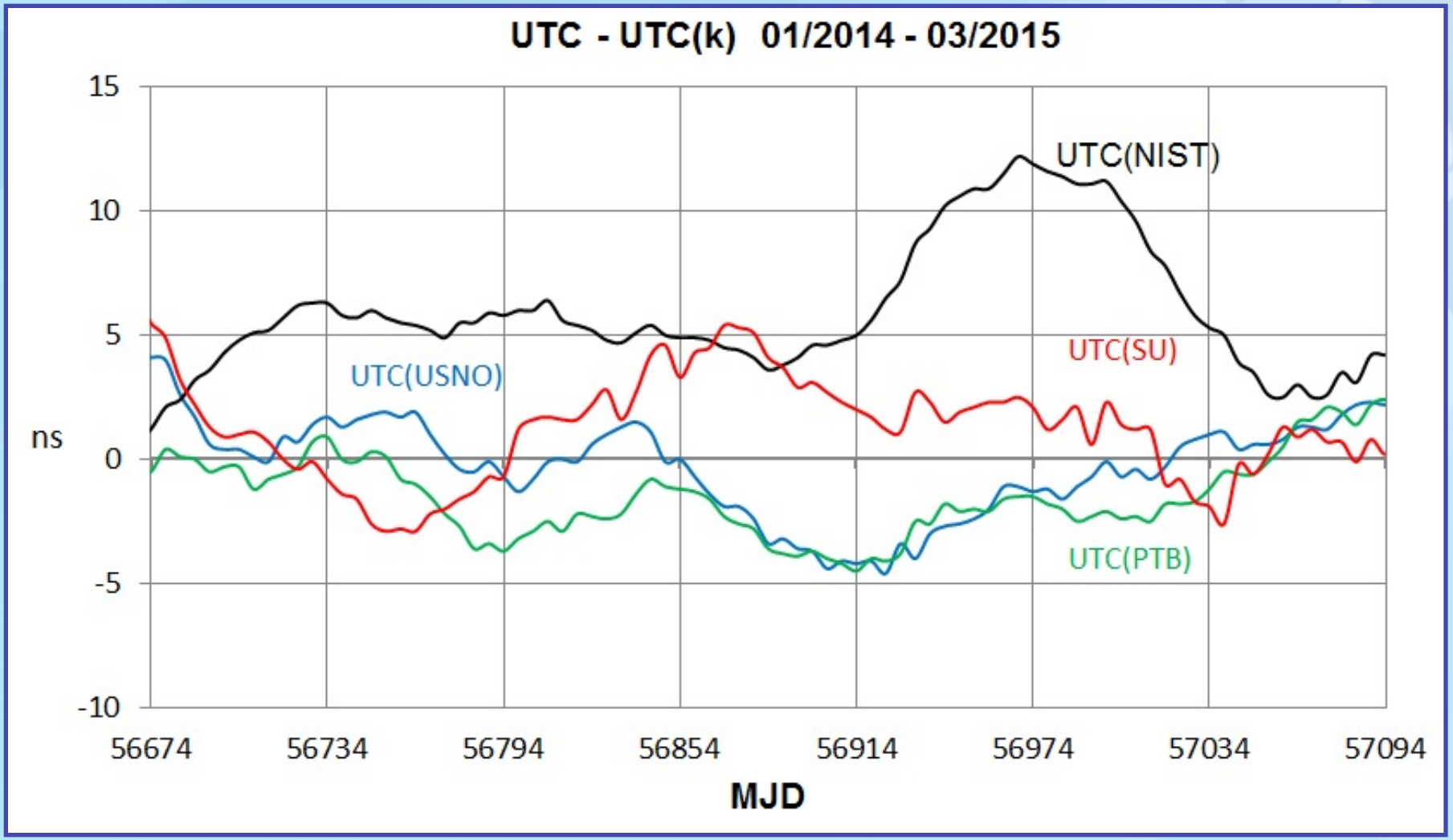
Mobile time-transfer standard

error less than 2 ns per 24 hours



Technical means of the National Time, Frequency and ERP determination Service(frequency stability within 1·E-15 for sample time 1 day)

Requirements fulfillment for national time scale UTC(SU) and international time scale UTC steering



UTC(SU) characteristics are on the level of the best UTC realizations

Development perspectives for GLONASS time-frequency assurance complex

Requirements	Basic requirements for 2011	Planed values								
		2012	2013	2014	2015	2016	2017	2018	2019	2020
User GLONASS time uncertainty access due to the space segment	5 ns					2 ns				1 ns
RMS (UTC(SU) – GLO system time)	120 ns					20 ns				4 ns
RMS (UTC– UTC(SU))	10 ns					7 ns				3 ns

New generation of on land GLONASS system time scale and GLONASS time synchronization means :

Allan deviation $\sigma_y(\tau)$ τ = 1 day

$\leq 5\times10^{-16}$ (I stage) $(1\text{-}2)\times10^{-16}$ (II stage)

Rb fountain standard, Allan deviation $\sigma_y(\tau)$ τ = 1 day (1-2)×10^{-16}

TWSTFT time transfer uncertainty ± (1,0-1,5) ns

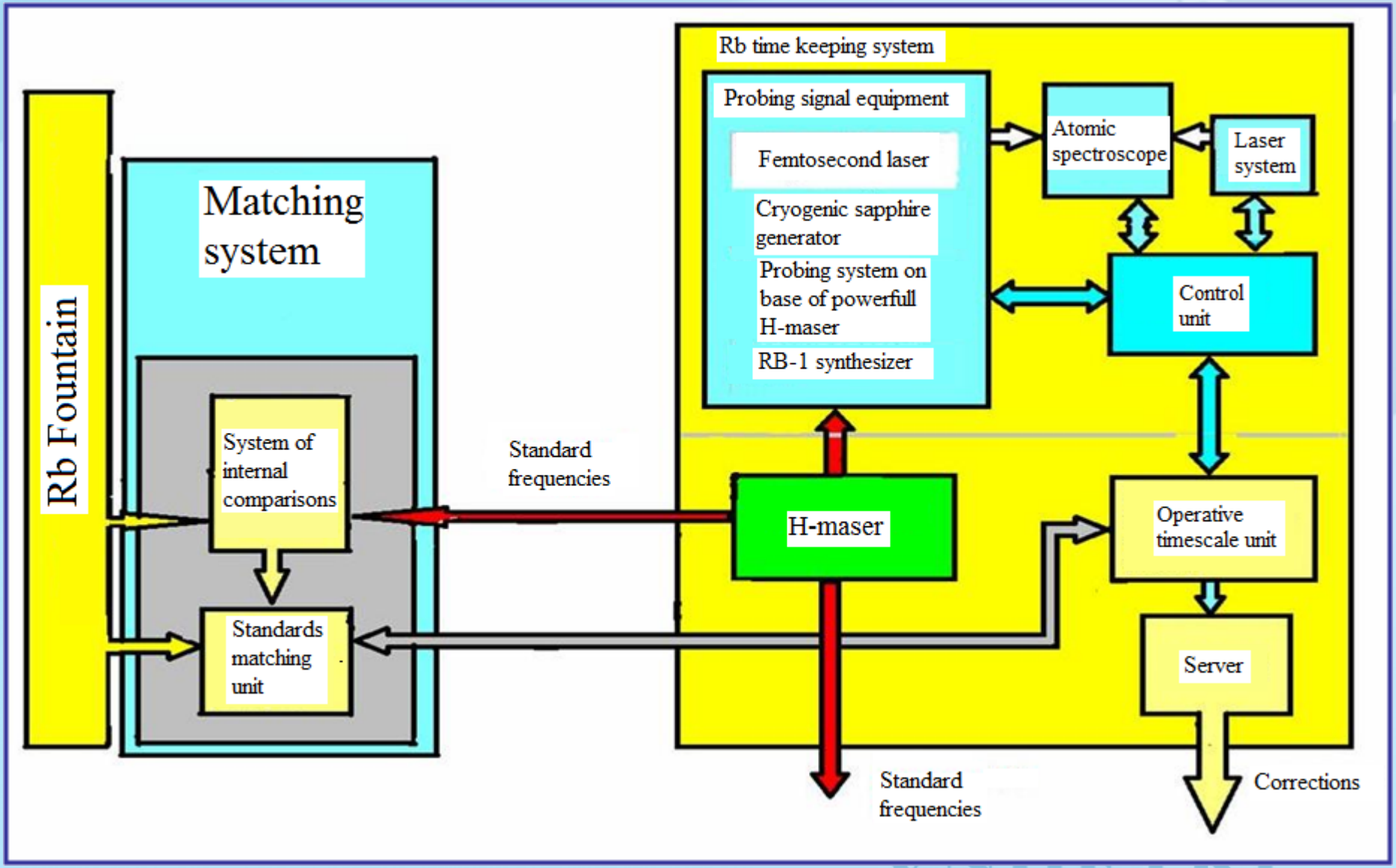
Cold atom optical frequency standard, accuracy ≤ 1×10^{-16}

Updated NTFS:

- Cold atom optical frequency standard;
- Updated H-maser ensemble;
- Updated time transfer technique;

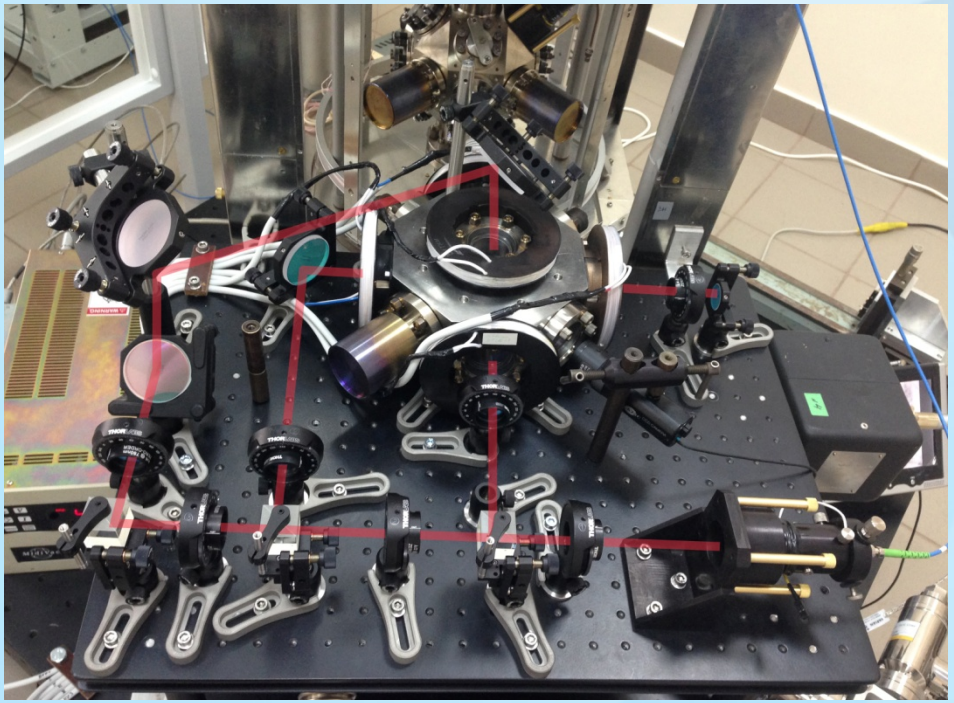
1) Time unit accuracy $\leq 1\times10^{-16}$;
2) Allan deviation $\sigma_y(\tau)$ $1\text{-}2\times10^{-16}$ $10 \leq \tau \leq$ 30 days $(1\text{-}2)\times10^{-16}$.
3) Remote time scale transfer uncertainty 1.0-1.5 ns.

Time and frequency keeping system scheme on base of Rb Fountain



Time and frequency keeping system development on base of Rb Fountain for the standards of time and frequency

Optical part



Spectroscope

Project start date – 07.2012 г.
Project completion date– 12.2016 г.

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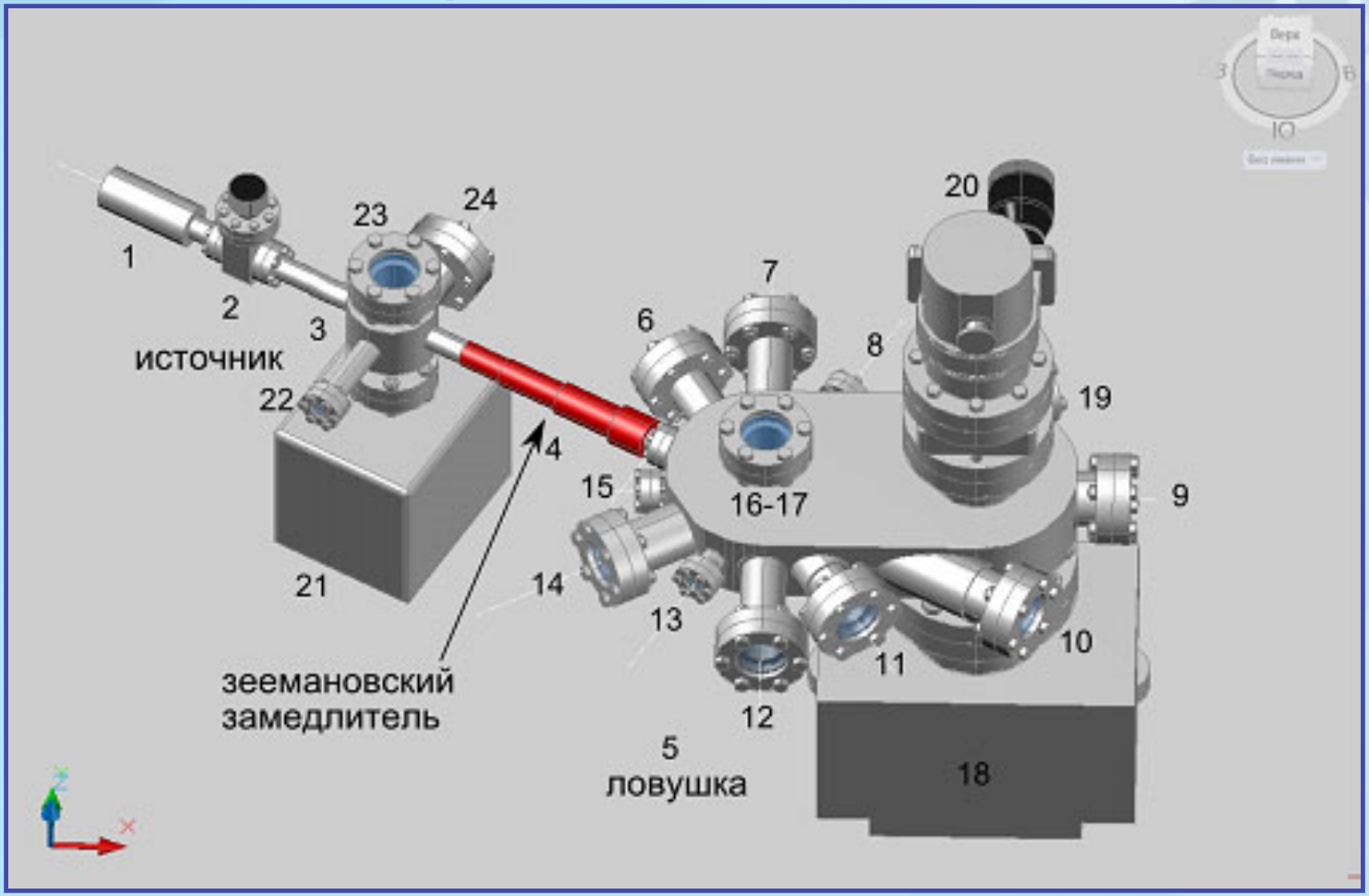
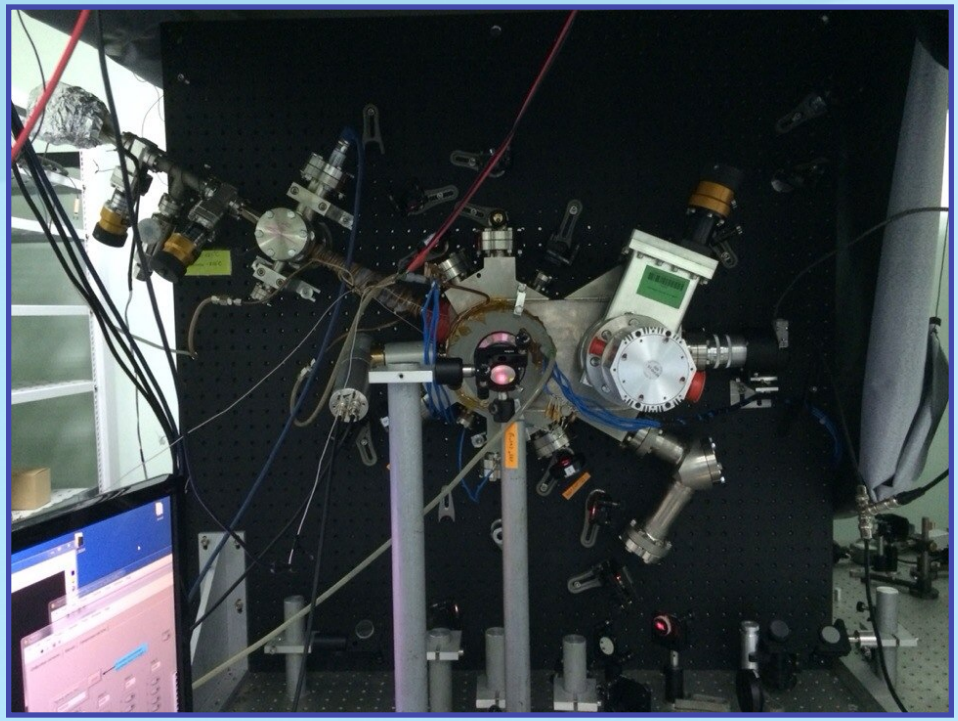
3-D model of the optical spectroscope

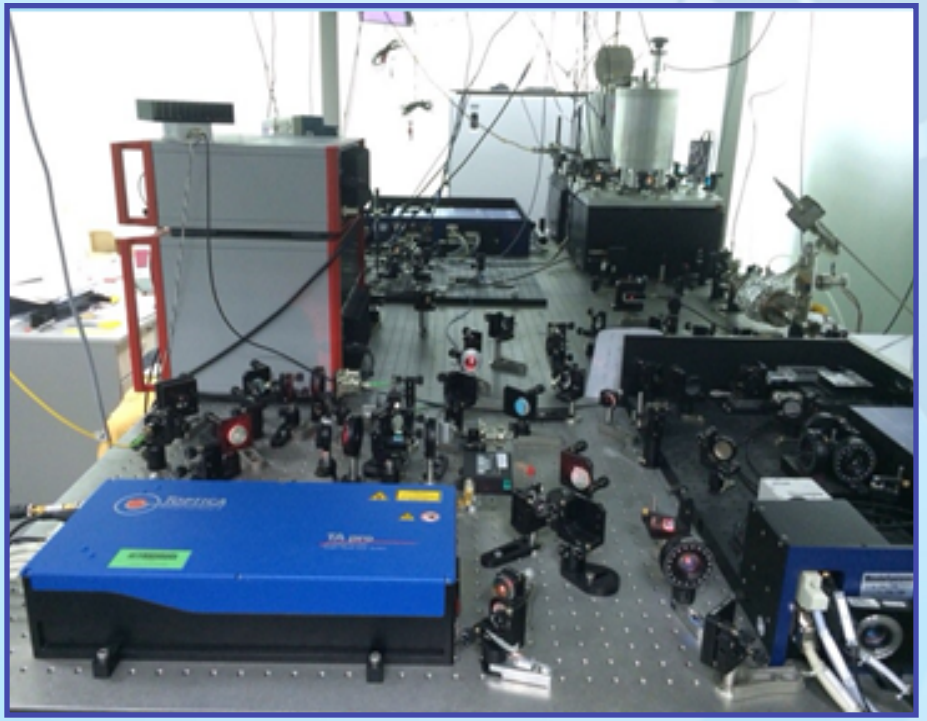
Four isotopes Sr: 88 (81%), 87 (7%), 86 (10%), 84 (2%)
Cloud formation temperature ~500 ^{0}C



Optical frequency standard on cold atoms development



Prototype system



Optical system for secondary cooling

Project start date – 07.2012 г.
Project completion date– 12.2016 г.

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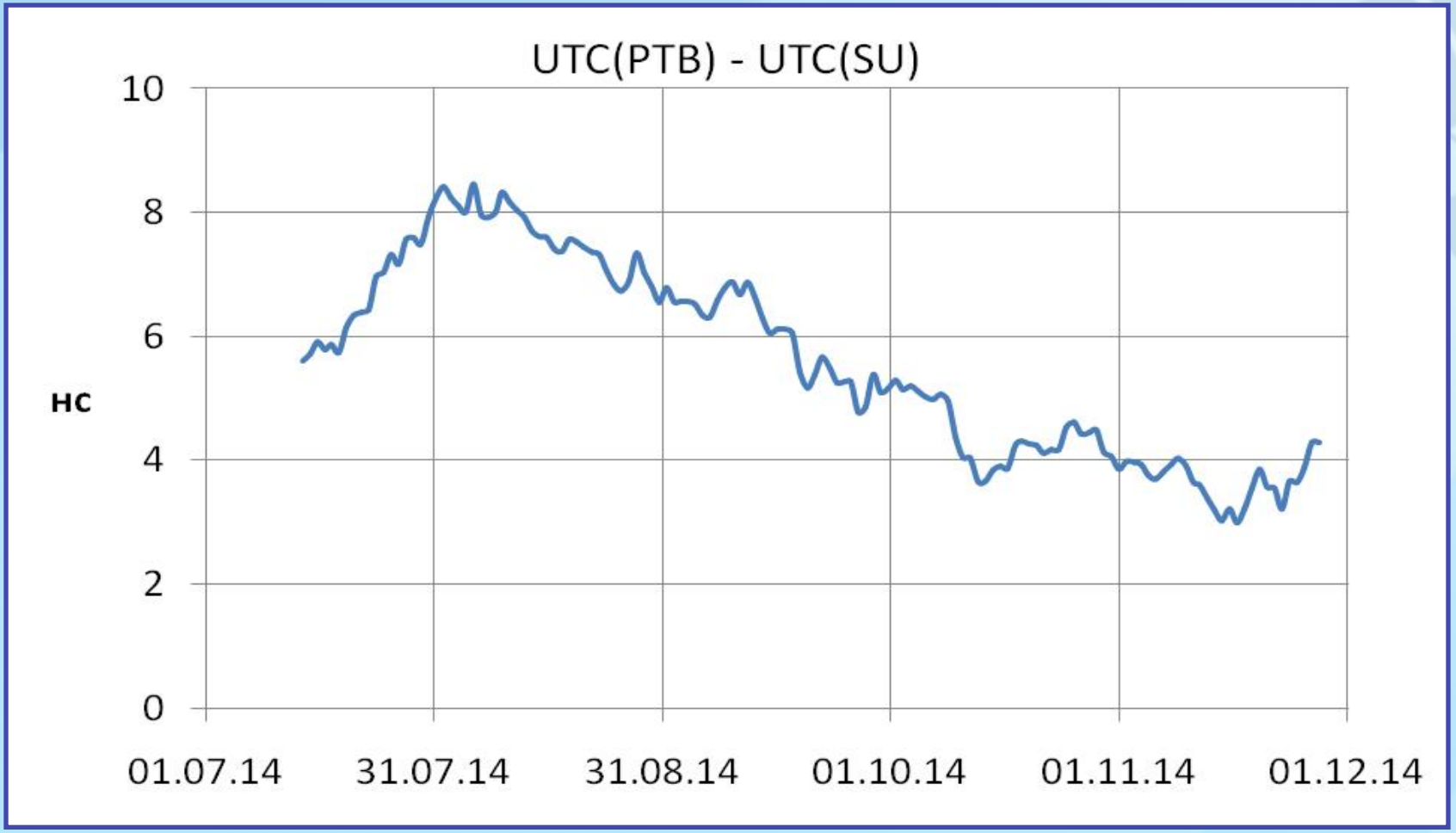
Results of UTC(SU) and UTC(PTB) comparing using TWSTFT



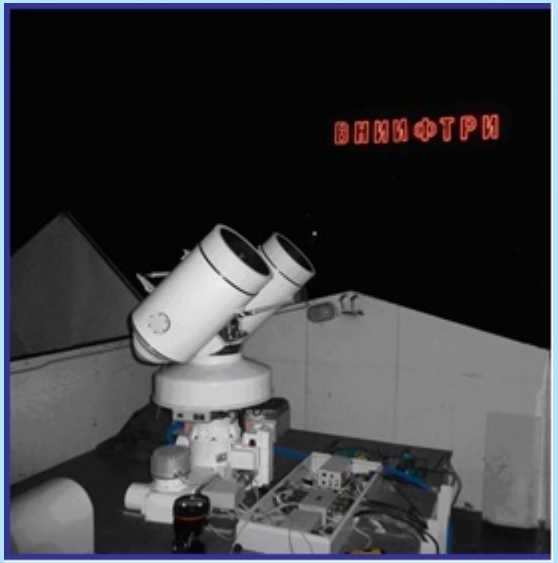
Circular T 322 BIPM (октябрь 2014)
TWSTFT link VNIIFTRI - PTB :
uA < 0,5 ns uB < 1,1 ns

Stationary and mobile GLONASS metrological assurance complexes development in the field of radio-technical measurements

- Stationary metrological assurance complex for GLONASS passive and active radio-technical measurement means characteristics evaluation
- Mobile metrological assurance complex for GLONASS passive and active radio-technical measurement means characteristics evaluation
- Stationary metrological assurance complex for navigation satellite measurement means characteristics evaluation
- Metrological assurance complex for navigation equipment characteristics evaluation

Project start date – 07.2012 r.
Project completion date– 12.2016 r.

Metrological assurance complex for GLONASS passive and active radio-technical measurement means characteristics evaluation



Modernized SLR system for pseudorange measurements in the optical range (accuracy 0,2 ns)

Stationary navigation parameters measurement means (accuracy 0,03-0,05 м)

Active H-maser (accuracy 7E-14 for 1 s; 7E-16 for 1 day)

NTFS UTC(SU)

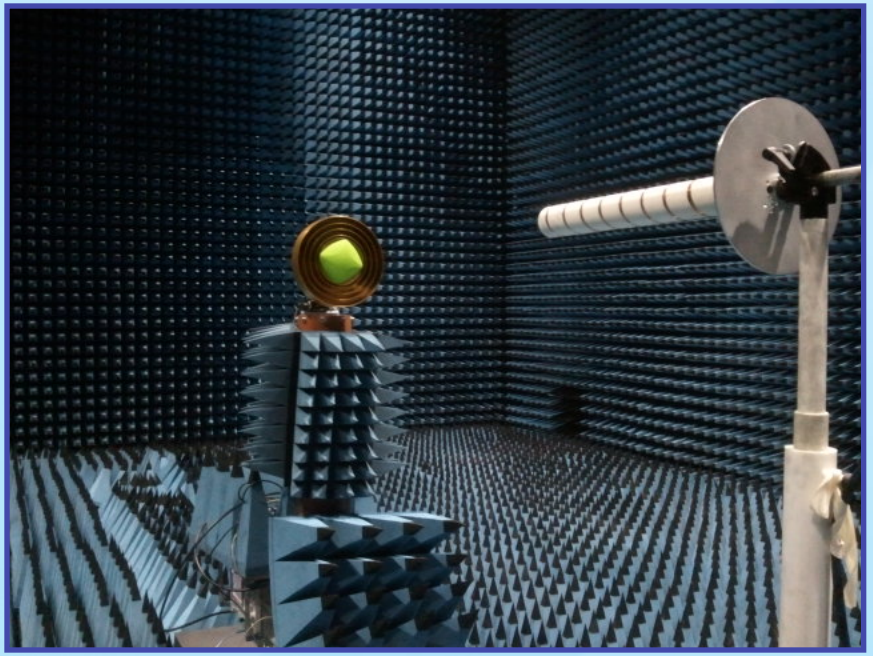
UTC(SU)

UTC(SU)

GLONASS passive radio-technical measurement means calibration

Imitation of GLONASS (L1, L2), GPS (L1, L2, L5), Galileo (E1, E5ab, E6) signals; accuracy (RMS) of the absolute time delay measurement in the receiver no more than 0,1 ns.

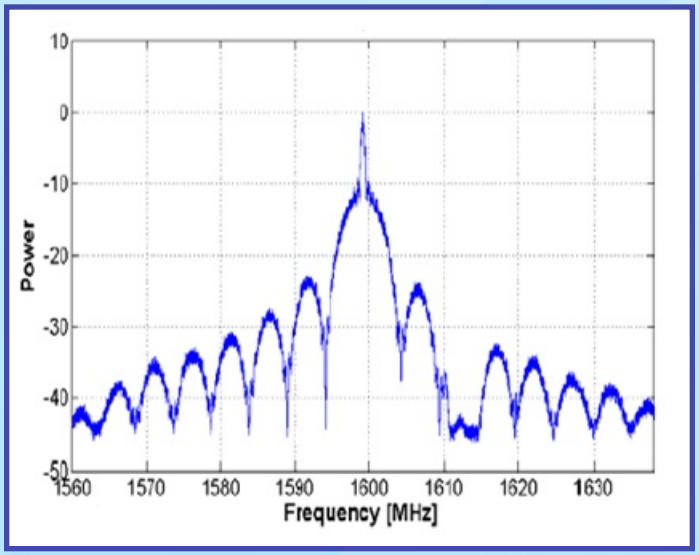
Size 19,5×13,7×8,9 m; reduction of external electromagnetic interference not less than 80 dB; anechoic factor for the working area no more than -35 dB in the frequency range from 1 to 40 GHz; accuracy (RMS) of the absolute time delay measurement in the antenna no more than 0,1 ns.



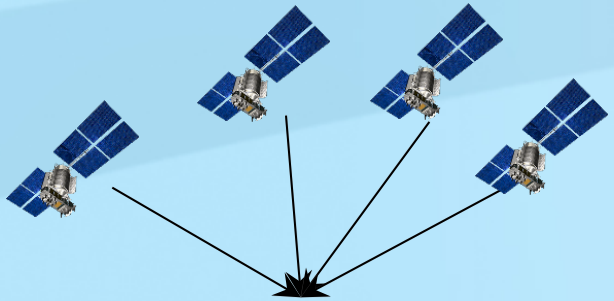
Metrological assurance complex for navigation satellite measurement means characteristics evaluation

Antenna system on base of the 12-m mirror antenna:

- GLONASS (L1, L3, L3), GPS (L1, L2, L5), Galileo (E1, E5ab);
- noise quality factor
  - 1200 MHz no less than 17 dB/K;
  - 1600 MHz no less than 19 dB/K;
- Signal to noise ratio no less than 35-40 дБ (for L1 range).



Metrological assurance complex for navigation equipment characteristics evaluation

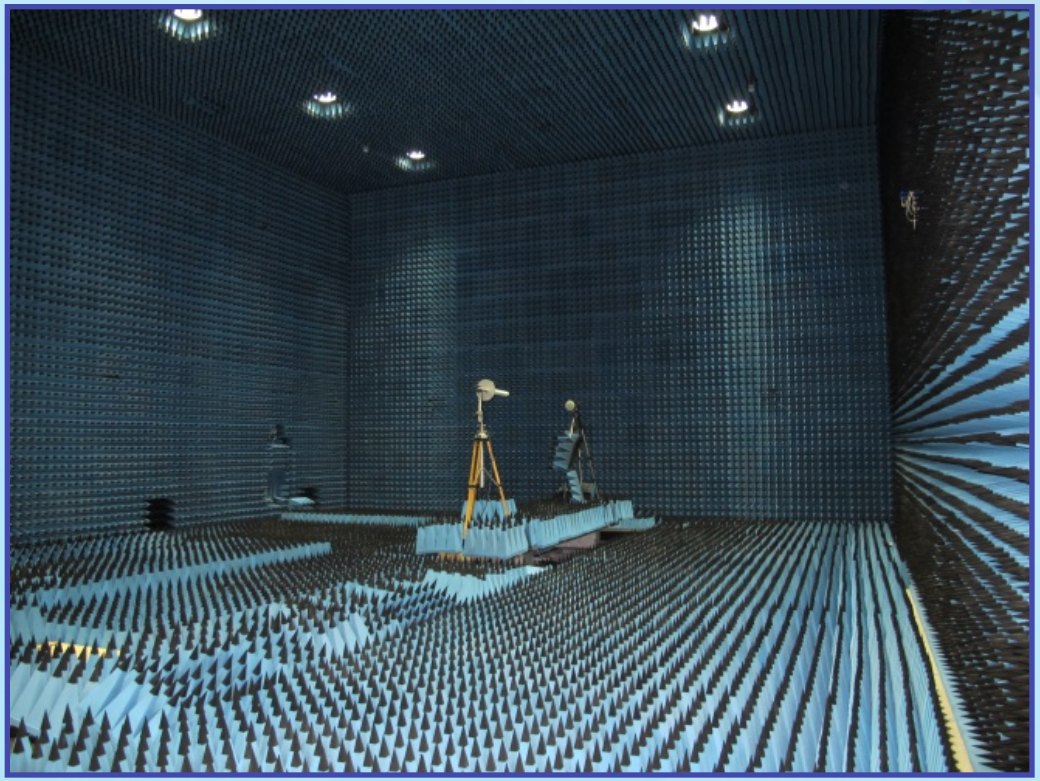


Mobile laboratory:

- Coordinate accuracy 0,01 м;
- Speed accuracy 0,01 м/с;
- Angle accuracy 6’.

Radio anechoic chamber, size 19,5×13,7×8,9 m (Class 1 GOST R 50414-92 level of shielding in the frequency range from 0,3 to 40 GHz) with artificial GLONASS/GPS navigation field:

- 24 GLONASS/GPS emitters;
- 6 noise emitters.



Conclusion

1. Time-frequency and metrological assurance complexes development for GLONASS system is an extremely important task for the development of the national global navigation system.

2. New generation of time and frequency standards being developed on base of the cold atoms “fountain” and on the use of the atoms optical cooling technology are on the front line of the scientific development in the field of time and frequency measurements.

Thank you for attention!

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