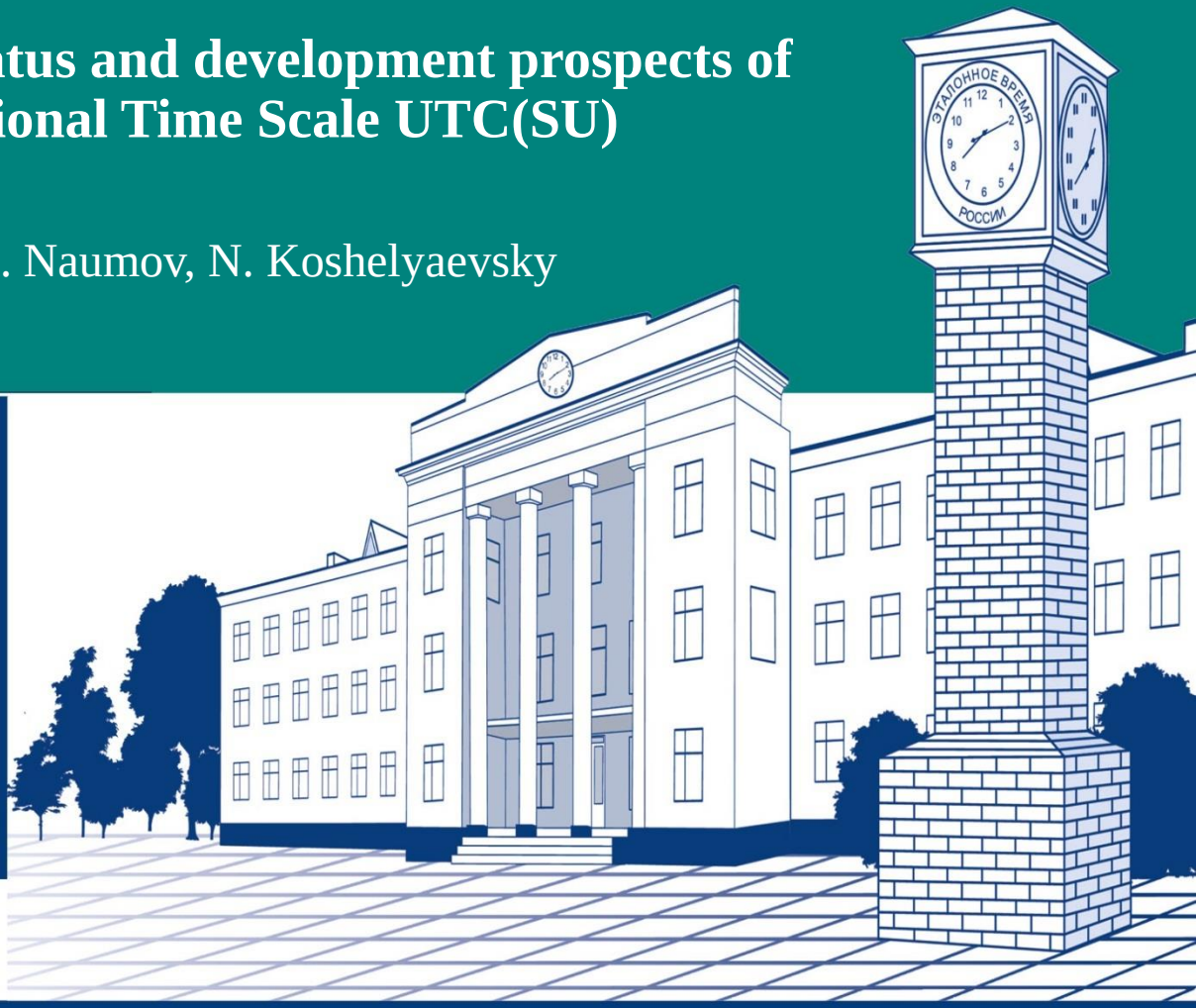
State Scientific Center
of the Russian
Federation

VNIIFTRI

National Research Institute for
Physical-Technical and Radio-Technical Measurements

Current status and development prospects of National Time Scale UTC(SU)

A. Naumov, N. Koshelyaevsky



ICG-13

Xian, China, 2018

OUTLINE

1. Legal basis for calculation and transferring of the National Time Scale UTC(SU) and the primary time and frequency standard New clock ensemble
2. Cs fountain standard
3. ^{87}Sr neutral atoms in an optical lattice frequency standard
4. Rb fountain frequency standards
5. Keeping complex of national time scale
6. Time and frequency transfer techniques based on different technologies

Legal basis for calculation and transferring of the National Time Scale UTC(SU) and the primary time and frequency standard

Federal Law "On the calculation of time» № 107-FZ of 04.03.2011

National Time Scale of the Russian Federation - an ordered sequence of numbers of units of time, reproducible and stored by the State Service of Time, Frequency and Earth's Orientation Parameters on the basis of the State primary standard of time, frequency, and the National Time Scale.

Interface control document GLONASS ICD 05.01, March 2008

Reference time scale for the GLONASS system is a national coordinated time scale UTC(SU).

Government Decree № 323 of 30.04.2008

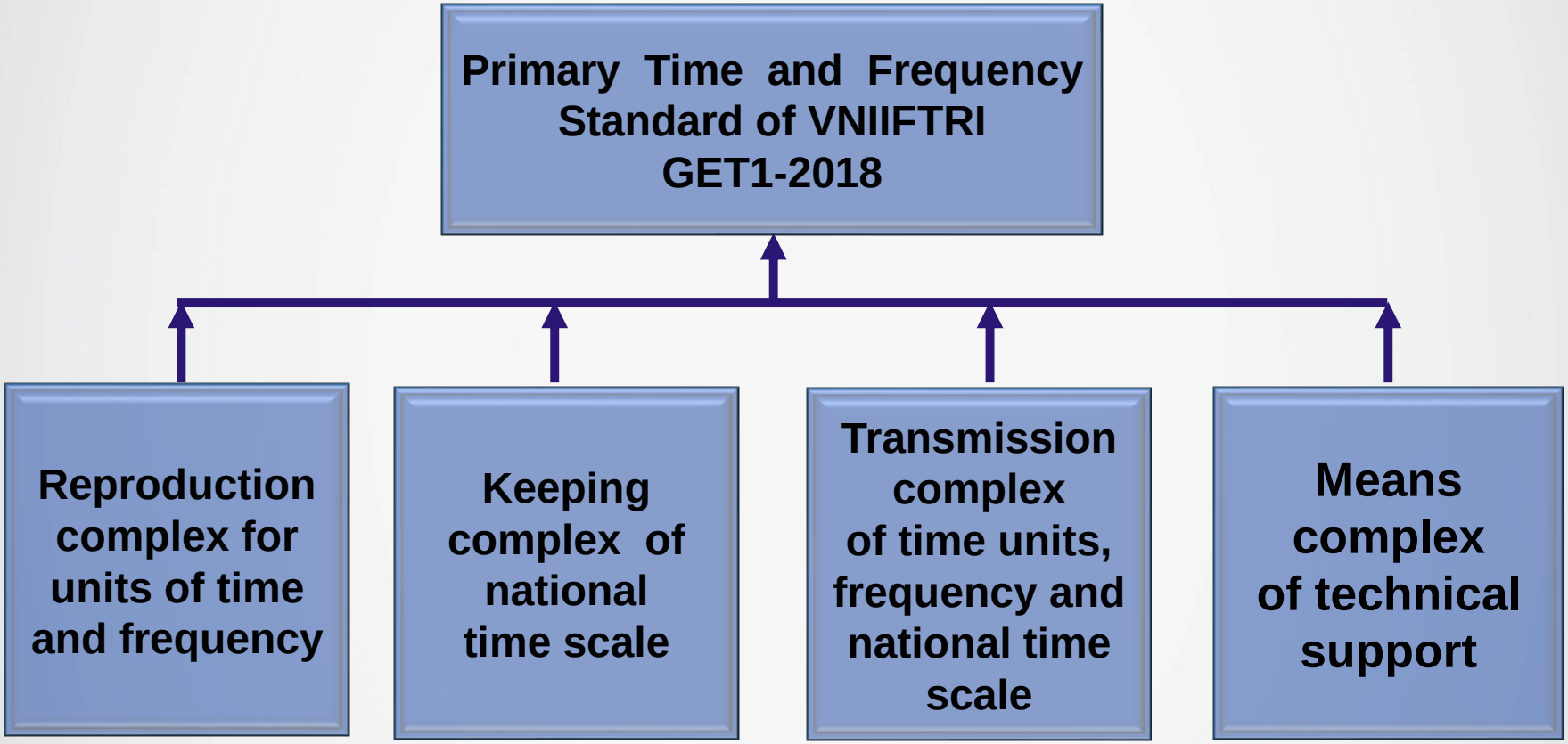
Federal Agency for Technical Regulation and Metrology carries out support for GLONASS reference values of time and frequency, the National Time Scale and the Earth's Orientation Parameters data.

Primary and Secondary Time Standards of Russia

Our closest goal within 3-4 years is to re-equip primary and secondary laboratories.

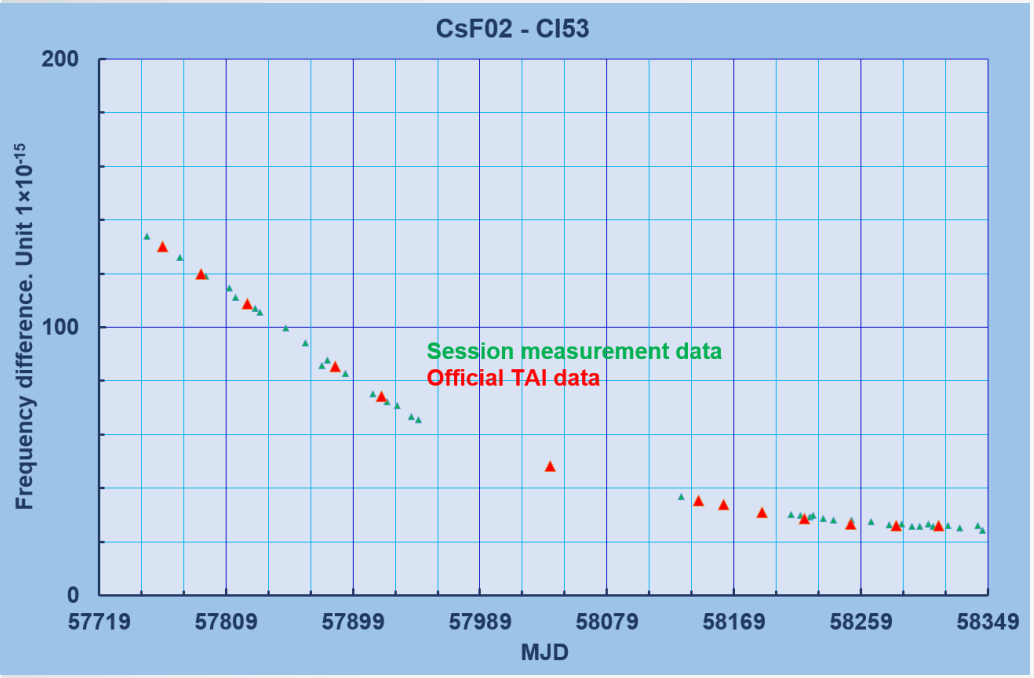
Apart from H-maser ensemble all laboratories will be equipped with a new set of GNSS receivers and TWSTFT stations. As a result we hope to be able maintain time scale basing on ensemble of 20 to 30 H-masers.

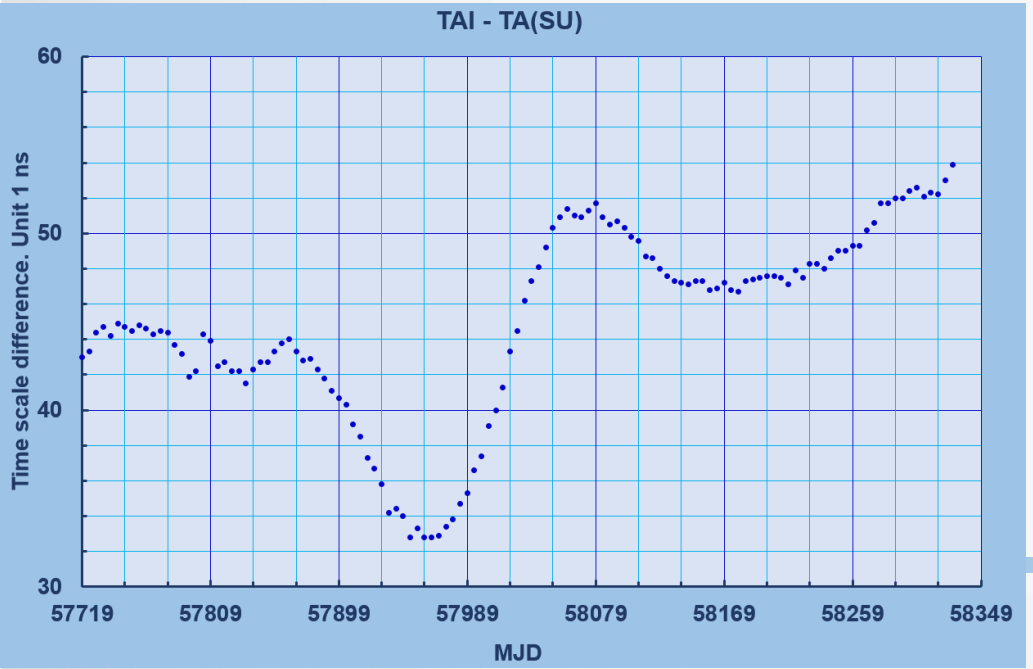
Primary Time and Frequency Standard



The new National Time and Frequency Standard of Russian Federation in pursuance of Decree No. 600 dated 02 April 2018 of Federal Agency on Technical Regulation and Metrology has been commissioned

TA(SU) referring purely on primary Cs fountain standard





- Cli frequency predicttion is based on official one reading per month data delivered to the BIPM as contribution to the TAI;
- 10-11 month estimation period and 1 month ahead prediction;
- For some clocks due to essentially nonlinear drift and some times lack of data more or less accurate prediction was very sophisticated and looked like a guess-work.
- The whole clock ensemble is involved in TA(SU) forecast to full extend by means of weighting procedure
- Particular clock contribution to TA(SU) depends on clock's statistical weight;
- Clock's statistical weight is composition of a few components:
  - ➢ the proximity of successive clock's frequency prediction relative to primary fountain standards (the main contribution);
  - ➢ clock's frequency prediction uncertainty relative to primary standards;
  - ➢ clock's frequency prediction uncertainty relative to TA(SU);

SU CsFO2 $Ub^{6} \leq 5 \cdot 10^{-16}$

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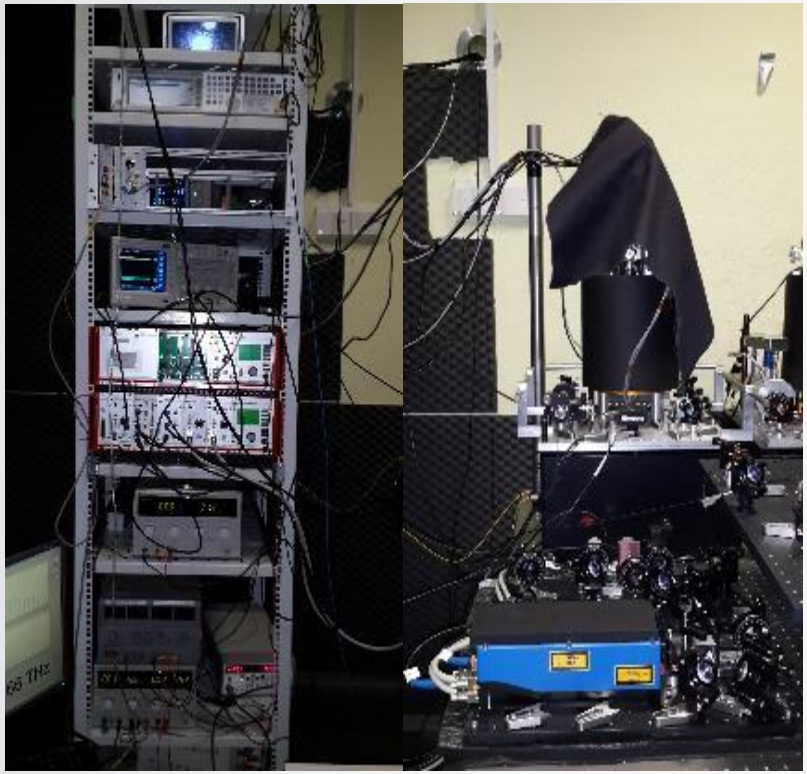
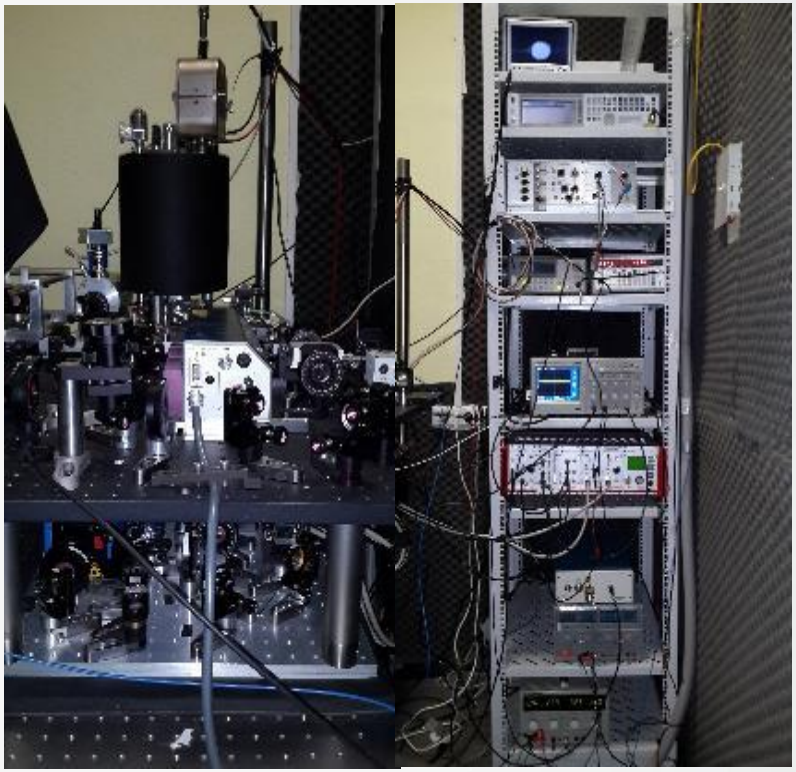
^{87}Sr neutral atoms in an optical lattice frequency standard



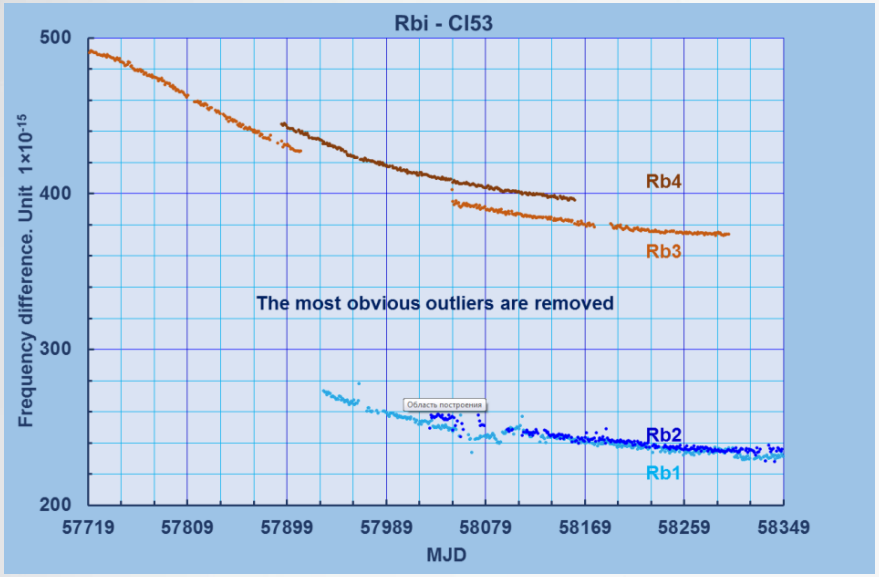
Secondary cooling laser frequency stabilization system on high Q ULE-cavity and control rack



ULE-cavity, clock transition laser frequency stabilization system and control rack

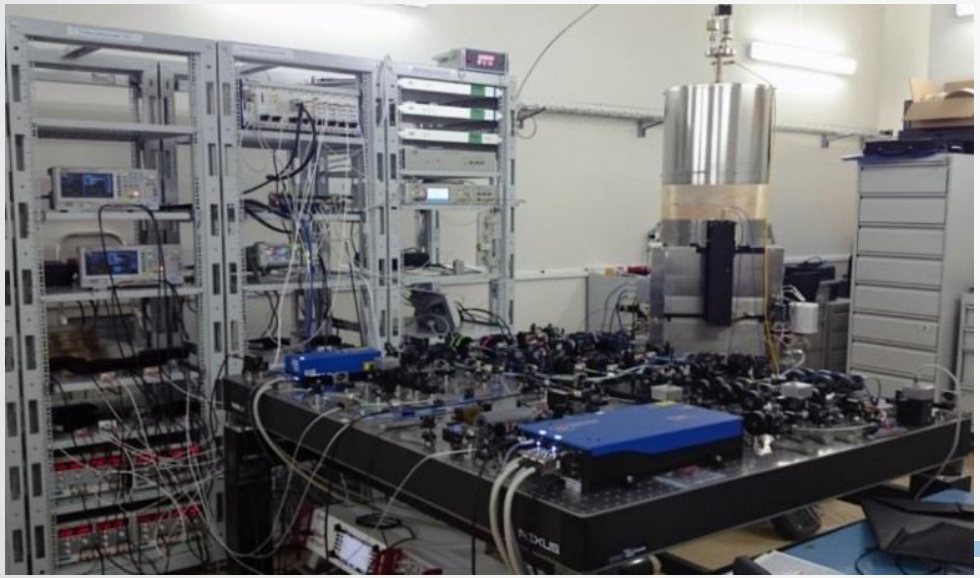
$Ub \leq 1 \cdot 10^{-16}$

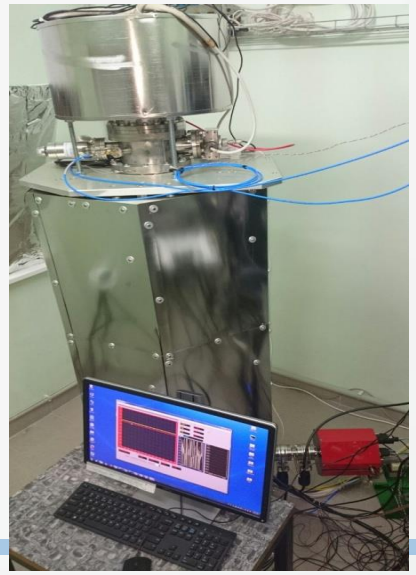
Rb fountains standards and new opportunities



Rb fountain standards offer new opportunities:

- these standards work continuously and produce Rb-Cli measurement data at one day basis;
- such a dense data stream offers new opportunity for clock frequency prediction;
- one may get Cli frequency prediction one day ahead basing on 3 months estimation period;
- despite one day Rb – Cli frequency readings are scattered within $(6\text{-}7)\times10^{-16}$, RMS of 1 day predictions $\sim(1\text{-}2)\times10^{-16}$, so comparable to frequency stability of the best H-maser;





Keeping complex of national time scale

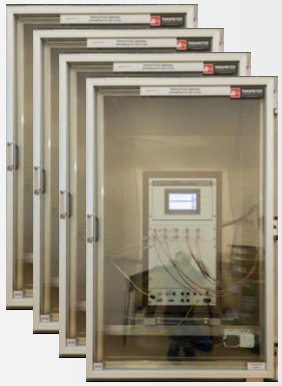
The complex is designed for keeping time and frequency units, providing both internal and external comparisons of the standard, forming working time scales, calculating the national atomic time scales TA (SU) and UTC (SU).

The complex includes:

- H-masers CH-75A-01 (8 units);
- H-masers CH1-1033 (4 units);
- New H-masers (4 units);

$\sigma_y(\tau) \leq 5{,}0 \cdot 10^{-16}$, $\tau = 1$ day

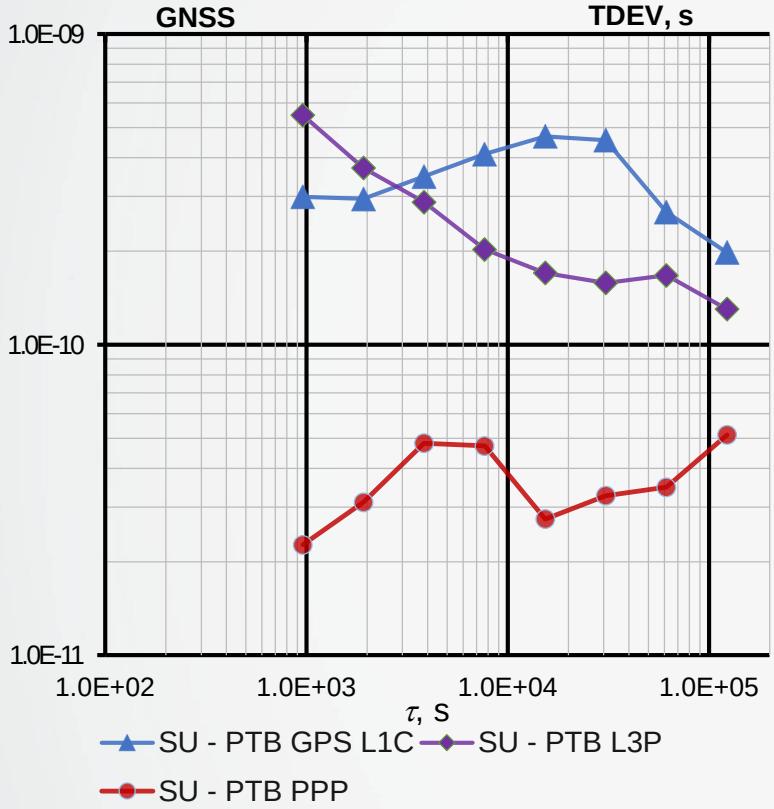
$\sigma_y(\tau) \leq 7{,}0 \cdot 10^{-14}$, $\tau = 1$ s



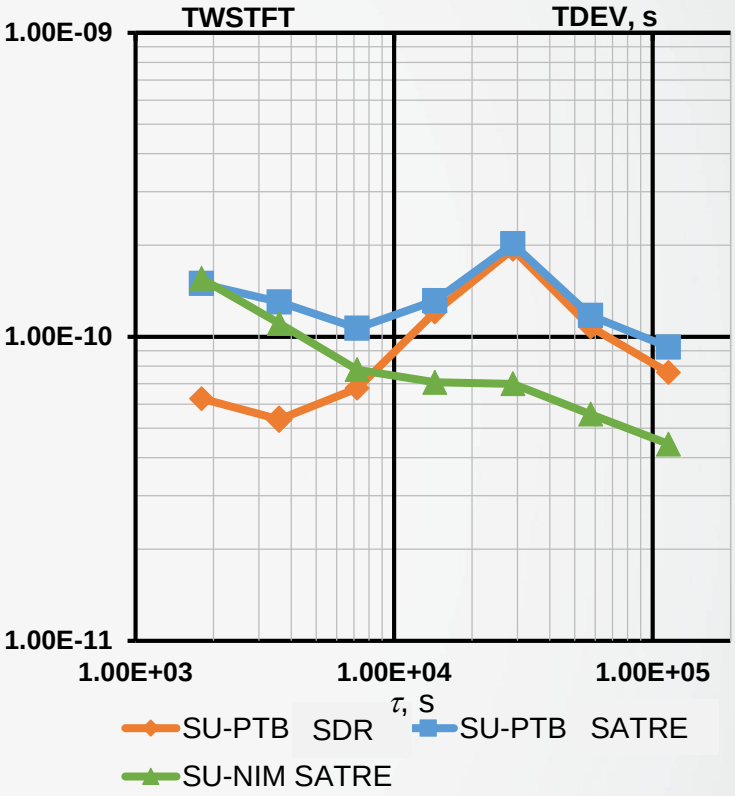
$\sigma_y(\tau) \leq 3{,}0 \cdot 10^{-16}$, $\tau = 1$ day

Results of comparisons for UTC(SU) using GNSS and TWSTFT

T&F transfer GNSS receivers



TDEV: L1C < 200 ps; PPP < 50 ps



TDEV: SATRE < 100 ps; SDR < 100 ps

T&F TWSTFT equipment

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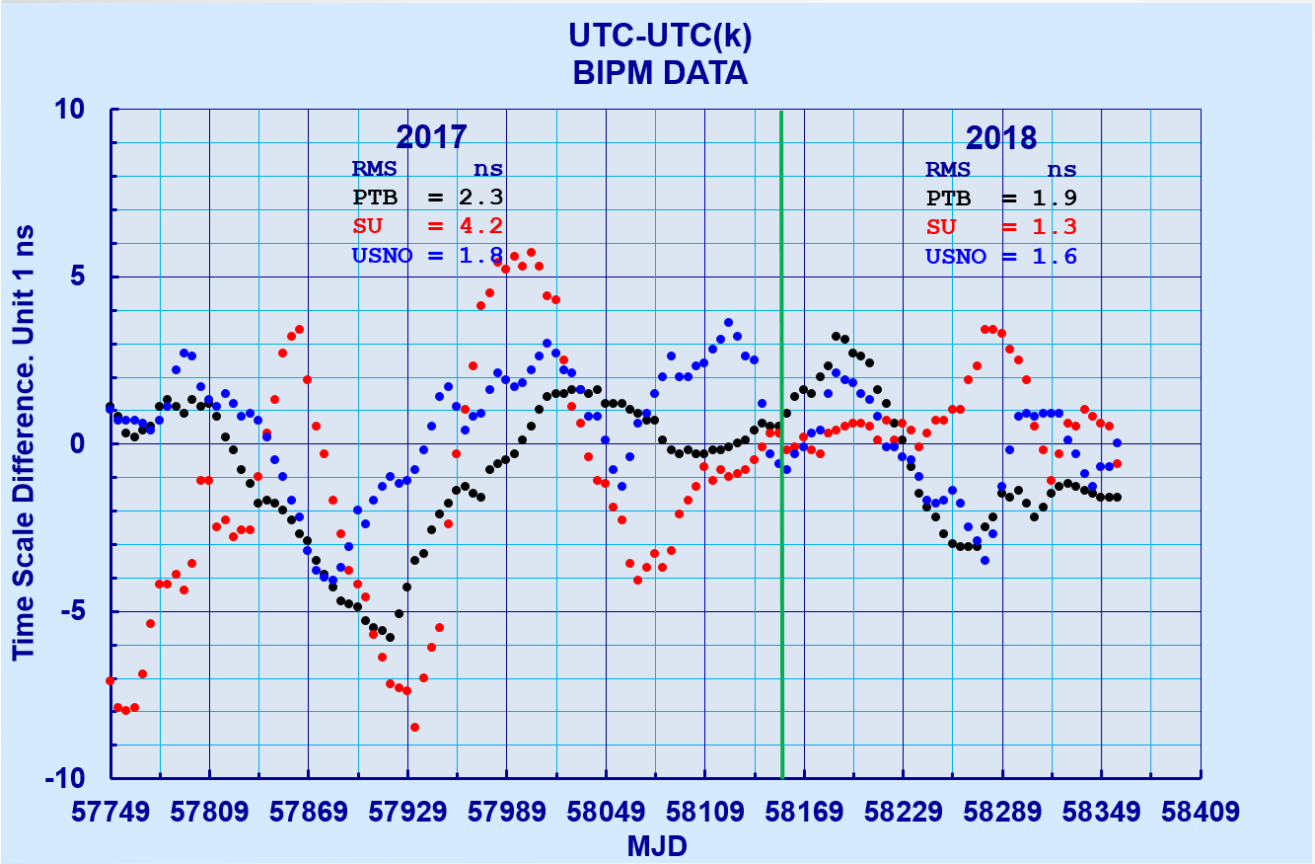
New results for the National time scale UTC(SU)



Strictly speaking the main goal of any national time keeping laboratory is to insure national real time realization UTC(k) of the world time reference scale UTC. The existence of local independent and stable TA(k) is only mean to get such a result. This picture demonstrates considerable progress in maintenance UTC(SU) in 2018 when Rb fountain standards (not the whole ensemble) were used generate TA(SU).

What has to be done to use the whole ensemble of Rb fountain standards to full extend?

- first of all Rb fountain standards MTBF (mean time before failure) has to be considerably improved;
- mean restoration time has to be essentially reduced, let us say about weeks;
- all available Rb fountain standards have to be regularly calibrated relative to primary Cs standards;
- TA(SU) operational software has to be updated and include module which will realize ensemble time unit keeper basing on all available Rb fountain standards.

Development Prospects of National Time Scale UTC(SU)

1. Modernization of the National Time Scale keeping complex to ensure consistency of comparison UTC(SU) - UTC with error no more than ± 3 ns
2. Developments of high-precision time comparison links to compare UTC(SU) with GLONASS System Time and other time laboratories
3. Studies on the creation of a high-precision links for transferring reference time and frequency signals over a fiber-optical lines
4. Improving of reproducing and keeping units of time and frequency in order to achieve the tactical and technical characteristics of the GLONASS system for year 2020
5. Improving the time scale comparison equipment and methods for geographically remote time standards comparison
6. Improvings of the time scale algorithms calculations

Summary

- Primary Time and Frequency Standard includes:
  - H-masers CH-75A-01 (8 units);
  - H-masers CH1-1033 (4 units);
  - New H-masers (4 units);
  - Rb fountains (4 units)
  - Results for T&F transfer instruments are presented.

- UTC(SU) realization is corresponding to requirements of CCTF;
- Development and investigations directions of the primary State Time and Frequency Standard of Russia are presented;
- The new complex is designed for keeping time and frequency units, providing both internal and external comparisons of the standard.

Thank you
for your attention