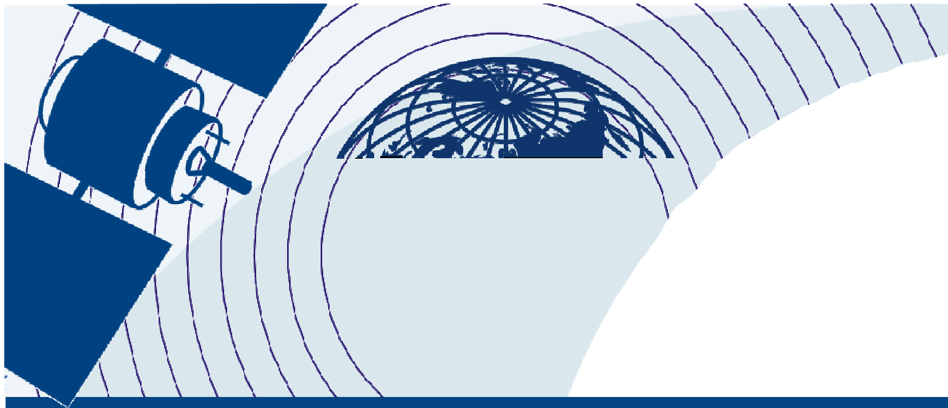


Legal Status of the State Service for Time and Frequency

According to Article 10 Statute of the State Service for Time and Frequency (SSTF):

"The SSTF Information on Time, Frequency and the Earth Orientation Parameters is obligatory within territory of the Russian Federation".

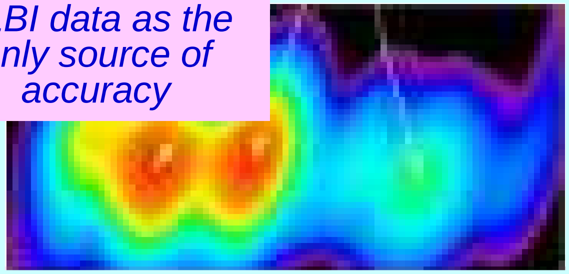
SSTF produces and disseminates at regular basis, including for GLONASS, following information:

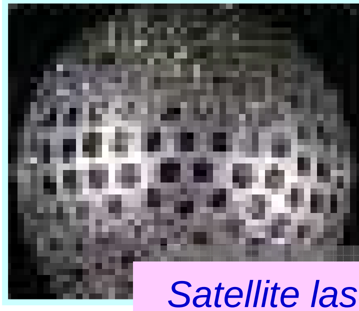
- Time scale difference between UTC and National Time Scale UTC(SU).
- Time scale and frequency difference between UTC(SU) and UTC (secondary laboratory).
- Time scale difference between UTC(SU) and GPS/GLONASS System Time.
- Daily, Weekly and Monthly EOP data.

Universal Time and the Earth Orientation Parameters

➢ *Data Sources and Storage*

VLBI data as the only source of accuracy



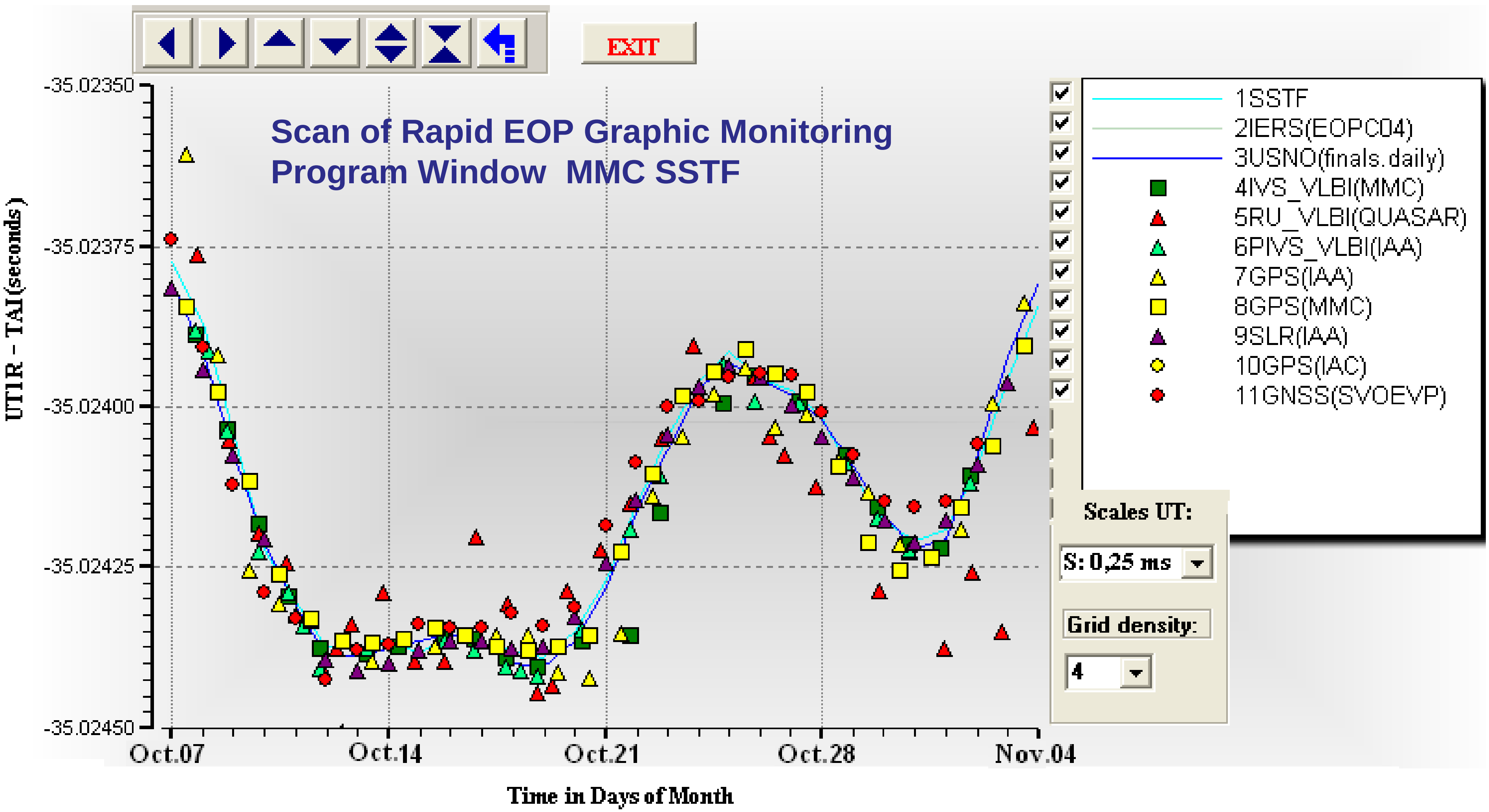


Satellite laser ranging data

GNSS phase carrier data is the most rapid and precise source

Daily EOP data
Weekly EOP data
Monthly EOP data
SSTF EOP data are in a good agreement with IEOS ones

(RMS UT < 0,027 ms)
(RMS Pole Coordinates < 0,0002”)



SSTF – Russian State Service of time, frequency and EOP

blue line – combined values of SSTF

red triangles – values which obtained by Russian interferometric network «QUASAR» from Russian sessions ONLY

MMC - Main Metrological Center of SSTF

IVS_VLBI - IVS VLBI sessions

The main achievements of the modernization campaign of the State Time and Frequency Standard

The primary Cs fountain standard

Two operational ensembles each of four H-masers in environmentally controlled chambers

New clock’s model for timescale generation

Free Atomic Time Scale

Upgrading of the secondary laboratories

New instruments and calibration activity in operational time transfer system

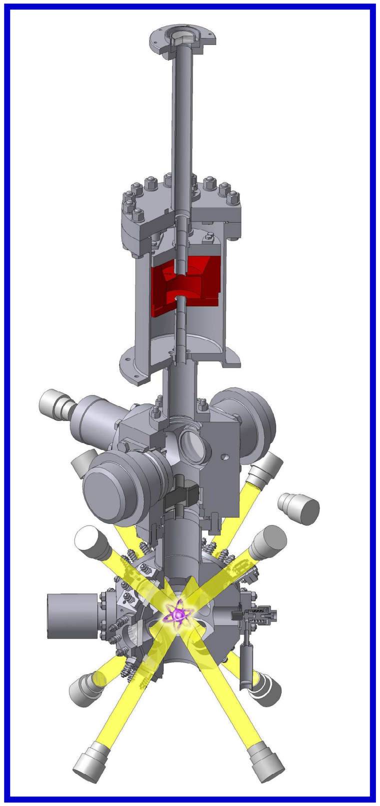
TWSTFT stations status

The primary Cs fountain standard

Heating & evacuation of the fountain physical package

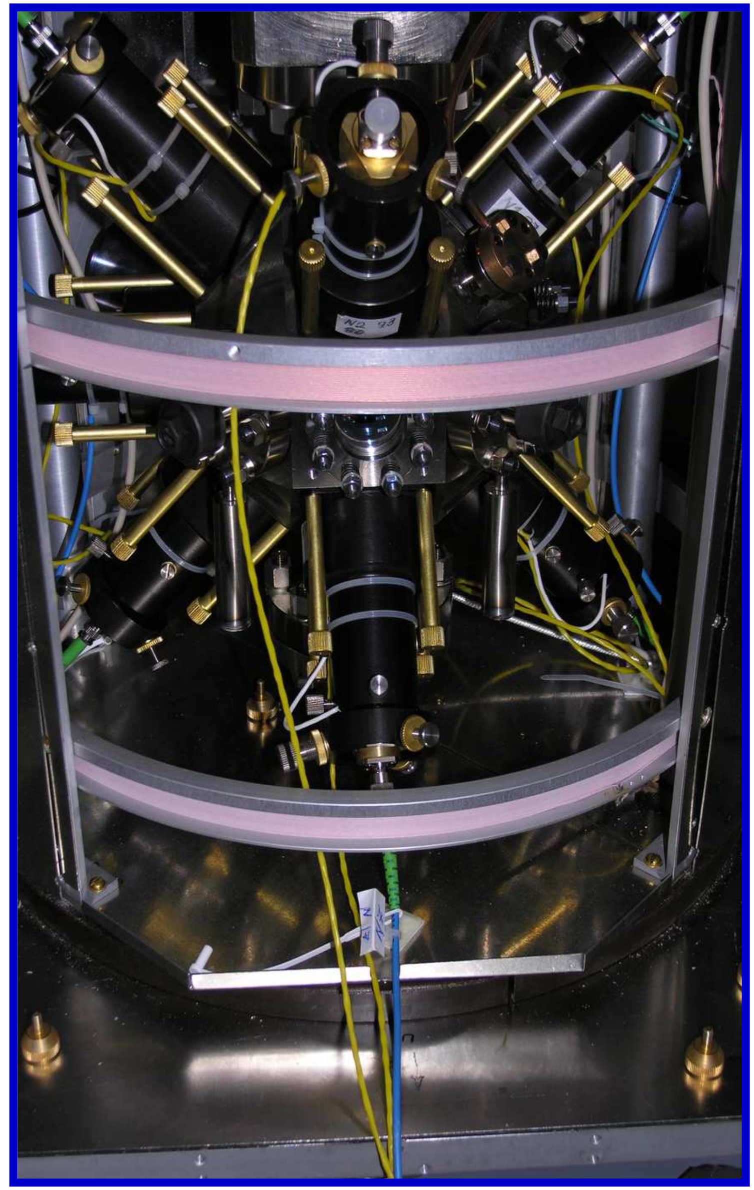
Assembling of the fountain mainframe & magnetic shield

Atomic fountains at VNIIFTRI

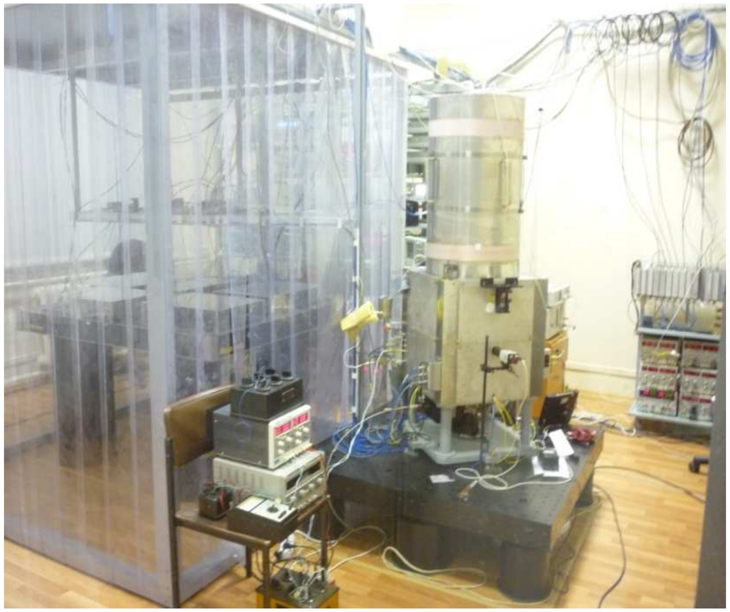


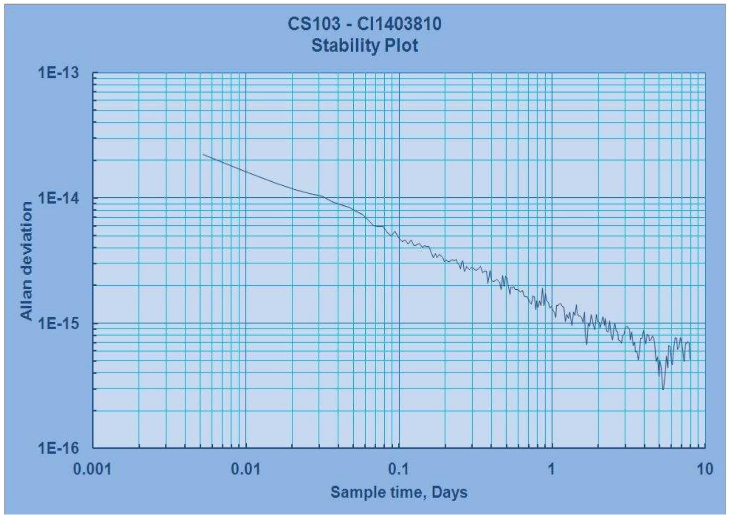
$\Theta_0 \sim 3x10^{-15}$ – 2009 .

$\Theta_0 \leq$ $5x10^{-16}$ – 2011 .



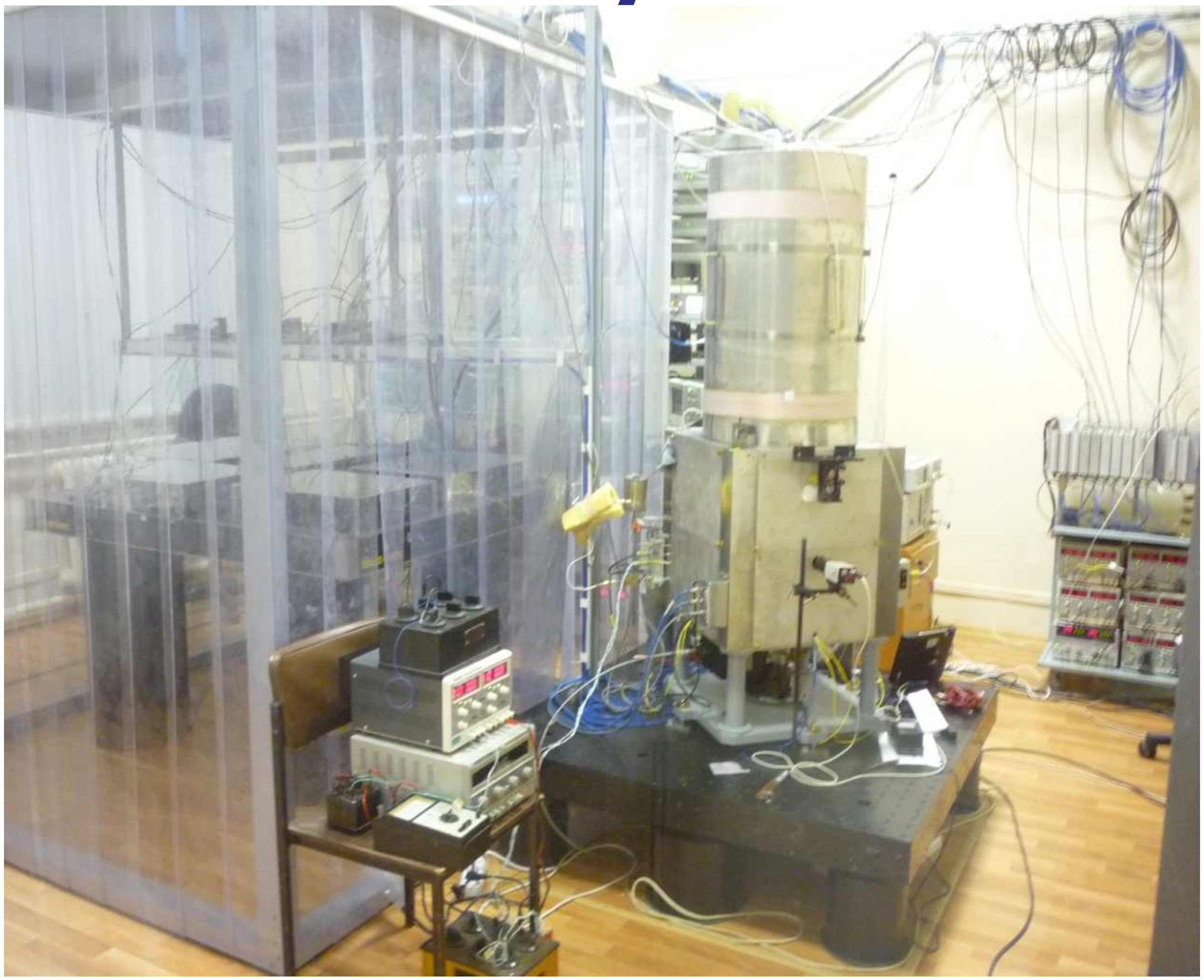
Investigations and status of fountain primary Cs standards

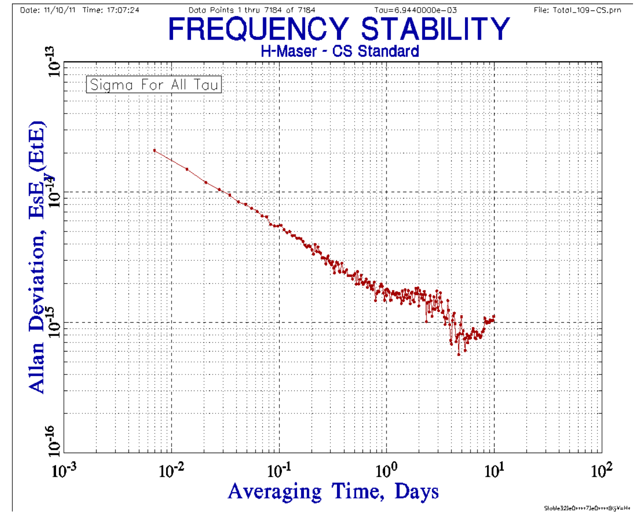


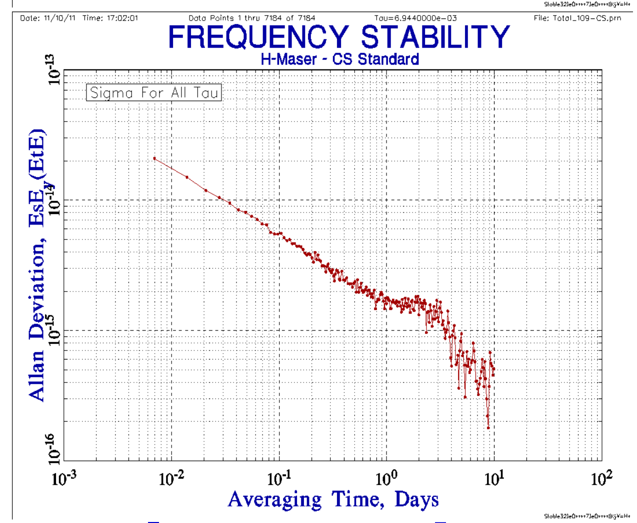


- Today in new laboratory building in thermo controlled rooms we have two standards: CS 103 and CS 105. General view of CS 105 is depicted below.
- At the end of 2011 an accuracy of CS 103 was evaluated as 4.8×10^{-16}. Later for practical purpose the number of low density atoms have been doubled . At present CS 103 errors budget is evaluated as 6×10^{-16}. CS 105 accuracy is evaluated as 1×10^{-15}.
- Recent comparison of SI time unit repro-duced by CS 103 during MJD 56104-56139 relative to that published in Circular T 295 coincided within $(8\pm7)\times10^{-16}$.
- The attached picture presents Allan freque-ncy deviation of Cs 103 relative to H-maser clock # 1403810 measured for the period of MJD 56104-56139.

Primary Cs Fountain Standard







CS fountain standard operates continuously more than one year.

ENSEMBLE of H-MASERS

- The clock ensemble will be based on new generation of H-masers.
- New H-maser cavity auto tuning system. H-masers will become all-sufficient instruments and may operate alone.
- Total number of clock have to amount to twelve instruments at 2014.
- σ_y(1 day) $\leq$ 5×10^{-16} - 2009;

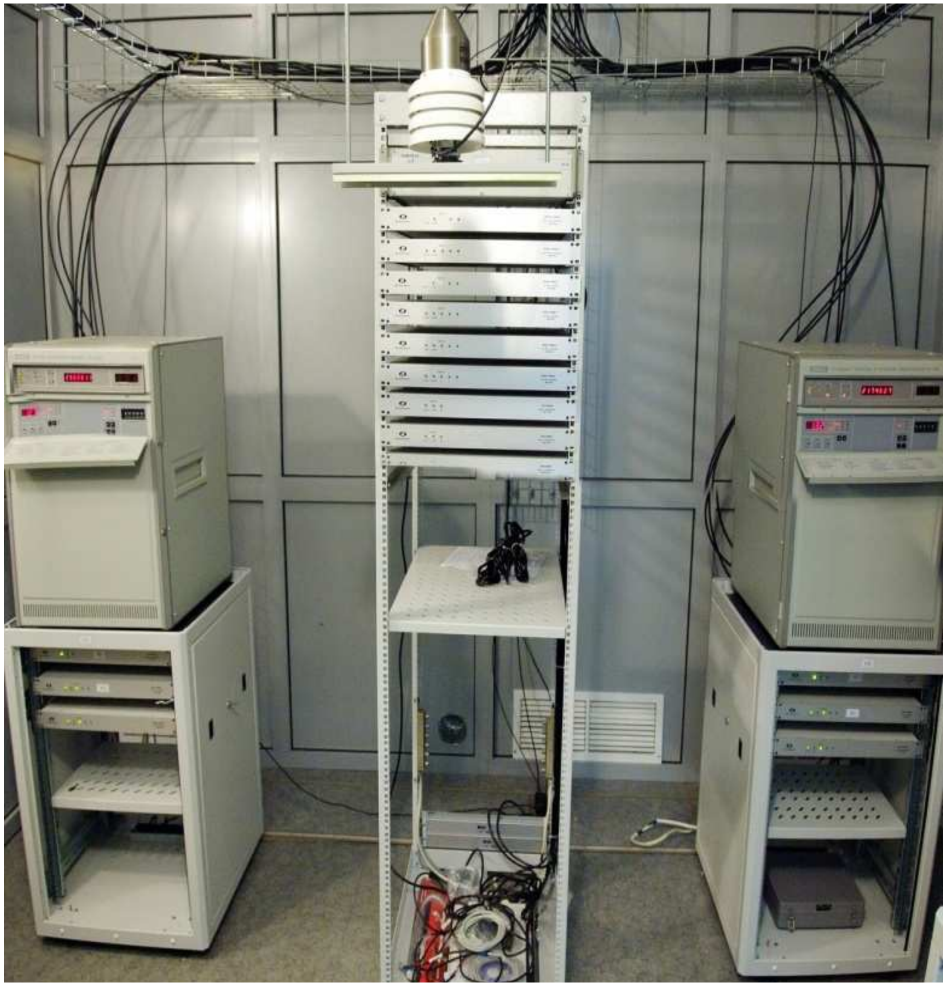
  $\leq$ 3×10^{-16} - 2011;

How to reduce or predict frequency drift?

Placing of H-masers in stable conditions will help to get more predictable behavior of clocks (smaller drift variation)

ВНИИФТРИ

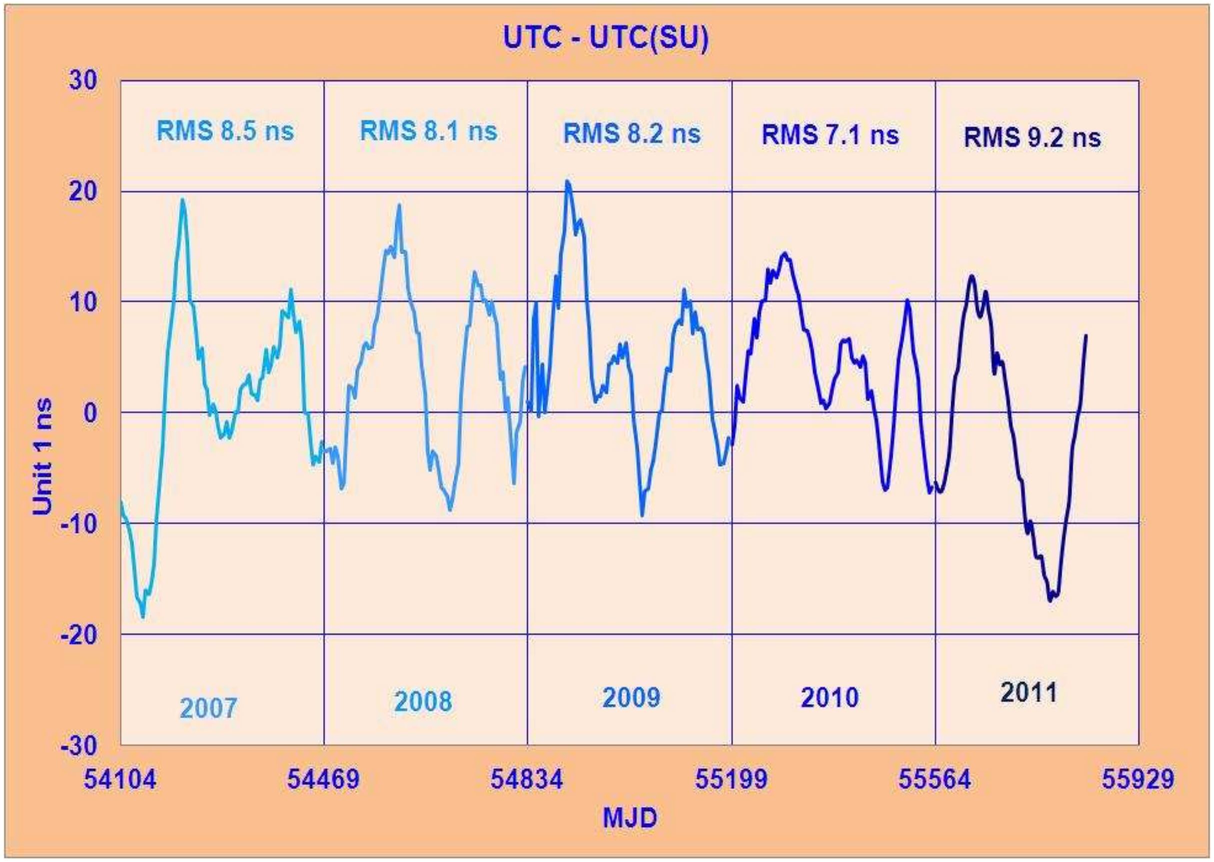
Two operational ensembles each of four H-masers in environmentally controlled chambers



The third chamber is under construction.

Individual frequency stability of the H-masers varies within $3\text{-}5 \times 10^{-16}$ for sample times 1 – 10 days

Operational ensemble of H-masers and UTC-UTC(SU)



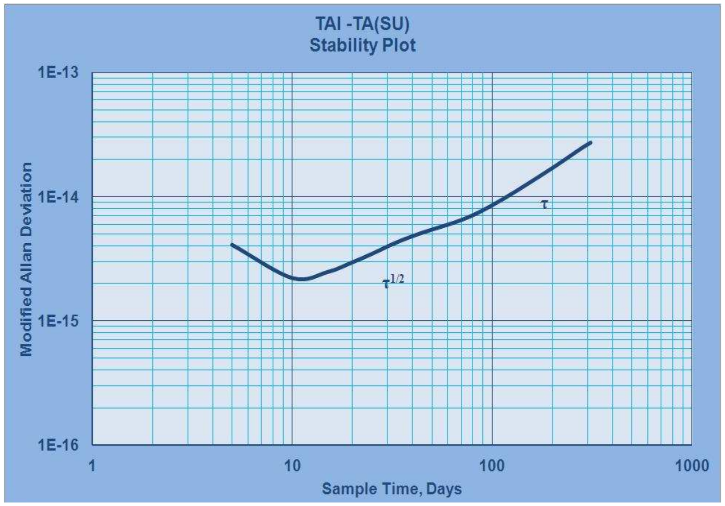
Two operational ensembles each of four H-masers in environmentally controlled chambers

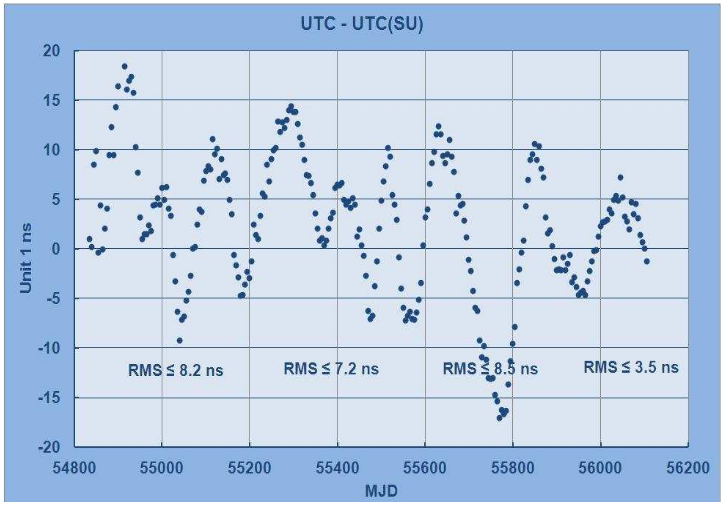
Frequency stability of the H-masers varies within 4-6×10^{-16} for sample times 1 – 10 days

Frequency drift of the H-masers 1-4×10^{-16}/day

Present time
RMS (UTC – UTC(SU)) ≤ 10 ns

UTC(SU) time scale maintenance





Operational activity

- The mainframe of time keeping instrumentation consists of H-maser ensemble. During 2009-2011 no considerable changes have happened in time keeping instruments - usual maintenance of H-maser's and inter comparison technique. Two time scales: coordinated UTC(SU) steered to UTC and free running TA(SU) continued to generate in conformity with algorithm introduced on MJD 53369 (30 DEC 2004).
- Because of TA(SU) have been based purely on free ensemble of H-masers clock ensemble manifested inevitable residual frequency drift. Despite this frequency instability of TA(SU) as compared to TAI σ_y (τ) $2\text{-}4\times10^{-15}$ $10 \le \tau \le 30$ days.
- UTC(SU) time scale have been steered to UTC at one month basis with RMS difference UTC-UTC(SU) ≤ 10 ns at least for last five years.

UTC(SU) time scale maintenance
New Time Scale Algorithm

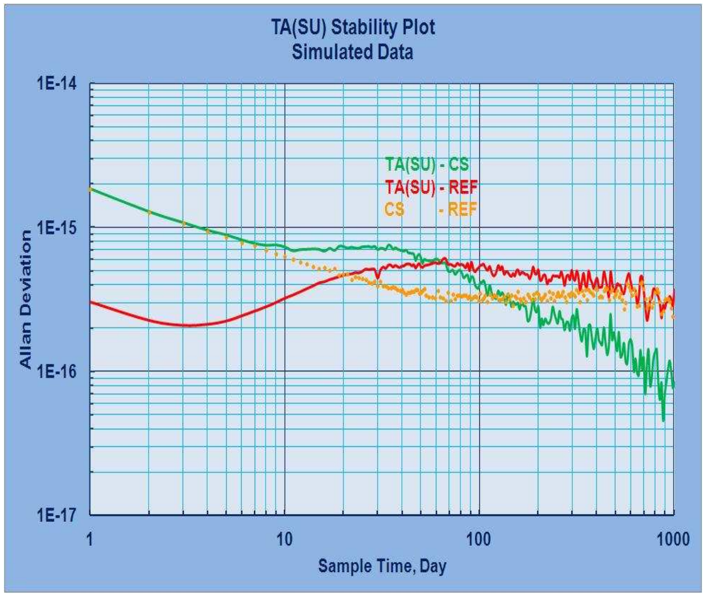
Implementation of two primary caesium fountain standards with uncertainty comparable to long term stability of the clock ensemble drastically changed possibilities for time algorithm to maintain atomic time scale TA(SU) and coordinated time scale UTC(SU).

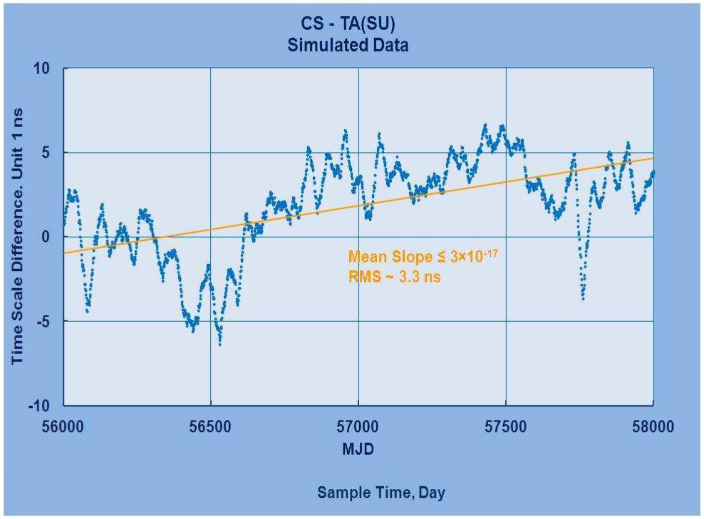
The new time algorithm based on the following principles have been developed:

- **the time unit reproduced by primary VNIIFTRI caesium fountain standards is kept by continuously operating H-maser ensemble;**
- **the time unit in TA(SU) corresponds to that SI(SU) reproduced by primary cae-sium fountain standards CS 103 and CS 105;**
- **atomic time scale TA(SU) is autonomous and independent;**
- **the coordinated time scale UTC(SU) is referred to TA(SU) as the most stable fre-quency source and by frequency steering corrections based on Key Comparison CCTF-K001.UTC UTC(SU) realizes time steering to UTC.**
- **time constants in the both algorithms are the same and equal to one month.**

UTC(SU) time scale maintenance

New Time Scale Algorithm (Test Results)

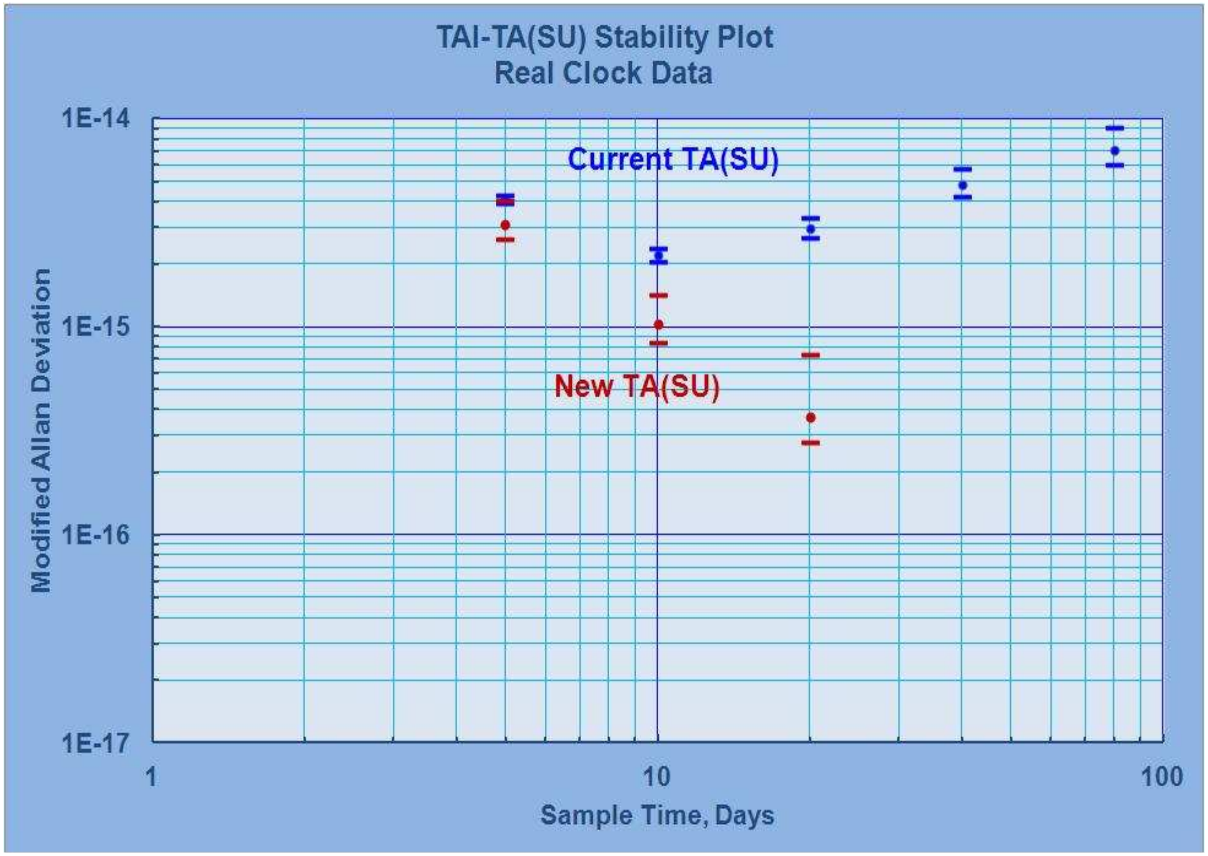




- **"Short" term stability (1 – 3 days) of TA(SU) - REF is de-termined by intrinsic H-masers instability and statistical averaging over ensemble.**
- **A bump at about one month which is in conformity to automatic frequency control theory and used value of time constant 1 month.**
- **For much more greater frequency stability estimations of TA(SU) - REF and CS - REF coincide and reach caesium estimations TA(SU) - CS for short time is limited by caesium fountain standards stability itself and for greater sample times demonstrate TA(SU) steering features relative to CS.**
- **In any case time algorithm stability analysis based on simulated data enables to expect marked improvement in TA(SU) stability up to level considerably better than $\sigma_y(\tau)$ 1×10^{-15}.**
- **Averaged TA(SU) and CS time unit difference $\leq 3\times10^{-17}$ demonstrates TA(SU) ability to keep time unit reproduced by primary caesium fountain standards without any degradation at least at level of stated CS 103 $u_B \leq 5\times10^{-16}$.**

UTC(SU) time scale maintenance

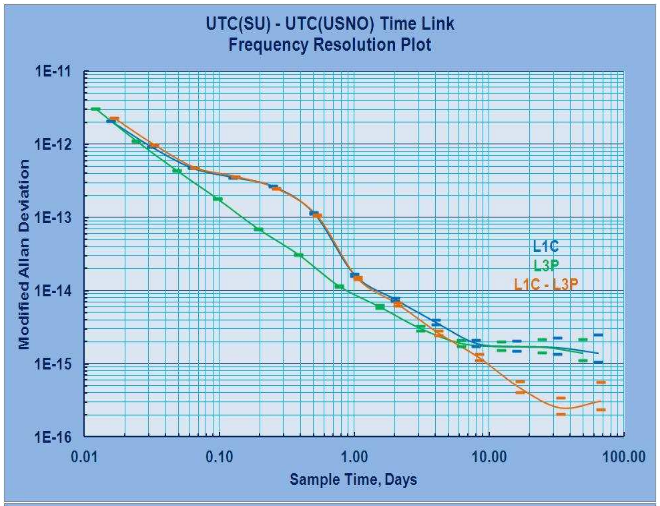
New Time Scale Algorithm (Real Clock Data)

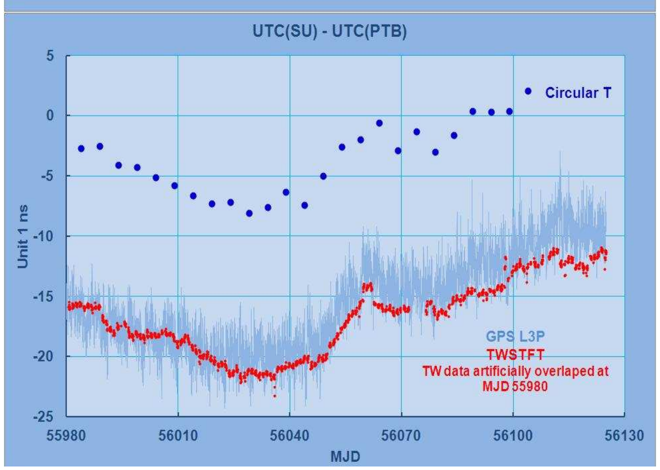


TA(SU) stability level obtained basing on real clock data and new algorithm for three months is in harmony with expectations within measurement uncertainty

Time transfer

GNSS and TWSTFT





GNSS

- Estimation of u_A uncertainty for long range time link between SU and USNO.
- VNIIFTRI TTS3#26 receiver (GPS C/A and P3)
- USNO AOS SRC TTS-2 #014 (GPS C/A) and ASHTECH Z-XII3T #RT920012203 (GPS P3).
- Second Difference

$\{[UTC(SU)-GPSST]-UTC(USNO)-GPSST]\}_{C/A}$

$- \{[UTC(SU)-GPSST]-UTC(USNO)-GPSST]\}_{P3}$

TWSTFT

- Experimental sessions with PTB and Far East, and South East laboratories continues more than half a year via AM2 satellite.
- TWSTFT data from VNIIFTRI till now are referred to not to UTC(SU) but to UTC(SU) Master Clock.
- Till now this link is not calibrated and can’t be used to contribute to TAI to full extend. Nevertheless even now with existing status this link may be used for primary CS standard frequency comparison.

SECONDARY TIME AND FREQUENCY LABORATORIES

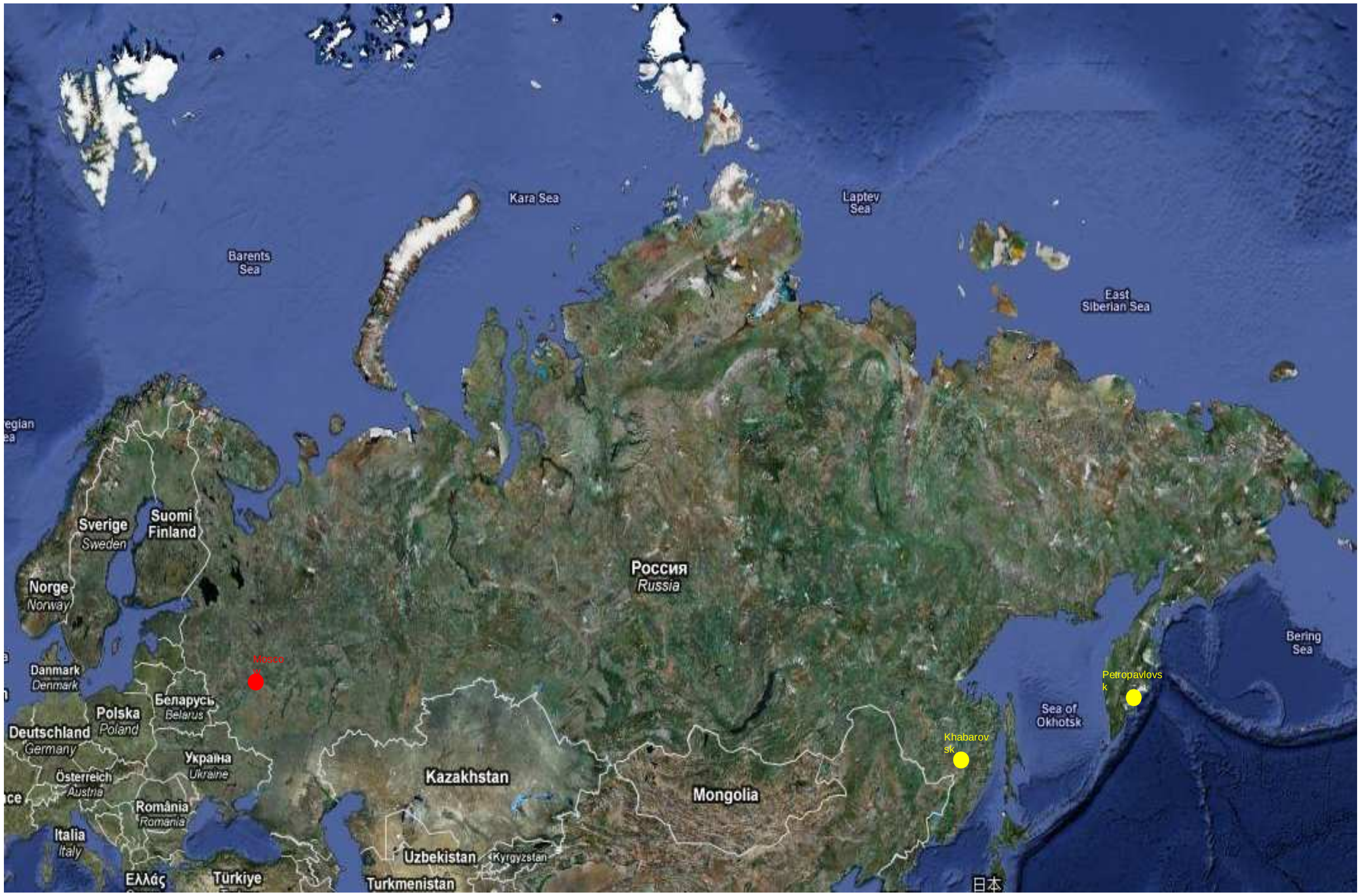
Existing time links offer time scale based on ensemble of remote clocks of secondary laboratories.

The weight of remote clocks of secondary laboratories will be dependent on clocks performances, that's why secondary laboratories will be equipped with the same type H-masers and time transfer instrument as primary laboratory.

The only difference of secondary laboratories equipment will be much more modest list of instruments. The ensemble of H-masers will consists of 4 clocks for each laboratory. The environmental conditions for instrument and reliability of the electrical power have to be comparable to primary laboratory.

ВНИИФТРИ

Upgrading of the secondary laboratories



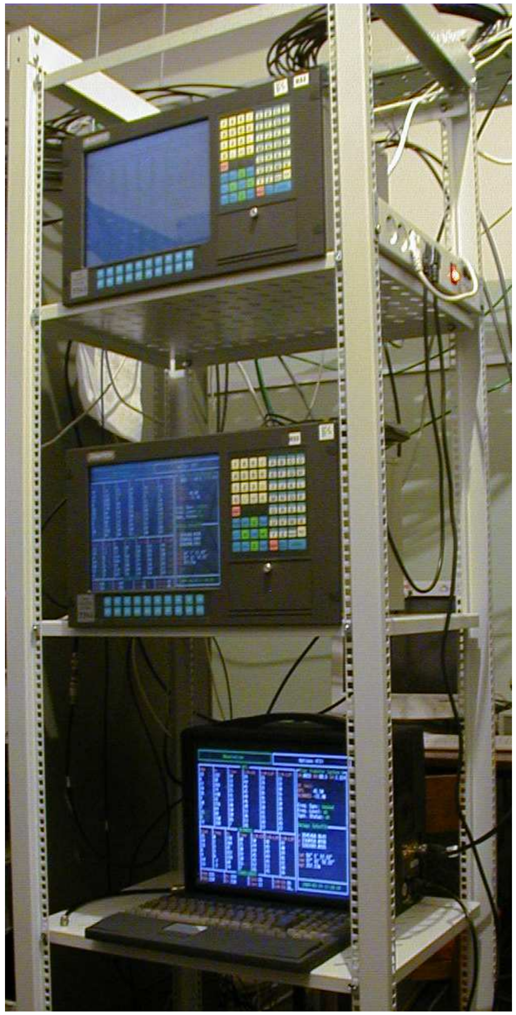
Petropavlovsk

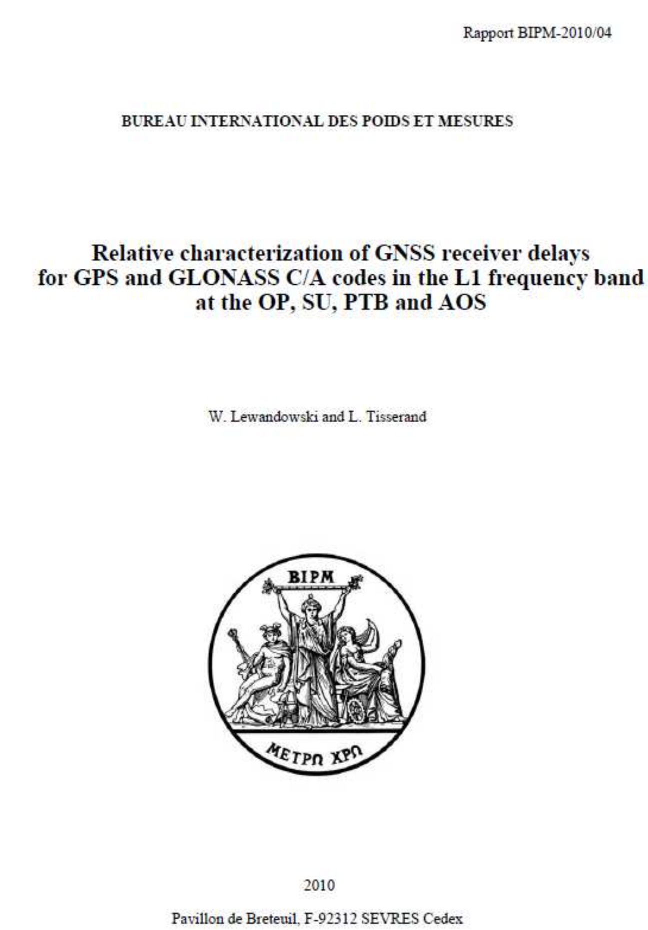
2 passive H-masers
2 5071 Cs standards in thermo stabilized chamber
T&F clock comparison system
TTS3 time transfer system (system have been calibrated by VNIIFTRI)

Khabarovsk

3+1 active H-masers in thermo stabilized chamber
T&F clock comparison system
TTS3 & TTS4 time transfer system (all systems have been calibrated)
TWSTFT system

Calibration activity and new instruments in the operational time transfer system





Rapport BIPM-2010/04

BUREAU INTERNATIONAL DES POIDS ET MESURES

Relative characterization of GNSS receiver delays for GPS and GLONASS C/A codes in the L1 frequency band at the OP, SU, PTB and AOS

W. Lewandowski and L. Tisserand

BIPM

ΜΕΤΡΩ ΧΡΩ

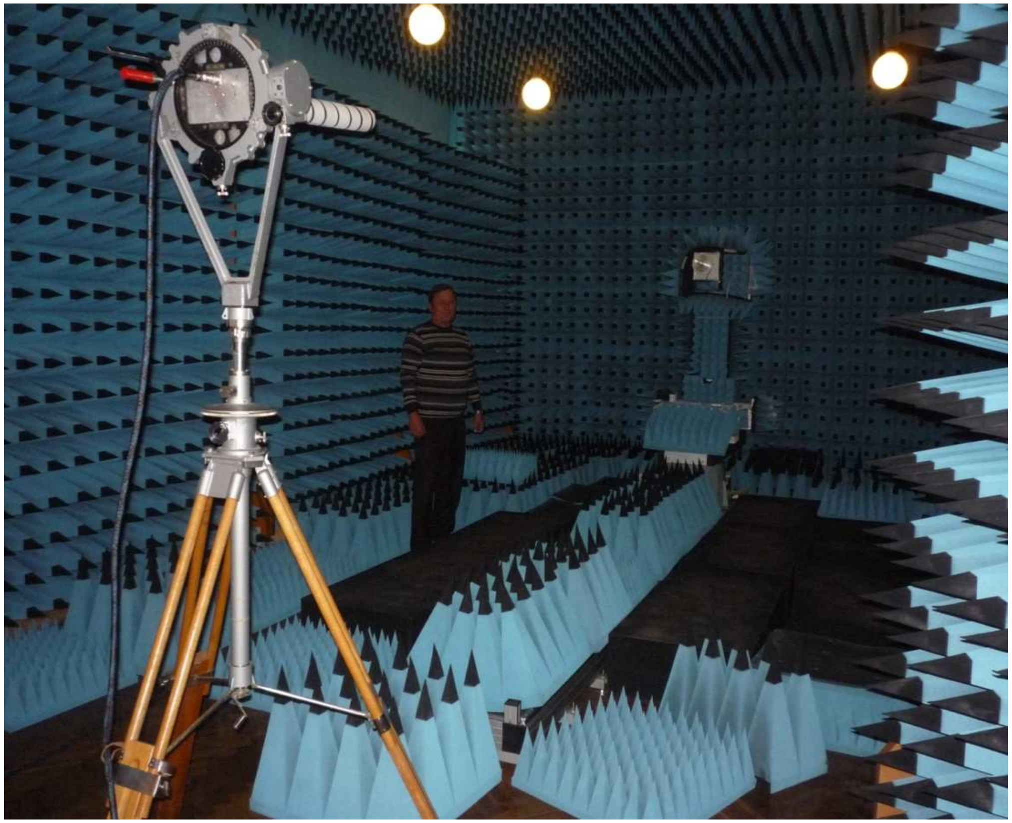
2010

Pavillon de Breteuil, F-92312 SEVRES Cedex

At the moment of calibration readings of the VNIIFTRI receivers coincide within 1 ns

Calibration campaign is not finished yet, but very preliminary data are optimistic and coincide with previous year results within 3 ns

Calibration activity and new instruments in the operational time transfer system



VNIIFTRI receiver's internal delays for GLONASS differs from that of the BIPM receiver about 200 ns. This value coincide with analogous data for previous year. The problem origin is that the BIPM and VNIIFTRI receiver's delay are traceable to the different not calibrated sources for about twenty years. And till now there is no accurately calibrated GLONASS time receiver.

We have scheduled such a work basing on new TTS4 receiver, ordered necessary equipment and hope to report result next PTTI.

TWSTFT stations status

Two stationary (one in VNIIFTRI, the other will be installed in Khabarovsk branch of VNIIFTRI) and one portable stations.
Stations will use AM2 satellite and VNIIFTRI join to Europe Asia TWSTFT link.
All stations with SATSIM system to monitor internal delays.
All station have been good tested .


TIMETECH
ГОСУДАРСТВЕННАЯ СЛУЖБА ВРЕМЕНИ
ГОСУДАРСТВЕННЫЙ
Научный
Центр
РФ
ВНИИФТРИ
ВНИИФТРИ

TWSTFT calibration

- In September 2011, FSUE VNIIFTRI joined the Eurasian TWSTFT workgroup with two stations: fixed station SU01 and mobile station SU02. For providing accurate comparisons of the time scale UTC(SU) with Eurasian TWSTFT workgroup time scales, a calibration of the SU01 station relatively to the PTB03 station of PTB needed to be done. In accordance with a preliminary agreement between VNIIFTRI and PTB from July 2012, a “Plan of preparing and realization SU01 VNIIFTRI TWSTFT station calibration affordable to PTB” was prepared. This plan anticipated a calibration with three independent methods. During the time October 26 to November 7 2012 (MJD 56226 – 56238) colleagues from VNIIFTRI and PTB in Braunschweig (Germany) successfully implemented this plan.

Fig. 2 – Route of the calibration trip

3.2 TWSTFT mobile station SU02

Before the trip to PTB (MJD 56209 - 56211) and after the trip (MJD 56238 - 56243) in VNIIFTRI mutual calibrations on a short base (30 m) between SU01 and SU02 TWSTFT stations were performed, using the passive H-Maser CH1-76A (HMV) in SU02 station. VNIIFTRI's calibration equipment connection schematic with using HMV is shown in Fig. 4. Herewith, SU01 and SU02 mutual calibration results in both cases were identical and

SU01 - SU02 = - 4.0 ns with uncertainty $u_{B1} \leq 0.5$ ns (Fig. 3).

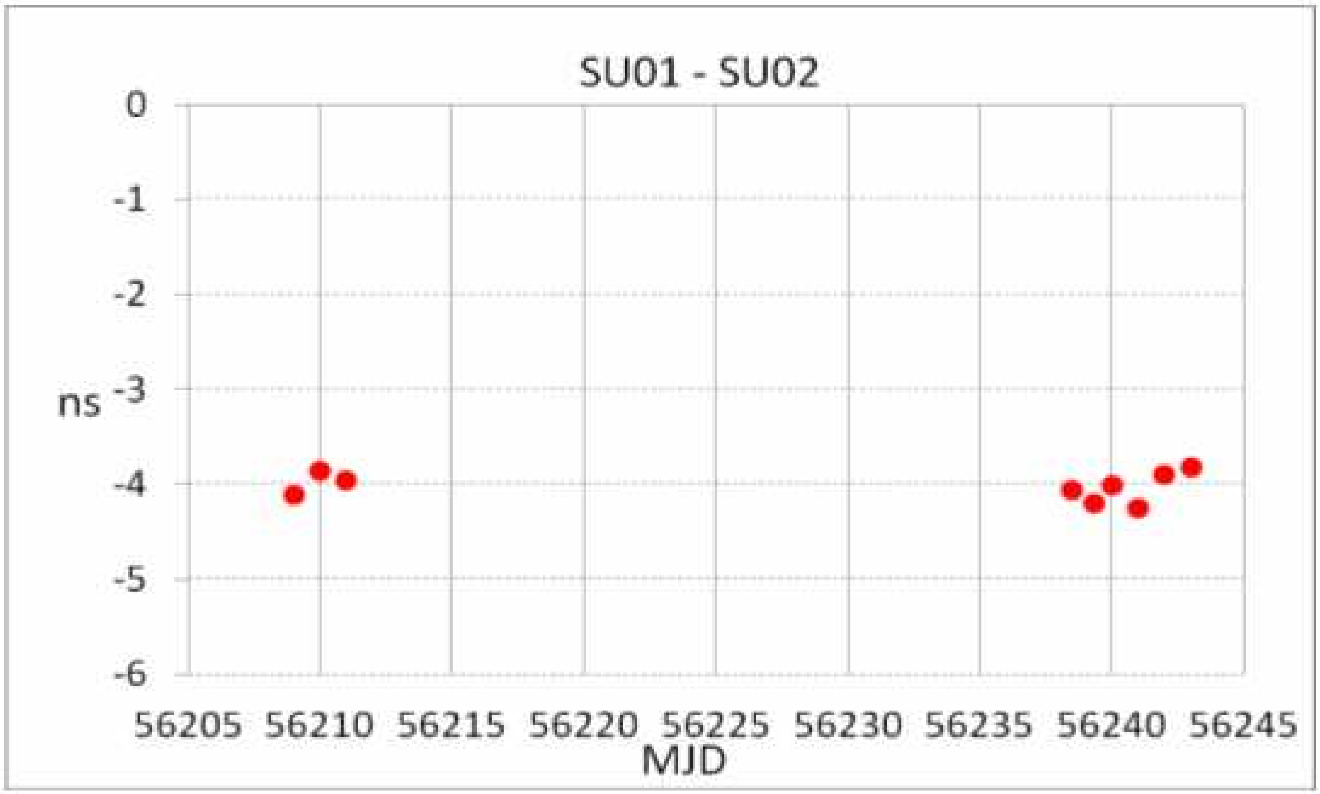


Fig. 3 – Results of calibrations between SU01 and SU02 stations on a short base

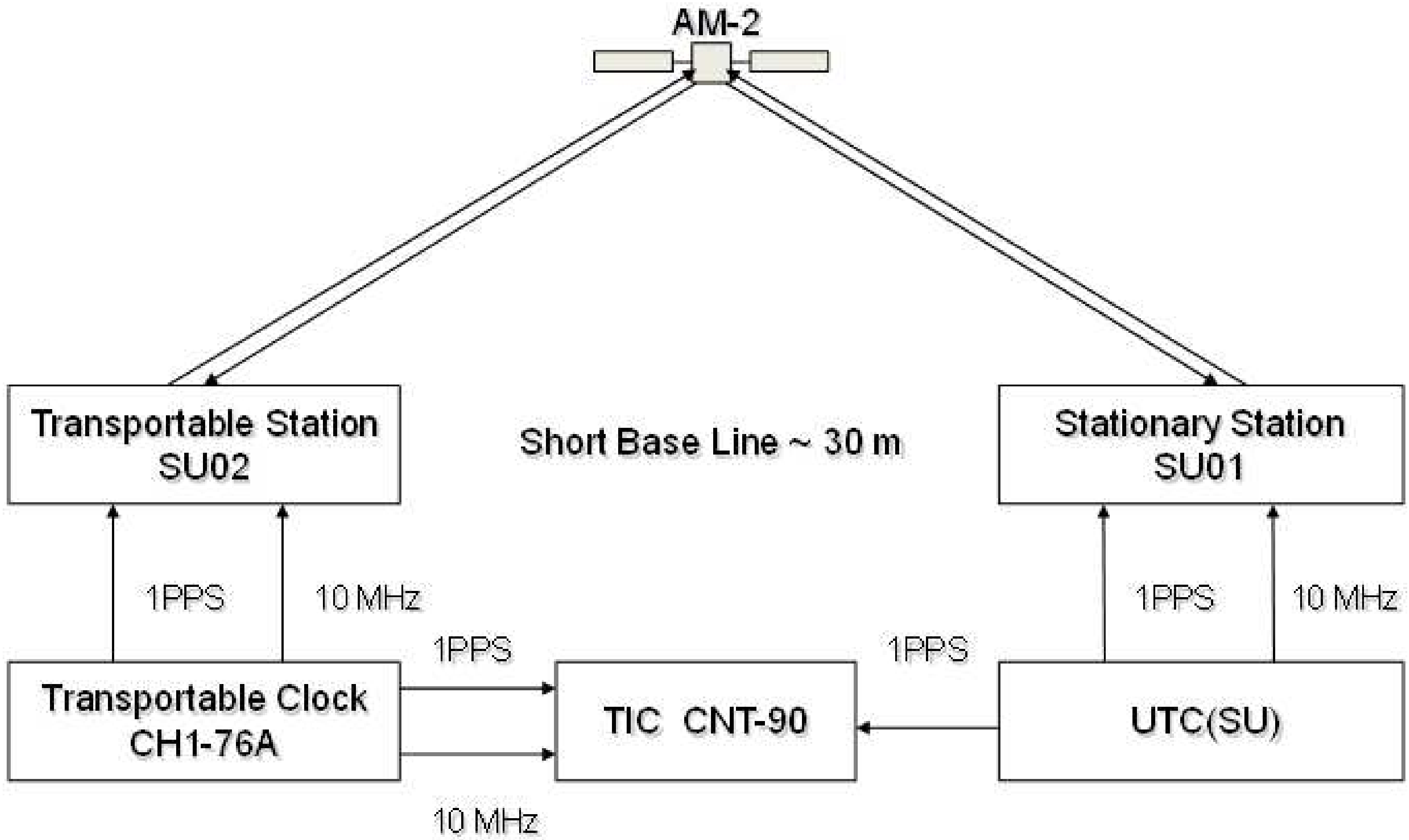
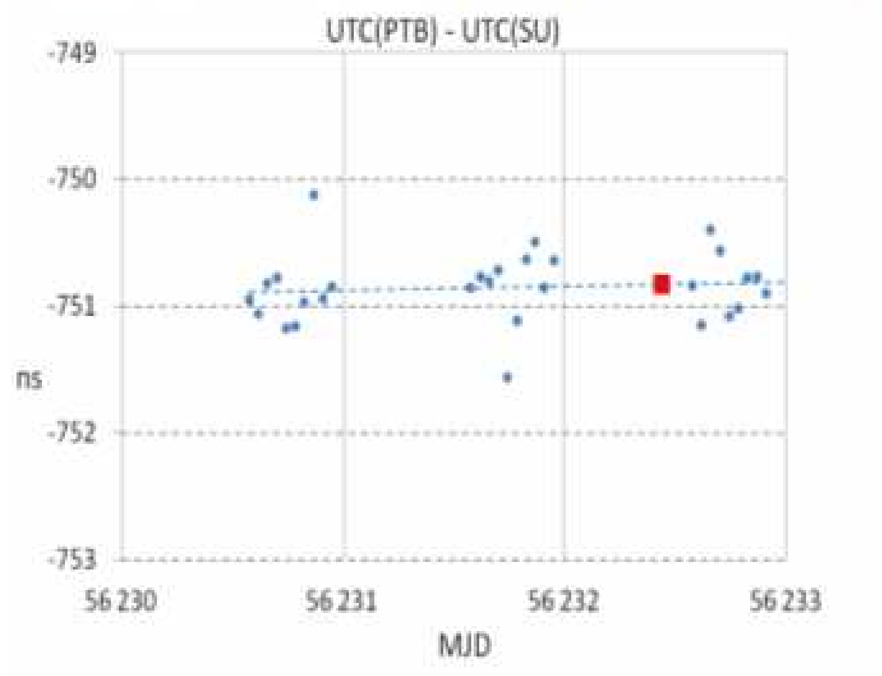


Fig. 4 – SU01 and SU02 stations connection schematic in VNIIFTRI

Table 2 – UTC(PTB) and UTC(SU) time scales comparison results

MJD	UTC(PTB) - HMV ns	UTC(SU) - HMVc ns	UTC(PTB) - UTC(SU) ns	u_A ns	u_{B1} ns	u_{B2} ns	u_{B3} ns	u_R ns
56232.44	339.2	326.5	12.7	0.3	0.5	0.2	0.9	1.0
56233.43	350.5	337.5	13.0	0.3	0.5	0.2	0.9	1.0

HMVc – with Sagnac effect correction and calibration on zero base



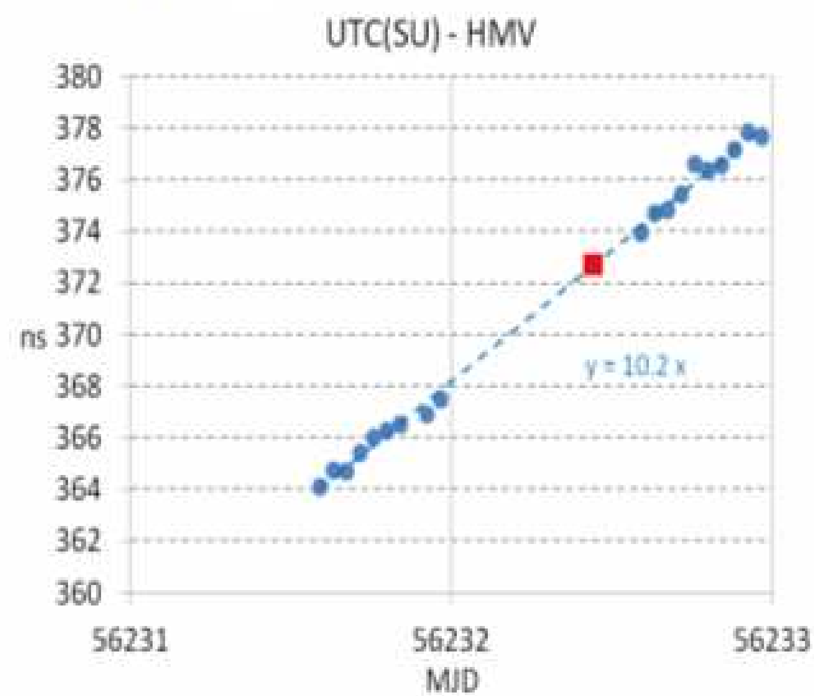
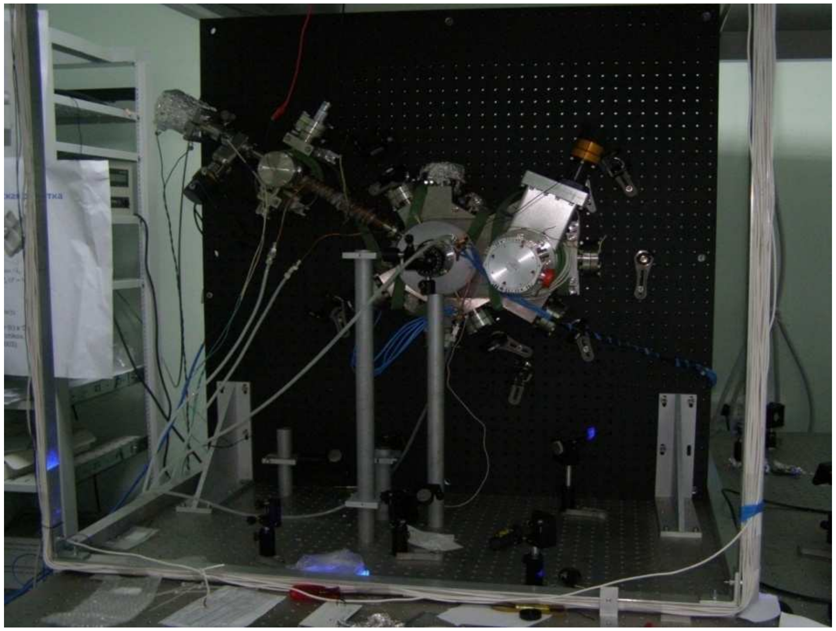


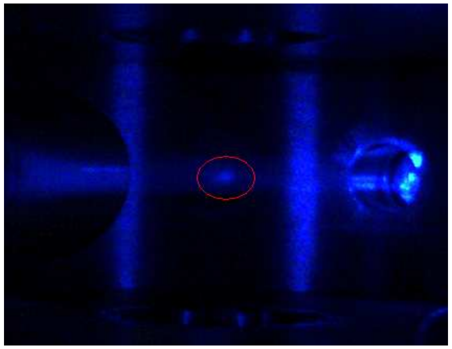
Table 5 - UTC(PTB) and UTC(SU) time scales comparison results MJD 56230 -56233

	UTC(PTB) – UTC(SU) ns		
	Mobile TWSTFT station SU02	GNSS receiver TTS-3	Transportable H-Maser CH1-76A
MJD 56231.50		13.5	
MJD 56232.44	12.7	12.9	12.9
MJD 56233.43	13.0	12.4	14.1
u_A	≤ 0.3	≤ 1.4	≤ 0.1
u_B	≤ 1.0	≤ 3.0	≤ 3.0
u	1.1	3.3	3.0

Investigation Program

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

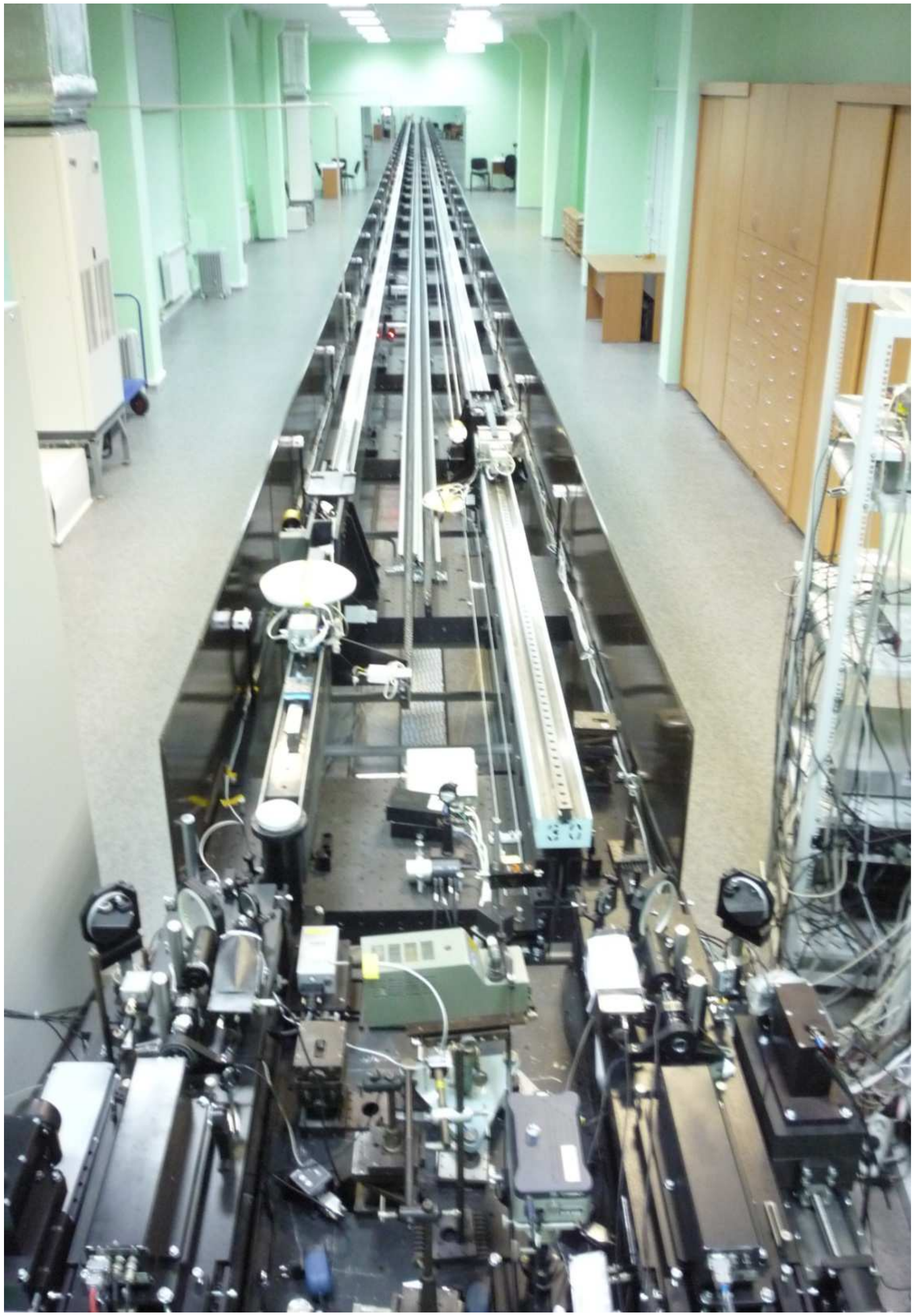




A cloud of cold atoms was succes-sfully trapped in Blue MOT (with-out repumping)

Time & frequency transfer by optical fiber links

The Long Range Length Standard



New Length Standard for ranges up to 60 m.

The Meter realization according to the definition in SI.

The basis of the instrument is Michelson interferometer with unequal arms – the longest one more than 60 meters. Light source for interferometer – two mode laser. The intermode frequency is stabilized across primary standard.

At the moment the length standard is under metrology investigation.

Expected uncertainties:

- **type A ≤ 10 μm**
- **type B ≤ (10 + 0.5 × L) μm**

where L is basis length, m


MenloSystems

CONCLUSIONS

The modernization program of operational means and investigation programs will lead to considerable improvements in performances of the National Primary Time and Frequency Standard of Russian Federation and chain of secondary time laboratories.

These programs make provision to achieve following performances at 2013:

- Accuracy CS fountain standard about 5×10^{-16}
- Time scale stability level 5×10^{-16} for sample time from 10 to 30 days
- Time link uncertainty level relative UTC about 1 ns
- RMS difference UTC – UTC(SU) $\leq$ 10 ns
- RMS difference UTC(SU) – Secondary Laboratories $\leq$ 10 ns

All these achievement inevitably will be reflected into GLONASS UTC(SU) dissemination. We hope that this will lead to UTC(SU) – $UTC(SU)_{GLONASS} \leq 10$ ns.

Thank you for attention!