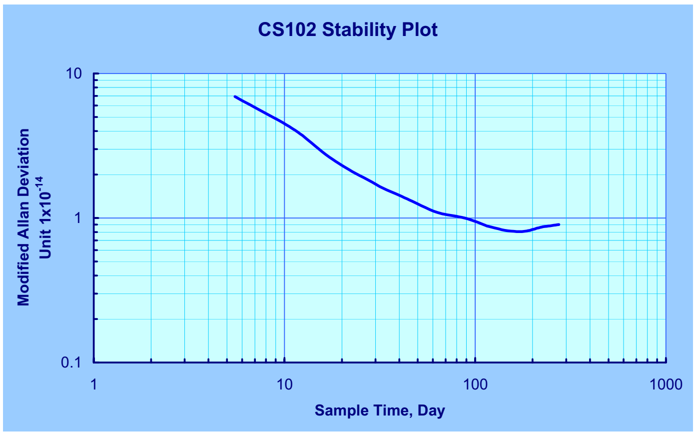
Time and Frequency activity at the IMVP FGUP "VNIIFTRI"

Thermal beam magnetic state selector primary Cs standard

The time unit – the second - independent operational reproduction according to its definition in SI is still realised in Russian Federation basing on classical thermal beam magnetic state selector primary CS 102 standard. Since last CCTF meeting no considerable chan-

ges have happened in it's physical package. On the contrary - some changes have been introduced into electronics: the old synthesiser was replaced by HP3325B, new nanovoltmeter of HP34420A type have replaced old one. Apart from it a new control software was also introduced. As a result instrument operates much more reliable and produces more than 60 determination of the unperturbed Cs frequency transition each year. The uncertainty type B for the instrument is estimated as $u_B \approx 3\times10^{-14}$. The mean time unit difference between TAI and CS 102 for the period of 2001 – 2003 is about 0.13×10^{-14}. Stability plot relative to TAI is depicted at the following chart.



CS Fountain Primary Standard

The work has been carried out to prepare microwave part of the physical package and to make a magnetic screening of the interaction region. An experimental set up was finished to make experiments with atom cooling and launching.

Magnetic screening.

The demands to magnetic system arose from the following. In order to decrease an error due to magnetic field inhomogeneity till the level of 10^{-15} we should satisfy the following:

$$\sqrt{\Delta H^2} \leq 1.4 \times 10^{-8} T$$

We expect that the mean value of the magnetic field in the interaction region should be near $(2 \div 6)\times10^{-7}$ T. In this case magnetic frequency shift won't be more then $1\cdot10^{-12}$. Three magnetic layers with diameter 220, 280 and 360 mm were manufactured. According to calculation they attenuate transverse magnetic field by 10^4 times.

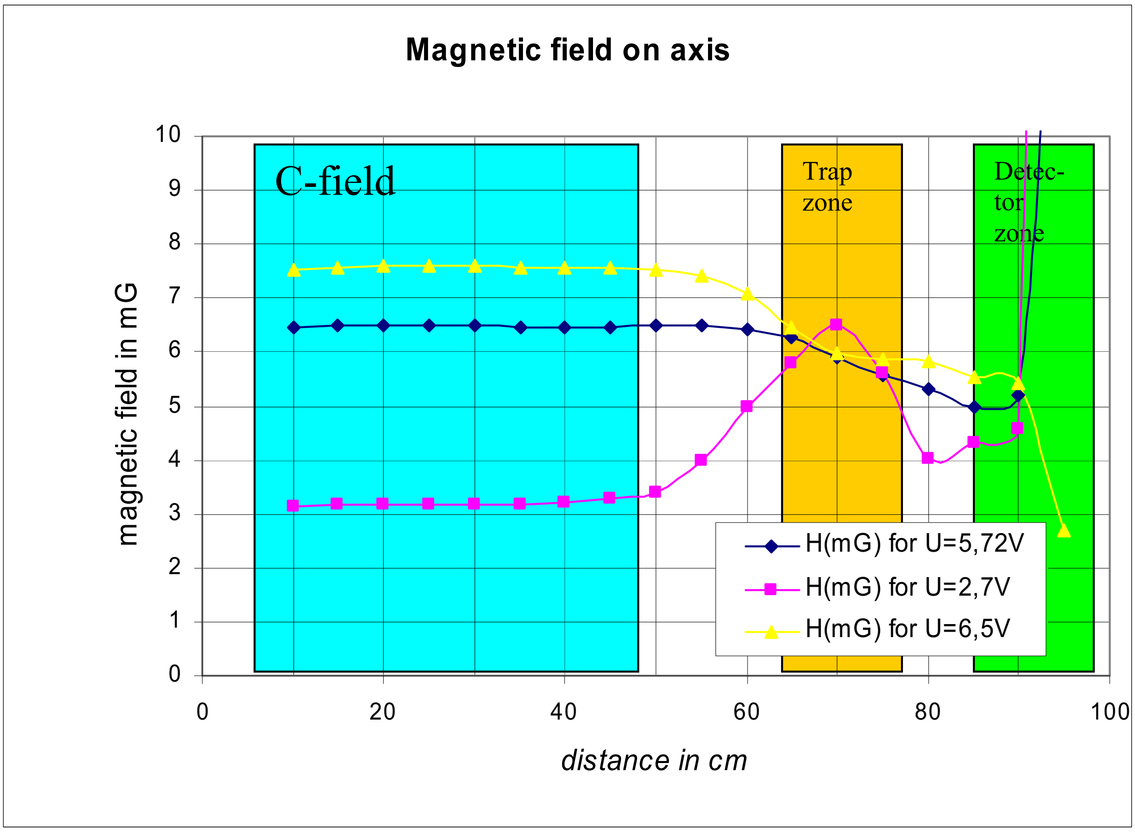


Fig.1.

The measured magnetic field inhomogeneity in the interaction region was not more than $3\cdot10^{-9}$ T and the mean value of the magnetic field was 6×10^{-7} T. Figure 1 presents the dependence of the magnetic field on different coil currents.

Distribution of the laser beam in X-Y plane is shown on fig.2. The beams are going into from the four side. Intensity balance is achieved with the help of PBS and half-wave plates. The feature of the scheme is an opportunity to use returning mirrors. The use of the returning mirrors does contradict the idea of the polarization cooling but enable us to increase the number of atoms by two times.

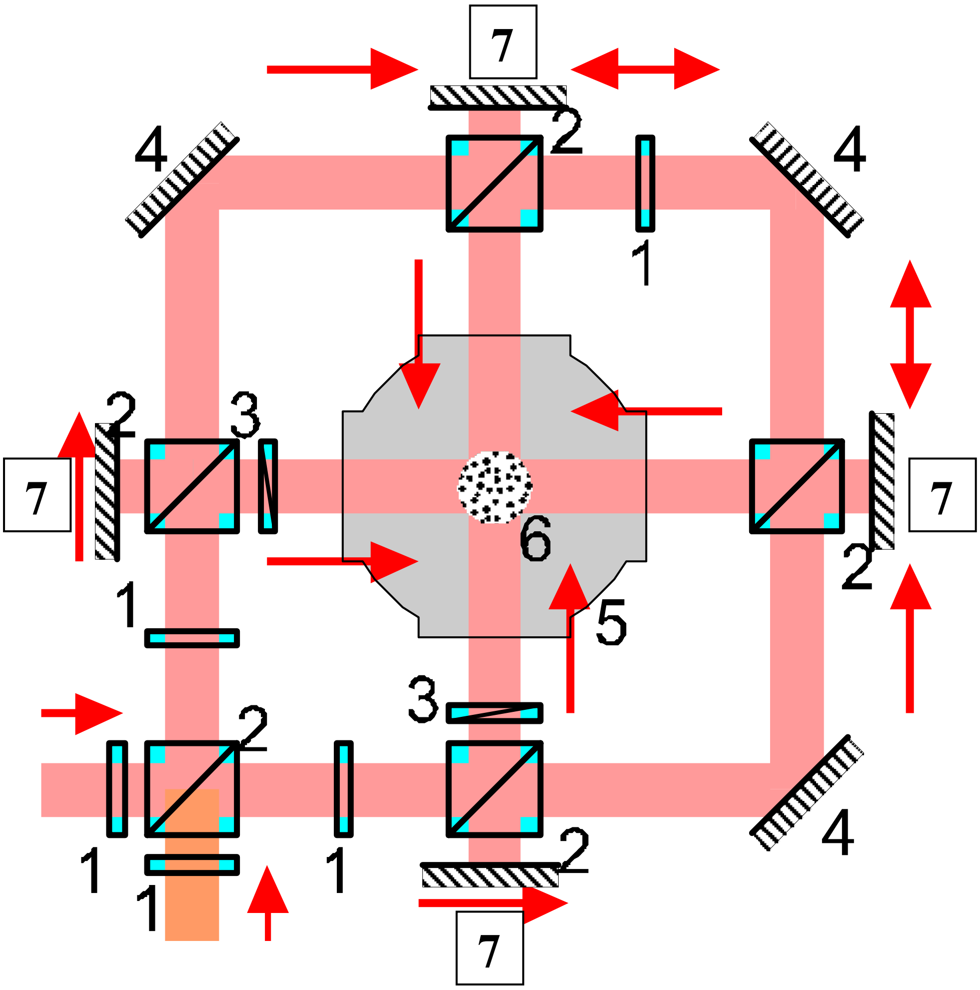


Fig.2.

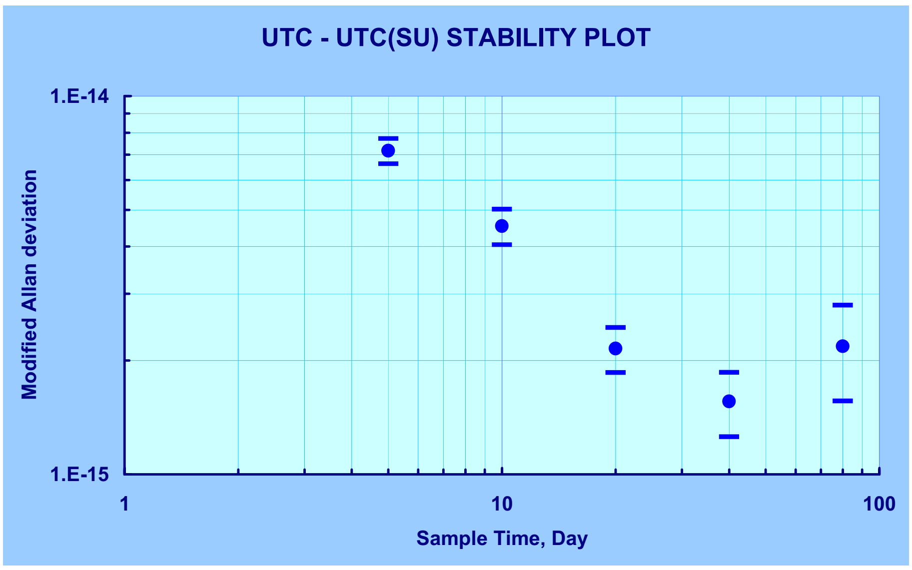
1- half-wave plate , 2 PBS, 3-polarizing plate, 4 – corner mirrors, 5-vacuum chamder, 6- optical molasses, 7- returning mirrors

Successful experiments were carried out to cool and to launch atoms. Near 1 μK temperature was achieved. Atoms were launched to a working height and Ramsey oscillations were observed. Ramsey pick width was near 1Hz and Rabi pedestal is near 60 Hz. The strength of C-field was determined via m=1↔m=1 transitions. All these experiments were carried out using only one detector. Now system is modified. Detection system is repaired and the microwave synthesizer is in a finishing stage. The work of almost any system of the cesium fountain was checked experimentally.

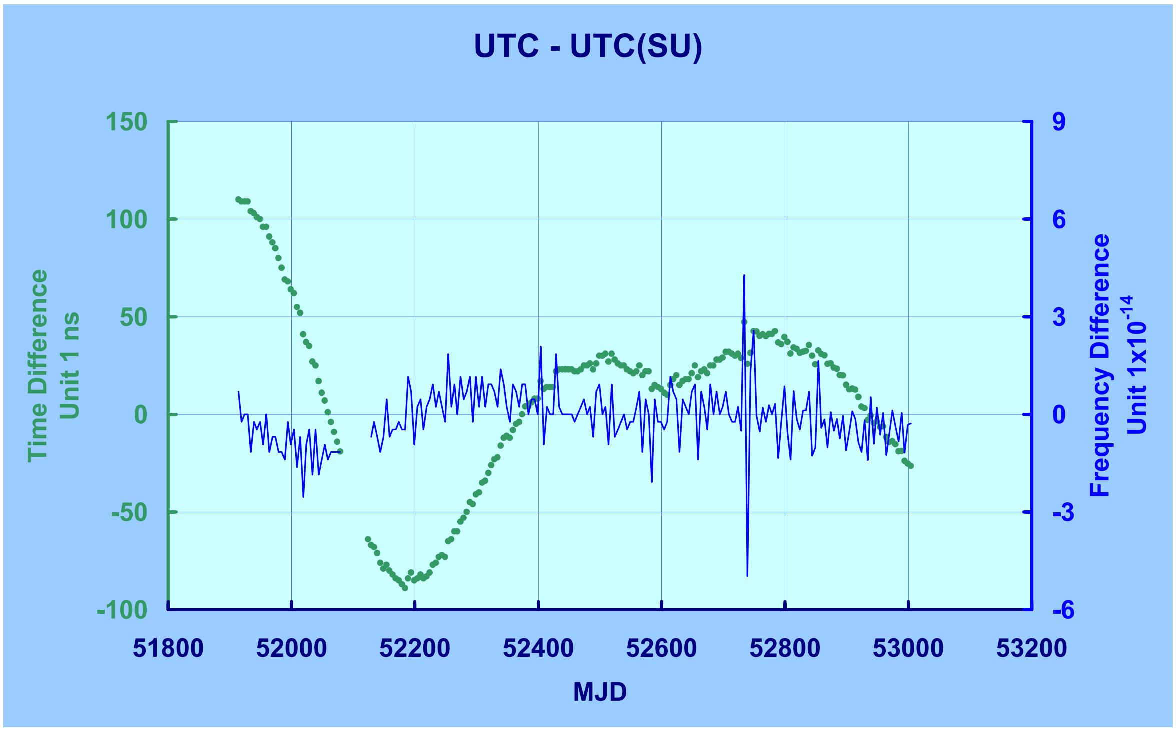
UTC(SU) time keeping and scale generation

As previously the mainframe of time keeping instrumentation consists of about 10 H-maser ensemble. Since last CCTF four new instruments were introduced into ensemble. Their most striking feature is computer controlled cavity autotuning. These new instruments somewhat increased reliability of time keeping procedure.

There are two main problems in time keeping basing the ensemble of H-masers. The first one is considerable frequency drift of the standards. One may reach few parts $\times 10^{-16}$ /day. And the other – lack of reliability. As a mater of fact there is no problem to predict frequency changes of the H-maser, but lack of reliability strongly limits uncertainty of prediction. Nevertheless basing on the ensemble of existing H-masers we have reached timescale stability level $\leq 2\times10^{-15}$. Till now we apply very simple time algorithm which consists of prediction of the clock readings including possible frequency drift and then their binary weighting. As a result UTC-UTC(SU)

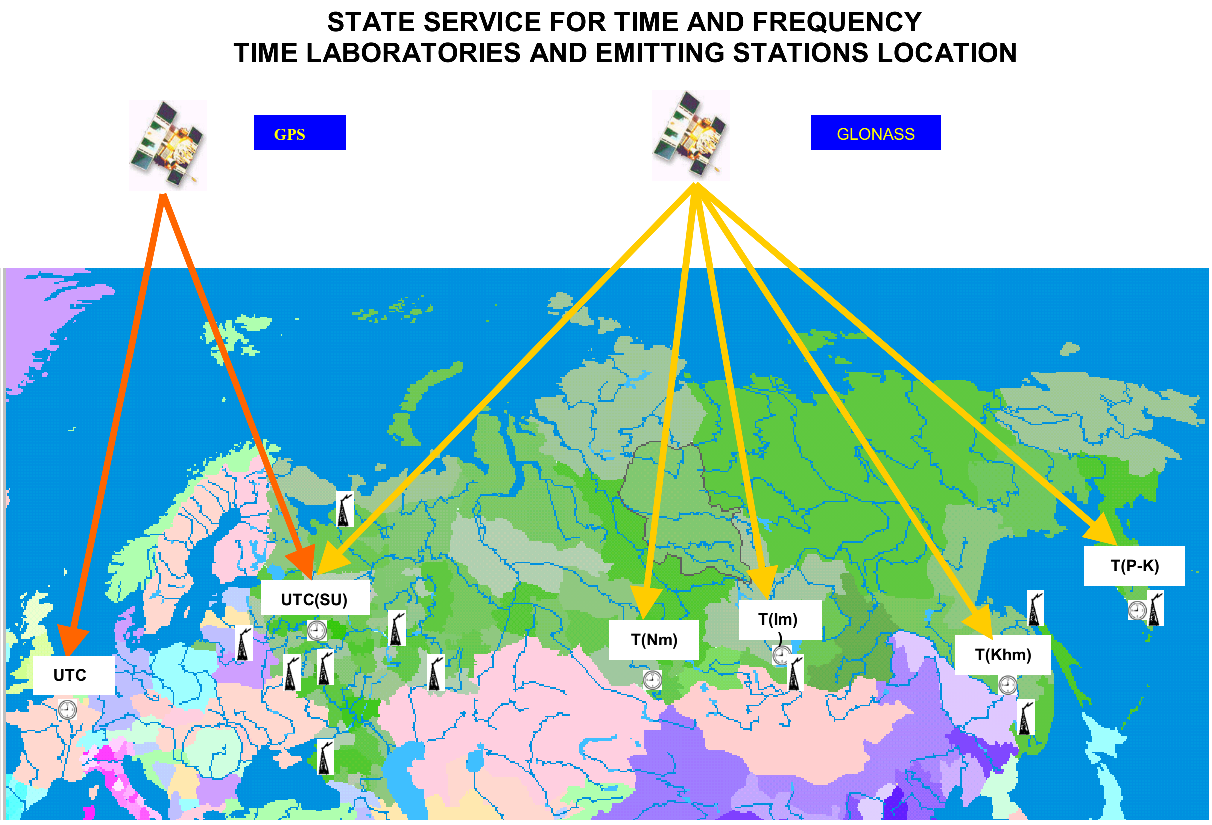


time scale difference and frequency differences for at least last few years looks in following way.

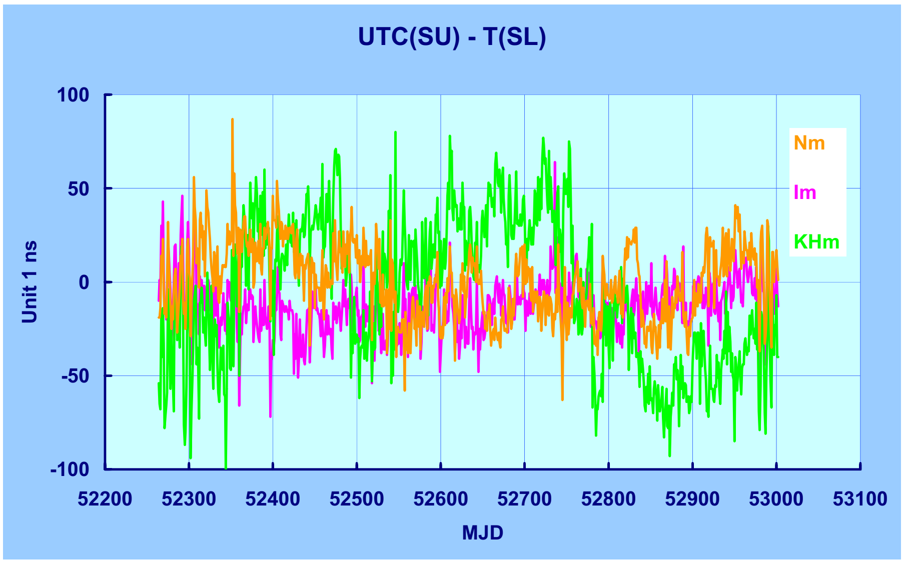


Time and frequency traceability

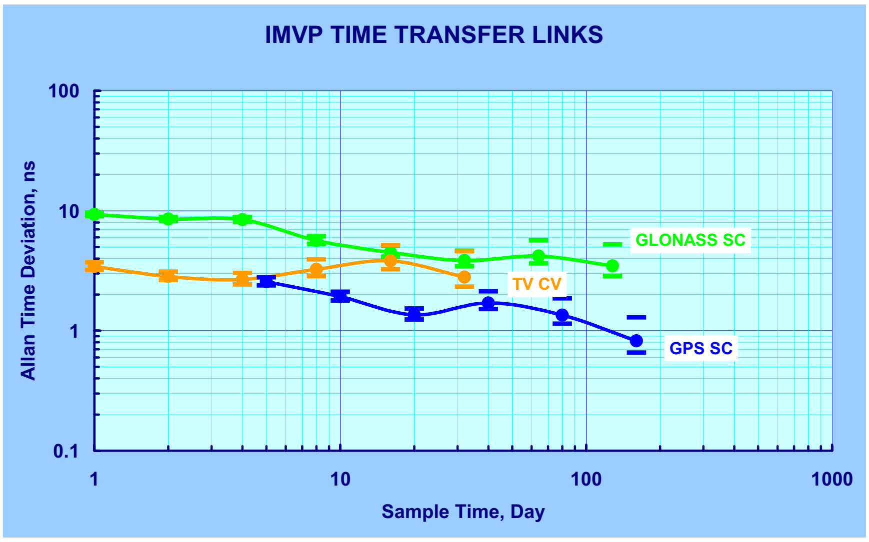
Apart from support of the National time and frequency standard and National time scale generation Institute of Metrology for Time and Space as the Main Metrology Centre of



the National Time and Frequency Service (NTFS) is responsible for supervision of set of secondary national time laboratories located in Novosibirsk (Nm), Irkutsk (Im), Khabarovsk (KHm) and Petropavlovsk-Kamchatsky. The basis of time keeping instrumentation of these laboratories also consists of H-masers. Time link to UTC(SU) is single frequency, single channel GLONASS CV. High quality time keeping instruments and time links together with qualified personnel results in high accurate time and frequency transfer and dissemination through the whole territory of Russian Federation as it depicted at following figure.



The main links between time and frequency laboratories in Russia and between Russia and international timing community are now based on GNSS CV. Along with it there are few regional networks, first of all in Moscow region, which still operate TV CV link together with existing GNSS links. Among them few DoD laboratories, Spa-ce Flight Centre of RASA, etc. Time resolution of the main time links is depicted at the following picture.



Time and frequency measurement unification through the whole territory of Russian Federation is ensured not only by synchronisation of main time laboratories but also for large variety of anonymous users via time codes and standard frequencies emitted by GLONASS, manifold on land radio station, TV etc. There are at least two long wave stations under direct supervision of the NTFS: RBU in Moscow region and RTZ in closest vicinity of Irkutsk, and short wave station RWM in Moscow region. Apart from it there are wide network of Loran and Omega like stations under supervision of DoD's institutions, which on other hand work in closest co-operation with National time and frequency standard. According to Russian norms all transmitted time codes and standard frequencies have to be conformed with UTC(SU).

The closest goals

The most important and closest goal is to develop operational fountain Cs standard. As it was mentioned previously the experimental prototype have been developed yet, the most critical and sophisticated technologies have been tested. Today we are waiting for a considerable governmental financial support. Keeping it in mind a special room is prepared for installation new CS standard in the operational building. A list of necessary equipment and accessories is made up and we hope to get expected result during coming years.

The next one, strongly tied to previous problem, is modification and improvement performances of the operational time and frequency keeping ensemble. The goals here are on one hand to improve stability level of the time keeping instrument up to the level ~ 1×10^{-15} for one day and ~3×10^{-16} for 10 days, and on other hand improve time links to TAI frequency resolution to the level ~1×10^{-15}/day. These both goals seem to be quite feasible. Even now the most reliable H-masers stability reaches level of 2-3×10^{-15} for 1 day sample and ~1×10^{-15} for 10 days. Keeping in mind that instrument temperature sensitivity is ~1×10^{-14}/K and temperature variations may be about or even exceed 1 K per day simple individual H-maser temperature stabilisation may results in expected goal.

Concerning time link we also have optimistic perspectives. Today in our disposal are few GLONASS/GPS multichannel sensors, some of them operates two frequencies. Because primary goal is to get frequency transfer very accurate time calibration is not necessary at least at the beginning and key question will concern developing a software which meets requirements of the CGGTTS for existing sensors and time measuring instruments and, once more, temperature stabilisation of the most critical parts of the instrument – antenna and cables.

As a part of clock keeping ensemble improvement we are going to install a new time and frequency intercomparison and data collection system. The most striking features of future system, strictly speaking it have been just delivered, is simultaneity and high resolution of frequency comparisons of all clocks in the ensemble with sample time up to 1 second. Time signals will compared across each other in series as previously. This new system will produce enormous data flow. Our closest task is to develop proper software to manipulate this data flow and to test the whole measuring system.

As far as multichannel GNSS time transfer techniques will be introduced into secondary time laboratories operational activity we hope to involve into the time keeping process more and more number of the remote clocks. As a first step it will be Moscow region time laboratories clocks involving (expected number few tens), then more distant laboratories. The expanding clock number inevitably leads us to the changes in operational time algorithm – we plan to introduce statistical weighting into it.

Regarding time dissemination facilities within federal program on GLONASS modification we do all our best to improve its time dissemination performances for anonymous users.

On other hand keeping in mind the explosive growth of Internet users (today more than 10 000 000) and network technologies in Russia a time servers will be run in closest future in main NSTF facilities.