ACTIVITIES AND UPDATES AT THE STATE TIME AND FREQUENCY STANDARD OF RUSSIA

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Abstract

As it was announced, a campaign on the State Time and Frequency Standard modernization is under realization.

A new prototype of the primary Cs fountain standard with an uncertainty of 3×10^{-15} is under metrological investigation, which is expected to be finished at the end of 2009.

For today, we have two new ensembles each of four H-masers of type of CH1-75A with individual cavity auto-tuning systems. The whole instrumentation set includes distribution amplifiers, a frequency and time measuring system, and a real-time time scale generation and distributing system. All these instruments are installed in thermally and humidity controlled chambers. Typical temperature and relative humidity variations are well below 0.1 ^{o}C and ~1% respectively. As a result, the frequency stability of the H-masers on a 1-day basis is about few parts in 10^{16}.

The new remote clock comparison system consists of several multichannel dual-frequency GLONASS/GPS TTS-3 receivers. All receivers have been differentially calibrated relative to a portable receiver as part of a calibration campaign arranged by the BIPM.

A TWSTFT station is under construction in VNIIFTRI. The closest main goal is to arrange a time link to PTB and NICT via the IS-4 satellite.

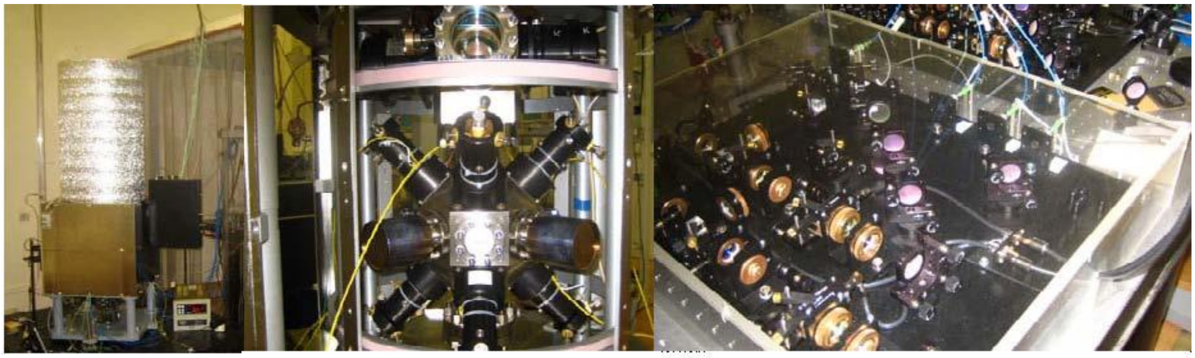
The same instrumentation set (four H-masers, a frequency and time measuring system, and time transfer equipment) will be installed in secondary laboratories in Novosibirsk, Irkutsk, Khabarovsk, and Petropavlovsk Kamchatsky.

INTRODUCTION

According to metrological regulation of Russian Federation, all technical means which transmit time signal and standard frequencies must refer to UTC (SU) – the time scale of the State Time and Frequency Standard. GLONASS ICD specifies UTC (SU) as the reference time scale for GLONASS SYSTEM TIME. That is why the GLONASS modernization campaign also includes a modernization program of the State Time and Frequency Standard and a set of secondary laboratories. The modernization campaign is under realization in the following main directions: new prototypes of the primary Cs fountain standard; ensembles of H-masers in environmentally controlled chambers; a new operational remote clock comparison system; secondary laboratories; a free Atomic Time Scale; and other investigation projects.

THE PRIMARY CS FOUNTAIN STANDARDS

At the moment, there are two fountain primary Cs standards under construction. One of them, depicted in Figure 1, is under successful metrological investigation. The main goal of this year is to achieve an accuracy level of $(1\text{-}3)\times10^{-15}$ for the prototype presented.



(a) (b) (c)

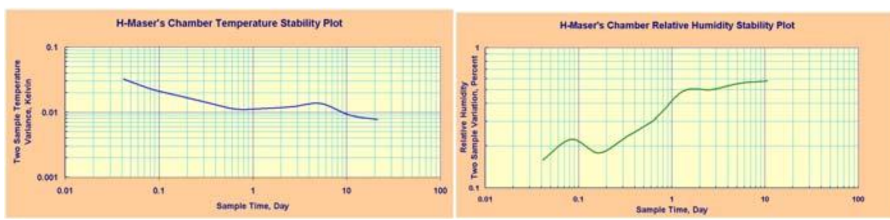
Figure 1 (a). The general view of the whole physical package; (b) molasses; and (c) laser cooling system.

The next instrument, with an expected accuracy level of $\leq 5\times10^{-16}$, is scheduled for the end of 2011 and is now being assembling in the next room.

THE ENSEMBLES OF H-MASERS IN ENVIRONMENTALLY CONTROLLED CHAMBERS

Today, we have two specially designed climate controlled chambers for clocks and intercomparison instruments (see Figure 2). A third one will be constructed in 2010. Each one is designated for four H-masers with autonomous cavity auto-tuning systems. To avoid possible leakages and/or mutual influence of clocks, the chambers contain distribution amplifiers and an H-maser intercomparison system. A minimal number of clock signals from other chambers are fed into an intercomparison system. Today, we have two ensembles of four new H-masers, for a total of eight. In 2010, the total number of clocks in VNIIFTRI will be 12. One of the most important goals of these new chambers is to create very stable temperature and humidity controlled environmental conditions. Typical temperature and humidity variations (two-sample variation) in these chambers are depicted in Figure 3 (a) and (b) respectively. Such a level of temperature stability looks quite reasonable, keeping in mind the temperature/frequency sensitivity of an H-maser at a level of about $\leq 1.5\times10^{-16}$/°K. The frequency stability of the best H-masers operating for about 1 year (see Figure 4) is $\leq 3\text{-}4\times10^{-16}$ for a sampling time of 1 day and a frequency drift less than 1×10^{-16}/day. The instruments with shorter exploitation periods have a stability level a little bit less than $\leq 1\times10^{-15}$ for a sampling time of 1 day and a typical drift of $3\text{-}5\times10^{-16}$/day.

Figure 2.



(a) (b)

Figure 3.

Figure 4.

Apart from H-masers in each climate-controlled chamber is installed a new time and frequency comparison system (see Figure 5) with a set of distribution amplifiers. The time comparison resolution is defined by a time-interval meter of the SR 620 type and is validated by the three-cornered-hat method at a level less than 25 ps single shot. The resolution of the frequency measurements is $\leq 2\times10^{-17}$ for a 1-day sample time, determined by a phase comparator of type 10265 from TimeTech. All instruments are coupled by an RS 232C interface and an RS-to-LAN interface converter and are controlled by a remote computer.

Figure 5.

THE NEW OPERATIONAL REMOTE CLOCK COMPARISON SYSTEM

Today, we have several GPS/GLONASS time receivers of the TTS-3 type (see Figure 6). These receivers have been GPS/GLONASS differentially calibrated relative to BIPM TTS-3. Implementation of these receivers into an operational TAI time link improved twice the uA uncertainty in Circular T.

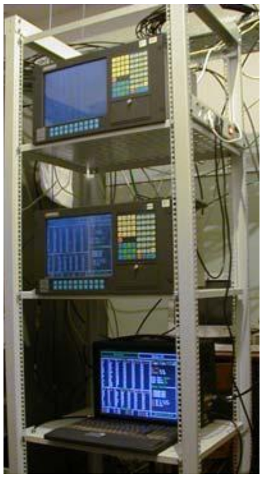


Figure 6.

Figure 7 depicts a time resolution plot of a time link between Mendeleevo and USNO (a distance about 8,000 km) and Mendeleevo and Irkutsk (a distance about 5,000 km). A typical time-link resolution level is a little bit less than 1 ns for a 1-day averaging time.

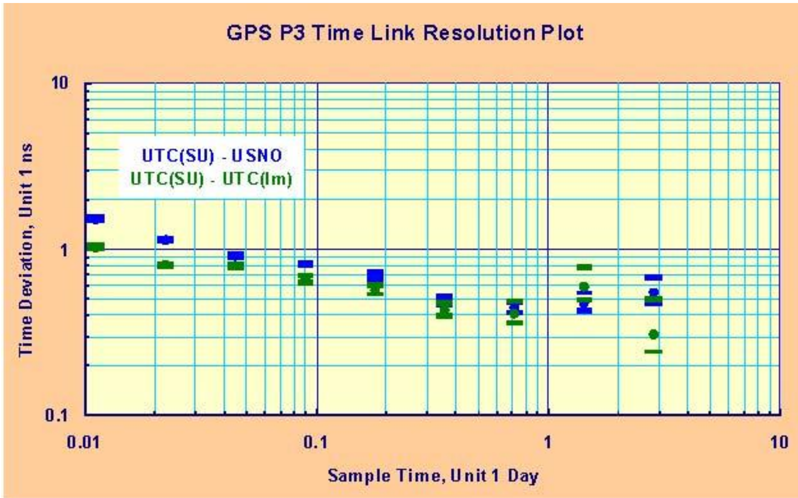


Figure 7.

Three such receivers have been delivered last year to Irkutsk, Khabarovsk, and Petropavlovsk. The Novosibirsk secondary laboratory is on schedule. Just before the 41st PTTI Meeting, we finished a new TTS-3 calibration campaign. During this campaign, portable TTS-3 receivers have been delivered to Irkutsk and compared with a local stationary TTS-3 receiver. This comparison confirms the result of the initial receiver calibration made a year before within an uncertainty less than 3 ns.

Along with GNSS techniques, a TWSTFT station is under construction right now in Mendeleevo. The closest main goal is to arrange a time link to PTB and NICT via the IS-4 satellite at a 1-ns accuracy level and improve considerably our time link to UTC. The next possible place for a TWSTFT station is Irkutsk at the halfway point between the European part of Russia and the Pacific. This link will be via domestic satellite and is scheduled for 2011.

THE SECONDARY TIME LABORATORIES

Along with improvement of the State Time and Frequency Standard, the modernization campaign is being expanded to secondary laboratories, which more or less uniformly cover the Siberian and Far East regions of Russia (see Figure 8).

Environmental chambers similar to that in VNIIFTRI will be erected in Novosibirsk, Irkutsk, Khabarovsk, and Petropavlovsk Kamchatsky. All these laboratories will be equipped with similar instrumentation sets of timekeeping and comparison equipment, with the only difference being that their H-maser ensembles will consist of four instruments. Thus, the total number of H-masers under VNIIFTRI supervision will be at least 24 instruments.

Figure 8.

Based on 12 H-maser ensembles in VNIIFTRI, 12 H-masers in secondary laboratories, some H-masers in other time laboratories (e.g., VLBI equipped with high-performance H-masers), and modern time and frequency transfer techniques, we are going to develop a Free Atomic Time Scale (FAT) with a stability level of about few parts in 10^{16} for a sampling time of from 10 to 30 days. FAT may play a role of a very stable flywheel for a further atomic time scale (TA (SU)) with a time unit in conformity with the domestic primary CS fountain standard.

OTHER INVESTIGATION PROJECTS

First of all, VNIIFTRI is conducting an investigation program on a new generation of frequency standards based on ^{87}Sr neutral atoms in an optical lattice. The main goal of this project is to achieve an accuracy level better then 1×10^{-16}. This project may be considered as the groundwork for further possible secondary or even primary standards.

There is an investigation and development program on time and frequency transfer by optical fiber links. The goal is to achieve a transfer accuracy of $<1\times10^{-17}$ in frequency and <1 ns in time.

Within work on metrological support of the GLONASS fundamental segment, VNIIFTRI is developing a new realization of the meter in the range of from 24 to 60 m, from 60 m to a few kilometers, and then from a few kilometers to a few thousand kilometers. The first step of the project, 24 to 60 m, is depicted in Figure 9. This is a Michelson interferometer with a one-arm length of more than 60 meters and a two-mode laser as a light source.

Figure 9.

CONCLUSIONS

These programs make provisions to achieve following performances in 2011:

- Accuracy of a CS fountain standard of ≤ 5×10^{-16}
- Time scale stability level of $\leq 5\times10^{-16}$/10 to 30 days
- Time link uncertainty relative to UTC of about 1 ns
- RMS difference of UTC – UTC(SU) of ≤ 10 ns
- RMS difference of UTC (SU) – Secondary Laboratories of ≤ 10 ns.

Today, the State Time and Frequency Standard of Russian Federation is the only contributor and traceable body to the UTC time scale at a level of 5 ns. STFS is the only national institute with internationally recognized T&F links to ensure time compatibility and interoperability of GLONASS with other GNSSs.

The operational means modernization and investigation programs will lead to considerable improvements in performances of the State Time and Frequency Standard and will provide GLONASS with a much more accurate, precise, and robust time scale.

ACKNOWLEDGMENTS

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