ACTIVITIES AT THE STATE TIME AND FREQUENCY STANDARD OF RUSSIA

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Abstract

A campaign on the State Time and Frequency Standard modernization is continuing.

A second prototype of the primary Cs fountain standard with an uncertainty of 5×10^{-16} ***is under assemblage and is scheduled to be ready by the end of 2011.***

Today, we have two new ensembles each of four H-masers of type 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 scale generation and distribution system. All these instruments are installed in thermally and humidity controlled chambers. As a result, the frequency stability of H-masers for a 1-day basis is about a few parts in 10^{-16}.

The new remote clock comparison system consists of several multichannel dual-frequenys GLONASS/GPS TTS-3 receivers. A new GLONASS/GPS/GALILEO TTS-4 receiver is expected by the end of November. All TTS-3 receivers were differentially calibrated relative to BIPM's portable receiver last year. Just now, we have completed new measurements within a new calibration campaign arranged by the BIPM.

Two TWSTFT stationary stations and a transportable one were tested in VNIIFTRI last summer. VNIIFTRI is ready to join the Europe-Asia link via the AM-2 satellite when it receives a radio license.

During the last year, considerable changes have happened in the secondary laboratories in Khabarovsk and Petropavlovsk Kamchatsky.

The paper delivers somewhat detailed information and some preliminary results.

INTRODUCTION

According to metrological regulation of the Russian Federation, all technical means which transmit time signals and standard frequencies must be referred to UTC (SU) – the time scale of the State Time and Frequency Standard. The GLONASS ICD specifies UTC (SU) as the reference time scale for GLONASS System Time. That's why the GLONASS modernization campaign also includes a modernization program for the State Time and Frequency Standard and a set of secondary laboratories.

THE PRIMARY CS FOUNTAIN STANDARDS

At the last PTTI Meeting, we had reported that the first fountain primary Cs standard had successfully passed a metrological investigation and had reached an accuracy level of 3×10^{-15}. Today, we are pleased to report that a second prototype is under assemblage. The goal is to achieve a 5×10^{-16} accuracy level.

The present status of their mainframes, with multilayer magnetic shielding and a vacuum chamber with an RF cavity, flight zone, molasses, and detection zones, is depicted of Figure 1 a and b respectively. The multilayer magnetic shield is under assemblage and testing of the shielding factor and residual magnetic field uniformity. The vacuum chamber is under a many-day process of heating and evacuation.

The whole instrument is scheduled to be ready by the end of 2011.

Figure 1 (a) (b)

TWO OPERATIONAL ENSEMBLES EACH OF FOUR H-MASERS IN ENVIRONMENTALLY CONTROLLED CHAMBERS

Today, as a year ago, we have two specially designed climate-controlled chambers for clocks and inter-comparison instruments (Figure 2). Each one contains four H-masers. A third chamber for an additional four H-masers is under construction. Two and a half years of continuous H-maser operations have given us useful information on their individual performances and allowed us to make more reliable forecasts.

Figure 2.

A NEW CLOCK MODEL FOR TIMESCALE GENERATION

The main outcome of two and a half years of data from the continuous operation of the H-maser obviously indicated that, despite comparable 1-day stability levels, the long-term performances of the clocks are considerably different, not only on the quantitative level (Figure 3).

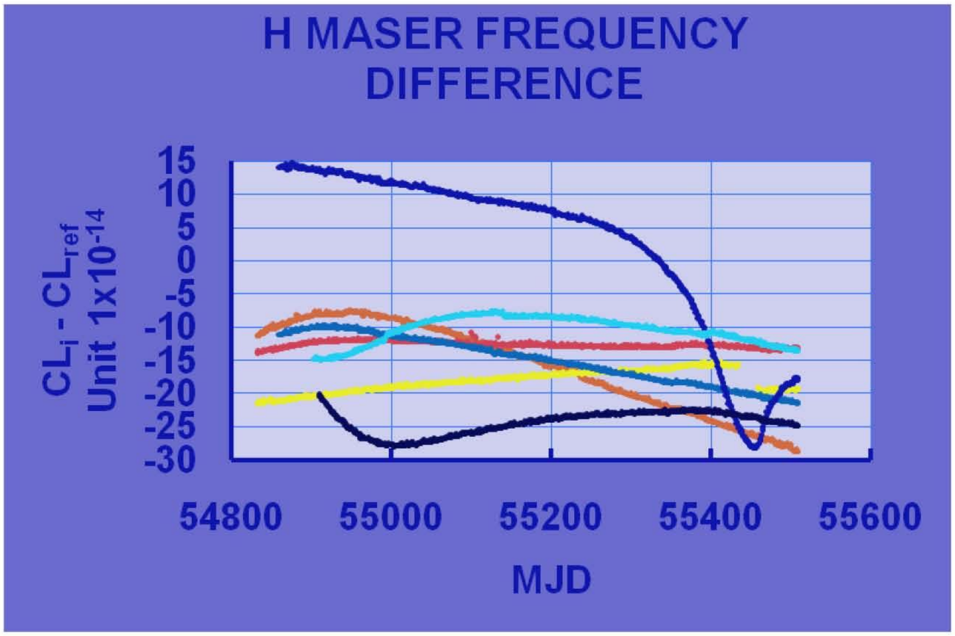

Figure 3.

That's why, when producing H-maser frequency forecasts for timescale generation, we were forced to apply different estimation intervals (2 or 3 months) and different powers in the polynomial model (the most typical model is third order, which includes initial time bias, initial frequency, initial frequency drift, and initial drift acceleration):

$$x(t) = a_3t^3+a_2t^2+ a_1t^1+a_0t^0.$$

As a result, for the most predictable H-masers, the RMS difference between a 1-month forecast and post-processed data is less than 1×10^{-15} (Figure 4; the color palette for Figures 3 and 4 is the same). On the other hand, for the worst case, the RMS may be even a few tens of times more, for example for clock no. 1403816, according to the BIPM notation, after MJD 55200. In this case, the weight of this clock had fallen down to zero.

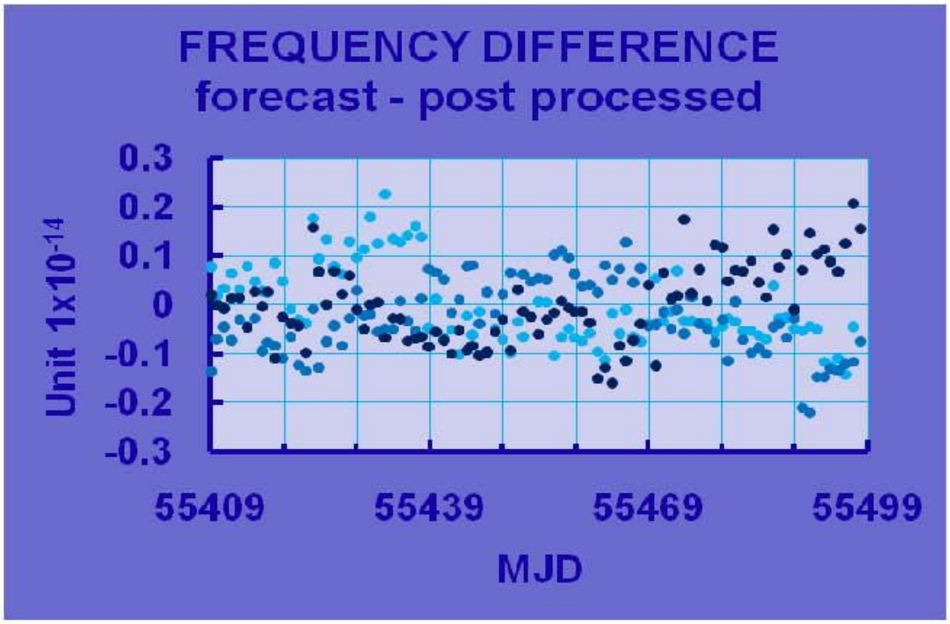

Figure 4.

THE FREE ATOMIC TIME SCALE

Keeping in mind the availability of new very stable H-masers in VNIIFTRI's secondary laboratories and other laboratories in Russia, including the DoD and the Russian Academy of Science, first of all VLBI laboratories, we considered it wise to try to arrange a so-called Free Atomic Time (FAT) scale based on an ensemble of remote clocks.

In many aspects, the free atomic time scale will be somewhat similar to the EAL scale produced by the BIPM. The most significant difference comparing it to the BIPM is the clock ensemble availability in VNIIFTRI. This provides a unique opportunity – short-term stability (1-10 days) will be based purely on the VNIIFTRI's H-maser ensemble. The time stability for longer sample times will be based on all the available H-masers. That's why the time algorithm structure will contain two time constants. VNIFFTRI's H-maser prediction model will be fixed within 5-10 days and then the model will be updated, first of all for frequency drift and the acceleration component of the model.

The main goal is to improve the long-term stability of the FAT for sample times of 10-30 days up to few parts in 10^{-16}.

UPGRADING OF THE SECONDARY LABORATORIES

During the last year, at least two secondary laboratories in VNIIFTRI's Far Eastern branches have been considerably updated. These are the Khabarovsk and Petropavlovsk-Kamchatsky laboratories.

In Khabarovsk, the laboratory has been moved to a new building where new infrastructure has been completed. These include thermal and humidity controlled chambers for the most demanding measurement equipment, first of all the timekeeping instruments. Then the power supply scheme has been rearranged, including an uninterruptable power supply. In the second half of year two, H-masers were installed. The third one was installed at the beginning of November. The fourth one is expected in the first half of 2011. The laboratory was equipped with necessary measuring instruments and we started to install and put into operation clocks and measuring and control instruments. So today the Khabarovsk laboratory is equipped with three active H-masers in a thermally stabilized chamber, a T&F clock comparison system, a microstepper to produce real-time realization of the local UTC (Kh) time scale, and TTS3 & TTS4 time transfer systems differentially calibrated relative to the VNIIFTRI reference receiver. The equipment for the TWSTFT system has been bought and will be delivered to the Khabarovsk laboratory in the first half of 2011.

In Petropavlovsk, the laboratory facilities have been completely redone. All new rooms have been equipped with a new power supply, including an uninterruptable power supply. Special thermally and humidity controlled chambers for clocks and some measurement equipment have been arranged. The main instruments installed in these rooms are: two passive H-masers, two additional Cs-beam 5071A frequency standards expected by the end of 2010, and a time and frequency distribution system and a remote clocks comparison system TTS3.

NEW INSTRUMENTS AND CALIBRATION ACTIVITY IN THE OPERATIONAL TIME TRANSFER SYSTEM

This year, as the year before, VNIIFTRI is taking part in the BIPM calibration campaign. Figure 5 depicts all the receivers involved. The BIPM transportable receiver TTS-3 is located at the top of the left rack.

The calibration campaign is not finished yet. All the necessary measurements in VNIIFTRI will have been done, including accurate antenna coordinate determination, antenna cable delay measurement for the BIPM receiver, and proper comparison measurements within about 10 days. The following measurements have to be done at the Paris Observatory when the receiver is delivered back and then all data will be processed by the BIPM.

Our preliminary results are:

- all VNIIFTRI's receiver internal delays regarding GPS coincide with each other within 1 ns
- all VNIIFTRI's receiver internal delays regarding GPS agree with the BIPM receiver within 3 ns for the previous year's results
- all VNIIFTRI's receiver internal delays regarding GLONASS also coincide with each other, but differ

from that for the BIPM receiver by about 200 ns. This value coincides with the analogous data for the previous year.

The issue regarding the GLONASS delay difference is very important and has very deep roots which originate in the late 80s when time laboratories first started GLONASS monitoring. The first Western results were obtained by P. Daly, the Russian ones by G. T. Cherenkov, N. Koshelyaevsky, and S. Pushkin **[1]**. Since that time, the BIPM started publication of the UTC – GLO ST based first on Daly's data. Then, over more than 20 years, not only receivers but laboratories have changed. Nevertheless, each new receiver has been compared with the previous one. In this way, UTC – GLO ST has been kept uniform. The same situation was the case in Russia – during this period, VNIIFTRI has changed its type of GLONASS time receiver three times, each time ensuring UTC (SU) – GLO ST data continuity. And even now there is no accurately calibrated GLONASS time receiver. We have scheduled such work based on a new TTS4 receiver, have ordered the necessary equipment, and hope to report a result at the next PTTI.

These measurements will include not only the delay in the GLO receiver's main unit itself, but all cables and antenna also. At the moment, VNIIFTRI has a temporal experimental facility and proper equipment for RF cable and antenna measurements (Figure 6), and now a special laboratory building is under construction.

One more piece of good news from VNIIFTRI: This year we have gotten two stationary (Figure 7) and one portable (Figure 8) TWSTFT stations (one for VNIIFTRI; the other will be installed in the Khabarovsk branch of VNIIFTRI). All stations have SATSIM systems to monitor internal delays. As a first step, stations will use the AM2 satellite and VNIIFTRI will join in the Europe-Asia TWSTFT link.

Figure 5.

All stations have been tested and now VNIIFTRI is waiting for a radio license, which is expected by the second half of 2011.

The portable TWSTFT station provides a unique opportunity for accurate calibration of TWSTFT stationary stations, not only within Russia but also abroad. Keeping in mind that the second domestic TWSTFT station will be installed in the Far Eastern region (Khabarovsk), a calibration campaign with the laboratories in Japan, Taiwan, China and Korea looks quite feasible.

Figure 6.

Figure 7.

Figure 8.

REFERENCE

[1] P. Daly, G. T. Cherenkov, N. B. Koshelyaevsky, and S. B. Pushkin, 1991, *"Satellite Time Transfer Between UTC (USNO) and UTC (SU) using NAVSTAR GPS and GLONASS,"* in Proceedings of the 4th International Technical Meeting (ION GPS-91), 11-13 September 1991, Albuquerque, New Mexico, USA (Institute of Navigation, Alexandria, Virginia.), pp. 199-206.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to all their colleagues for their diligent work and expert advice on modernization of the time and frequency laboratories in VNIIFTRI and in the secondary laboratories.