URSI AP-RASC 2019, New Delhi, India, 09 15
March 2019

Reduction of uncertainty of Primary Time Scale generating UTC(NPLI) to 2.8 ns

A. Agarwal*, M P Olaniya, S Yadav, P Kandpal, P. Arora, S. Panja, M. Das, P. Thorat, T. Bhardwaj, S. De, V. Bharath, N. Sharma, M. Dixit, Mamta, V N Ojha and D K Aswal
CSIR-National Physical Laboratory, Dr K S Krishnan Marg, New Delhi 110012
*ashish@nplindia.org

Abstract

CSIR-National Physical Laboratory (CSIR-NPL), New Delhi is the custodian of primary time scale generating Indian Standard Time (IST). In the present paper we report the major reduction of the uncertainty of Primary Time Scale from 20 ns to 7.2 ns and finally to 2.8 ns. We also discuss current time dissemination methods being employed and the tasks undertaken for upgradation and strengthening of the primary time scale to serve the pan India in a better way at par with the international level.

1. Introduction

The CSIR-National Physical Laboratory (CSIR-NPLI) maintains the national time scale of India and disseminates the time and frequency signals across the country. The time scale maintained by CSIR-NPL is designated as UTC(NPLI). UTC is formed after adding leap seconds to International Atomic Time (TAI) as shown in Fig 1. At the same time, TAI is generated from Free Atomic Timescale (EAL) through the addition of preannounced frequency steers determined by comparison with a weighted set of primary frequency standards. EAL is a worldwide weighted average of a large number of freely running frequency standards. Six of these frequency standards belong to CSIR-NPL. Figure 1 depicts the international chain of time scale starting from the ensemble of free running clocks to the formation of Indian Standard Time.

Over the period of time, the atomic clocks of national time scale aged and environmental conditions of the laboratory degraded. This article elaborates the tasks performed to strengthen the primary time scale and its dissemination capabilities to national users like Indian Space Research Organization.

The objective of upgradation is to cater to the national needs of e-governance, digital financial transactions, digital archiving, time stamping, cyber security, satellite navigation, smart power grid, improved transportation and communication systems, internet of things and so-on. Further to avoid any failure of primary time scale, a new backup time scale laboratory has been developed, which is already implemented by other National Metrology Institutes in United States, Germany and Japan [1,2].

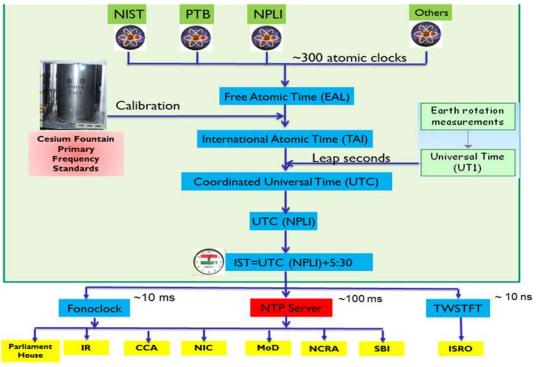

Fig 1: International chain of Time Scale

2. National Time Scale

This section elaborates the physical layout of the national time scale which basically comprises of bank of ultra precise atomic clocks and efficiently designed measurement and distribution system which is placed in a clean room with temperature constantly regulated at (22±1)℃ and relative humidity at (50±5)% with an uninterrupted power supply. Currently there are five commercially available cesium clocks and a hydrogen maser which is used to generate UTC(NPLI). The 5 MHz and 1 pps are the output of hydrogen maser which is fed to a micro-phase stepper. The main purpose of using a micro-phase stepper is to generate high resolution off-set so that it can be applied to correct UTC(NPLI) whenever required to keep it as close as possible to UTC. The output of micro phase stepper is UTC(NPLI) which is fed to a distribution amplifier and another to the Automatic Switching Unit (ASU). ASU performs the comparison between UTC(NPLI) and individual clocks and provide two reference signals (START pulse and STOP pulse) for comparison to the Time Interval Counter (TIC). TIC (Model no. SR620) is used to calculate time interval error between clock's 1 pps and 1 pps signal of UTC(NPLI) and this difference is constantly being recorded in the server. Another output of micro-phase stepper i.e. UTC(NPLI) is distributed for the time dissemination and time transfer for Phonoclock transmitter, Two Way Satellite Time and Frequency Transfer (TWSTFT)

system, etc. UTC(NPLI) is also disseminated to Length, Microwave and Voltage standards of CSIR-NPL.

3. Dissemination of Indian Standard Time

3.1 By Two Way Satellite Time and Frequency Transfer (TWSTFT)

An accurate time transfer method with ISRO has been adopted by National Physical Laboratory India (NPLI) having highest possible time transfer accuracy. It is used for comparing two remote clocks with an accuracy of about one nanosecond. TWSTFT signal is transmitted in the Ku band (12 GHz to 14 GHz) from one station to other station using a Geostationary Satellite (GSAT). A SATRE modem (a duplexer used for transmitting and receiving signal simultaneously) is used for generating 1PPS signal taking the reference from atomic clocks. Pseudo Random Noise (PRN) code and Binary phase shift key (BPSK) modulation techniques are used in TWSTFT. The delay between two remote clocks is measured by time interval counter (TIC) directly from the received 1PPS signal to reference (atomic clocks) 1PPS signal. Recently CSIR-NPL has established a time transfer link with ISRO using GSAT-10 satellite. The time is compared with an uncertainty of about 1.5 ns.

3.2 By Common View Global Navigational Satellite System (CVGNSS):

The CVGNSS method compares two clocks that are located at different sites.
The common-view clock signal is simply a vehicle used to transfer time from one site to the other. The time signal embedded in a GNSS signal is the most commonly used source of common-view clock because of its wide visibility, ease of reception with good signal to noise ratio and insensitivity to propagation effects. CVGNSS time transfer is a one-way method, the signal being emitted by a satellite and received by specific equipment installed in a laboratory.

(a) By the use of Internet

(i) Dissemination of IST through NTP servers

The present work deals with dissemination of time through Internet, using network time protocol (NTP). NTP is the most effective and robust method for time synchronization using Internet. NTP is a hierarchical protocol which is partitioned into stratum which defines the distance from the reference clock, which can be Atomic clock, GNSS time etc. Standard Time is passed from one stratum to another. Synchronizing the clock with server involves exchange of several packets. Each packet consists of a pair of request and reply. For dissemination of time, Presently CSIR-NPL use two NTP servers (model no Sync Server 350). CSIR-NPL is right now disseminating Indian Standard Time (IST) to users as a test service via domain name time.nplindia.org. Any user across the world can set his internet time to IST using this time service. Currently to make the system secure, logs Analysis and development of a Graphical user interface (GUI) for monitoring client hits for Time synchronization over the internet has been performed. Further to make this service more robust, 20 more NTP servers have been installed which will cater to the increasing demand for internet time throughout India.

(ii) Dissemination of IST through CSIR-NPL Website

Users can also synchronize their clocks which are traceable to CSIR-NPL through CSIR-NPL's NTP server i.e. time.nplindia.org. One can also find difference in time between their device and IST by CSIR-NPL's website. Figure 2 represents the snapshot of CSIR-NPL's website from where time synchronization can be achieved with the accuracy of milli-seconds.

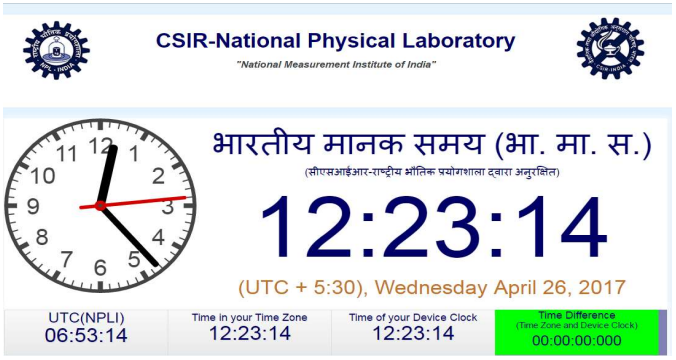

Fig 2: IST on the official website of CSIR-NPL

(b) Time dissemination over telephone network

Time synchronization over public switched telephone network is one of the simplest and low-cost solutions to set time of a clock remotely. Basic architecture of this technology consists of a time server at the laboratory end and receiver modules at users end. At CSIR-NPL, such service was named as Teleclock and its advanced version is named as FonoClock.

Teleclock service at CSIR-NPL has synchronization accuracy of the order of ±1 s. Present service uses CCITT V.22 analog modem with baud rate of 1200. Users can get the time information by dialing 01145608687 and 01145608688. During time broadcast hours, minutes and seconds information is transmitted. Existing Teleclock service has several limitations. The major limitations of the Teleclock system are as follows:

- Incomplete Time Information
- Slow Communication Speed
- Unidirectional Transmission
- Old Communication Protocol

Thus, FonoClock is designed to overcome the limitation of Teleclock. Basically, FonoClock is a system which is able to provide more accurate time synchronization over

telephone network (PSTN) than its predecessor Teleclock.. FonoClock time sever consists of a bank of 4 transmitter connected to PSTN via different service providers. A direct reference from UTC(NPLI) in the form of one pulse per second (1pps) is fed to the transmitter to synchronize its clock to IST. In addition to that, separate switches are available to set the time epoch.

4. Strengthening of National Time Scale:

CSIR-NPL undertook a major overhaul of the National Time Scale which is described in following two sections:

4.1 Upgradation of Primary Time Scale

The primary time scale of CSIR-NPL comprised of an ensemble of five poorly performing cesium atomic beam clocks and one Active Hydrogen Maser (AHM). Two poorly performing Cs atomic clocks have been replaced and three more will be replaced soon. Further one new AHM has been installed in order to provide the desired stability to the Time Scale. The major uncertainty contributing factor to UTC(NPLI) is the international time link uncertainty of 20 ns. Therefore, in order to minimize the link uncertainty, uncalibrated receivers were replaced by NMI calibrated GTR-51 Time & Frequency Transfer Receivers. This led to reduction of uncertainty to 7.2 ns. The international inter-comparison done with NICT Japan has now reduced the uncertainty of Primary Time Scale from 7.2 ns to 2.8 ns The continuous comparison of frequency generated by the National Time Scale with that of Cesium Fountain, India Cs-F1, is also planned in the future.

4.2 Development of Backup Time Scale

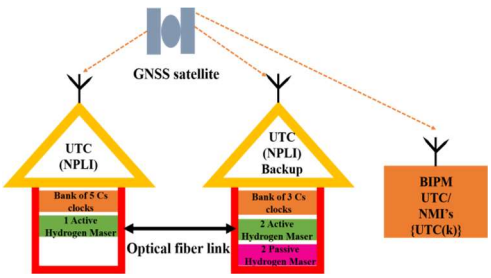

Fig. 3. New plan of National Time Scales generating UTC(NPLI)

In order to cater to the increasing demand of time and frequency services and to bring legalization of time in India, CSIR-NPL has developed a backup time scale which is analogues to the existing Primary Time Scale setup. Backup time scale is tightly coupled with primary time scale so that it stays as close to UTC(NPLI) as possible. At the same time, backup time scale will work independently so that it can generate UTC(NPLI) and provide all the services that primary time scale is providing in case of any failure to the primary Time scale. Back up time scale will generate the time scale with an ensemble of five cesium clocks, two active hydrogen masers and two passive hydrogen masers. In order to ensure redundancy, backup time scale is linked to primary time scale via optical fiber link as well as through GNSS receivers. Fig 3 shows the layout of primary and backup time scale generating UTC(NPLI). Due to the lower attenuation factor of optical fiber (~ 0.2 dB/Km) over copper cables, interlinking of backup time scale with primary time scale using optical fiber has been completed. In order to synchronize each and every computer and network clocks of the nation to IST, it is essential to increase the infrastructure required to disseminate time over internet. Initially 10 NTP servers linked to primary time scale have been setup and 10 more are planned to be commissioned at the backup time scale site.

5. Conclusion

In order to fulfill the fast-growing demand of accurate time within the nation and in order to establish a legal time in entire country, CSIR-National Physical Laboratory, New Delhi has develoed a backup time scale in addition to the existing one. Presently, the National Physical Laboratory is providing the accurate time to the institutions like Indian Railways, ISRO, National Knowledge Network and UIDAI.

Strengthening of Primary Time Scale and development of new backup time scale is able to disseminate IST more effectively to various industrial time and frequency users as well as millions of Indians synchronizing their computers clock through internet and web time display portal. The Indian Space Research Organization (ISRO) has developed Indian Regional Navigation Satellite System (IRNSS) with an operational name of Navigation with Indian Constellation (NAVIC) which is capable of providing accurate real-time positioning and timing services. So, the purpose of linking of national time, IST, with the NAVIC is to disseminate IST to whole subcontinent within an uncertainty of several microseconds.

The NAVIC is now synchronized with the Indian Standard Time and also traceable to Coordinated Universal Time (UTC) through UTC(NPLI).

For time dissemination over telephone network (FonoClock), a new hardware incorporating communication delay compensation has been developed to provide time synchronization accuracy of ± 10 ms. The strengthening of National Time Scale and National Time dissemination services is aimed to strengthen the national timing infrastructure and provide the legalization of Indian Standard Time.

6. Reference

1. Levine, Judah. "Realizing UTC (NIST) at a remote location." *Metrologia* 45.6 (2008): S23.

2.Judah Levine, Steering A Time Scale. 40th Annual Precise Time and Time Interval (PTTI) Meeting.