SP Technical Research Institute of Sweden, Borås, Sweden

# Report on Activities to the 19th Session of the Consultative Committee for Time and Frequency, September 2012

## 1. Staff

The staff involved in time and frequency at SP is about 4-5 persons. The work includes generation and dissemination, calibration, knowledge transfer and research. In addition to these, the group contains about 2-3 persons mainly involved in geodetic applications, positioning and navigation, and atmospheric research using GNSS.

## 2. Clocks for TAI

SP presently contributes to TAI with about 20 clocks (13 CS and 7 HM) maintained at three different locations in Sweden [1]. 6 clocks (4 CS and 2 HM) are located at the National time and frequency laboratory at SP headquarters in Borås (about 60 km inland from Gothenburg on the west-coast) were UTC(SP) is maintained. 3 clocks (1 CS and 2 HM) are located at the Onsala Space Observatory, Onsala (about 60 km south-west of Borås) and the remaining 11 clocks (8 CS and 3 HM) are located at STUPI, a clock facility in Stockholm (about 450 north-easts of Borås). The clocks located at the two remote sites are linked to UTC(SP) using GPS code observations. All 20 clocks are also supporting the on-going BIPM rapid UTC project.

## 3. Time Scales

UTC(SP) is a real-time time scale and defined at the output connectors of an auxiliary output generator (AOG) that is phase-locked to a 5-MHz signal, usually from one of the local hydrogen masers at SP. The output is steered so that the time and frequency offsets between UTC(SP) and UTC are minimized. The steering parameters are estimated from an ensemble clock based on a Kalman filter [2]. In a first step, in real time, these parameters are estimated from the 6 local clocks at SP. In a second step, about one month after the fact, the time difference between UTC(SP) and UTC, available from the BIPM and Circular T, is used as input to the Kalman filter which updates the clock states for more accurate steering. A redundant time scale is maintained with the same approach but with other hardware.

Similar time scales are also operated at the remote clock sites in Onsala and Stockholm using local clocks. We plan to develop the ensemble time scale algorithm and operation to include data from all 20 clocks which would improve the stability and accuracy of the time scale. Another development of the algorithm would be to include also data from the BIPM rapid UTC.

## 4. Remote Time and Frequency Comparisons

### 4.1. GPS

SP operates several GNSS receivers capable of producing both code- and carrier phase observables. GPS-data (CGGTTS and RINEX) from two receivers synchronized to UTC(SP) are sent to the BIPM on a daily basis, thus supporting also the BIPM rapid UTC project.

### 4.2. TWSTFT

SP operates since year 2003 a TWSTFT-station that today in combination with GPS carrier-phase data (i.e. TWGPPP) is the main time transfer link for SP to UTC. TW-data are sent on a daily basis to the BIPM.

### 4.3. GLONASS

SP operates no official GLONASS time link for the moment. New software provided by Pascale Defraigne of ORB is, however, presently evaluated for data from SP GNSS receivers. The software is an update of previous software [3] used for GPS RINEX- to CGGTTS-format conversion which now, in its latest version, also includes support for GLONASS observables.

## 5. Time Dissemination

### 5.1. NTP

SP operates several local NTP servers synchronised to UTC(SP). One of them is an authenticated NTP-service that uses NTPv4 autokey. Besides the NTP servers at SP, we have also established three traceable NTP nodes [4] at Swedish national exchange points for Internet traffic. Those nodes are securely placed within mined spaces below the ground and are considered critical infrastructure. The system’s timing is sustained by a local group of rubidium clocks linked to UTC(SP) using multi-channel common view.

### 5.2. Time code via telephone modem

From SP there is still a modem service available that serves UTC(SP) as European time code with latency estimation.

### 5.3. Speaking clock

A speaking clock service is distributed by TeliaSonera where SP provides traceable synchronization and speech synthesis.

## 6. Geodetic GNSS station

The time and frequency laboratory has several GNSS antenna systems available. The main antenna is placed on top of a concrete pillar and connected via a power splitter to several receivers in the laboratory. One of these receivers is SPT0 which is a part of the IGS network as well as SWEPOS (a Swedish reference network of permanent GNSS stations). SWEPOS (http://swepos.lmv.lm.se) is used in a number of applications. Among them the study of land uplift in Sweden (Onsala Space Observatory) as well as real time kinematic (RTK) positioning at the centimetre level (National Land Survey of Sweden). Time and frequency applications take advantage of a system implemented for antenna- and antenna cable temperature control [1].

## 7. Research and Development

Some of the on-going R&D projects are briefly reported on below.

### 7.1. New time lab

A new clock facility site is presently being built in Stockholm. The work is led by the time and frequency group at SP and founded by the Swedish Post and Telecom Authority. The facility is situated below ground in an EMP-protected housing and considered as a redundant infrastructure for both time and frequency dissemination in Sweden. The site will be equipped with 6 Caesium standards serving two hard-ware independent times scales, all traceable to UTC(SP) using GNSS time transfer. A redundant time transfer link using fibre-optical methods is also planned.

### 7.2. NTP

The NTP servers presently used according to section 5.1 above have been in operation for more than 10 years. Considering the development in Internet infrastructure and number of users, new, modern servers are needed. Presently, a new type of NTP-server is being developed by SP in a project funded by the Swedish Post and Telecom Authority. These servers are designed based on four major goals: (1) 10GE line rate capability; (2) line rate throughput. On a LAN 10GE this would require about 10,964,912 packets per second per interface to be answered for real DoS (Denial of Service) protection; (3) accuracy and traceability of NTP timing. Timing for the server timestamps shall be accurate with numerically defined uncertainties. The new server design shall be capable of tracing the NTP timing and individual packets time stamping to UTC; (4) IPv6 capabilities and service flexibility.

The solution [5] is based on a commercial time stamping network traffic analyser hardware for 1G and 10G Ethernet. These traffic analysers can be synchronized to an external time scale and the synchronization can be measured for traceability. Ethernet frames are continually captured and individually time stamped with a resolution of about 7.5 ns. The frames are hardware load-balanced to a number of receiving channels, which are handled in parallel using a multi-thread technique. Transmit uses a unique replay feature that allows timely release of frames to the network. On top of the analyser's API a user space IP-stack has been implemented that asynchronously handles all network traffic. The current software provides all necessary functions for a multi-homed IPv4/6 NTP server on VLAN tagged Ethernets.

### 7.3. Fibre Time and Frequency Transfer

*Two-way method:*

Some years ago SP started a project funded by the Swedish Post and Telecom Authority aiming at developing a time and frequency transfer method independent on well-established satellite-based methods and using the commercial fibre-optical communication infrastructure [6]. The method chosen is based on passive listening and detection of SDH frame headers in fibre-optical networks presently using an OC-192/STM-64 connection between core IP-routers at a nominal bit rate of 9953 Mbit/s, but is in practice with minor adjustments applicable to any STM line rate or packet-based data transmission network.

With new hardware developed a couple of years ago, a link between SP, STUPI and MIKES in Finland has been evaluated. The setup of the link is supported by three different network organisations: SUNET (Swedish University Network) and FUNET (Finnish University and Research Network) which are connected via NORDUnet (Nordic Infrastructure for Research & Education). The results [7] show potential frequency stability below 1E-15 @ 1 day. Daily variation of the order of a few nanoseconds due to temperature variations has been seen that limits the sub-daily stability.

*One-way method:*

The two colour one-way frequency transfer technique in optical fibre is an alternative method to two-way time and frequency transfer that is useful if there are unknown asymmetries in the connection. The method is possible to use in existing infrastructure and is able to coexist with data channels for example in WDM systems, which make it possible to broadcast to multiple users and enables the user to be anonymous to the time or frequency transfer.

The technique utilizes the difference of group velocity to estimate the delay variation of the timing signal in one of the wavelength channels. The first proof-of-concept used two modulated lasers at 1310 nm and 1550 nm [8] and wavelengths at 1535 nm and 1553 nm [9]. Those results showed the possibility to perform a one-way time and frequency transfer with two wavelengths and by evaluate these two against each other, create a correction signal for compensation for influences along the transmission path. Recent evaluations are performed with two wavelengths 8 nm apart and focused to develop a real-time compensation algorithm and evaluating different kind of error source in the receiver after propagating signals along the 160 km long fibre connection that included Erbium doped fibre amplifiers (EDFAs) [10].

### 7.4. GNSS geodetic applications, Positioning, and Atmosphere

SP investigates and develops new methods for positioning, velocity and acceleration [11]. These techniques are used for both rapid movements of vehicles and aircrafts and for smaller movements where very high accuracy is required. Examples of the latter are earthquakes [12] and land uplift after the last ice age.

GPS is frequently used for the construction of houses, roads and bridges. These applications are often performed using the RTK technology, which today provides the best accuracy in real time applications. In cooperation with the National Land Survey of Sweden SP further develops the RTK technology and its applications [13]. We also develop methods for GPS use in forests and dense urban areas.

SP determines routinely the amount of atmospheric water vapour from a large number of GPS receivers across Europe [14]. This is an important parameter in the study of our climate and the information is used to evaluate climate models. Another part of the atmosphere that SP is studying with the help of GPS is Ionosphere [15].

## 8. References

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