# SUMMARY OF TIME AND FREQUENCY ACTIVITIES AT NICT

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## 1. INTRODUCTION

The time and frequency standards groups, which consisted of the following 6 groups, Atomic Frequency Standards Group, Time and Frequency Measurements Group, Japan Standard Time Group, Quasi-Zenith Satellite System Group, Radio Astronomy Applications Group, and Time Applications Group in the National Institute of Information and Communications Technology (NICT) were integrated into one large group, Space-Time Standards Group with 4 subsidiary projects, Space-Time Standards Project, Space-Time Measurement Project, Next Generation Time and Frequency Standards Project, and Japan Standard Time Project in April 2006. All the activities of the research and service have been continued and progressed.

## 2. ATOMIC FREQUENCY STANDARDS

### 2.1. OPTICALLY PUMPED STANDARD, NICT-O1

The first optically pumped cesium primary frequency standard CRL-O1 changed its name to NICT-O1 in April 2004.. NICT-O1 operated from April, 2000 to June, 2006. The data of the accuracy evaluation of TAI scale unit have been sent to BIPM twice a year on average. Type B uncertainty of the standard was estimated as 5.4 x $10^{-15}$. In most cases during the evaluation period, the total uncertainties of the standard were less than 1 x $10^{-14}$.

**2.2. FOUNTAIN FREQUENCY STANDARD** NICT has conducted the development of a cesium atomic fountain primary frequency standard. We named it as NICT-CsF1. It has achieved a frequency stability better than 5 x $10^{-13}/\tau^{1/2}$. Several frequency shifts due to the systematic effects have been evaluated. So far, the combined frequency uncertainty has been estimated to be less than 2 x $10^{-15}$.

### 2.3. OPTICAL FREQUENCY STANDARD

NICT have developed an optical frequency standard using an electric quadrupole transition in single, laser-cooled, trapped $Ca^+$ ions. For a 729-nm clock laser system, we have obtained a laser linewidth of 66 Hz and a root Allan variance of 2 x $10^{-13}$ at 1 s. The electric quadrupole transition of single $^{40}Ca^+$ ions was detected by the shelving method, and we have measured the transition spectrum. For the optical-frequency measurement, a frequency comb system has been developed by using the broadband femtosecond-pulse laser.

## 3. TIME KEEPING

The generation system of Japan Standard Time (JST) has been largely renewed by using a occasion of moving the system to a new building. We have 4 hydrogen masers and 18 Cs atomic clocks. Hydrogen masers have been introduced into the JST system for the first time. The signal source of JST has been changed from a Cs atomic clock to a hydrogen maser, which improves a short-term frequency stability of both UTC(NICT) and JST. We developed a 24ch-DMTD system for the simultaneous measurements of time differences among the clocks. The precision of measurements is 100 times better than that by a time interval counter in the previous system. The reliability of this system has been strengthened by the improved monitor functions and triple redundancy. This new JST system has been operating February 7, 2006. UTC(NICT) generated by this system has been synchronized with UTC within around10ns since then.

## 4. PRECISE TIME TRANSFER

### 4.1. GPS

NICT has changed the P3 and Multi-Channel (MC) GPS receivers from ASHTECH Z-XII Metronome and Topcon Euro-80 to Septentrio PolaRX2, from Feb. 7, 2006. We have provided both P3 and MC CCTF data from the same receiver in order to avoid any errors caused by using different receivers.

We have also made a redundant system with three Septentrio receivers. These receivers are connected to the independent AOG signals, and as a consequence, the system is robust in the case that the receiver or the distribution system has a trouble.

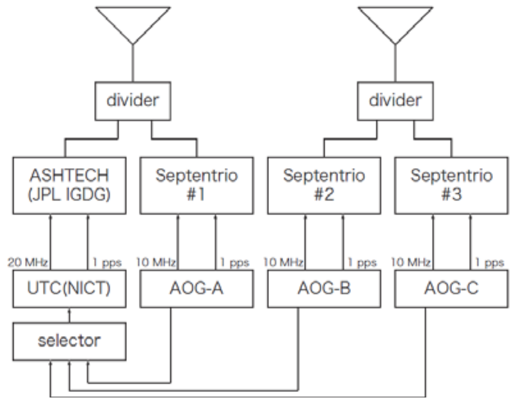


**Fig.1. GPS measurement system at NICT**

In addition, observation at IGS station of NICT (site name is KGN0) is finished on Apr. 1 2006. However, our RINEX files are continuously available for the carrier phase time transfer as follows; http://www3.nict.go.jp/w/w114/data/GPS/rinex/.

### 4.2. TWSTFT

NICT and major T&F institutes in the Asia-Pacific region, such as NMIJ in Japan, NMIA in Australia, NTSC in China, TL in Chinese Taipei, KRISS in Korea, and SPRING in Singapore, are cooperatively constructing a TWSTFT network in this region. To operate those links, we use multi-channel modem (NICT modem) developed by NICT. Time transfer is regularly performed and data/hour are reported to the BIPM. NICT carried out calibration trips by using a portable station between NICT and TL in February, 2006.

A TWSTFT link between NICT and PTB was established in July 2005. This link is connected by using the NICT modem. The time transfer is hourly performed and the data are also reported to the BIPM.

The TWSTFT link to USA has experimentally started between NICT and USNO by using a SATRE modem via VDB from April 2006. Since the link is conducted in a very low elevation angle and the quality of the link is not enough, we plan to change the relay station to Hawaii.

### 4.3. ETS VIII

NICT plan to conduct a precise time and frequency transfer experiment between a ground-reference clock and an atomic clock on the satellite ETS-8 (Engineering Test Satellite -8). ETS-8, which will be launched in FY2006, is a Japanese geostationary satellite equipped with cesium-beam frequency standards. NICT developed an equipment to carry out two-way time transfer by using carrier phase measurement. It is also possible to calibrate internal delays and delay variations of the transmitting and receiving paths between the satellite and the ground station.

By using this method, we expect to achieve precision of approximately 10 ps. We completed electrical test and environmental test of the equipment, and the ground stations are almost ready.

**4.4. QZSS**

Japan has started a project of Quasi-Zenith Satellite System (QZSS) from 2003. QZSS will be highly useful for supplement to the modernized GPS in urban canyon and mountainous area with its high visibility brought out by its inclined orbits. In this project, NICT is to develop a space-borne hydrogen maser (SHM) and time management system, and to carry out experiments by using them. By conducting two-way time transfer between the on-board clock and the ground clock by using Ku-band link, the management of the QZSS system time, which links to UTC(NICT), is expected to achieve nanosecond level. The engineering models (EM) of those on-board equipments were developed and have been taken environmental tests. The first satellite is planned to be launched in 2009.

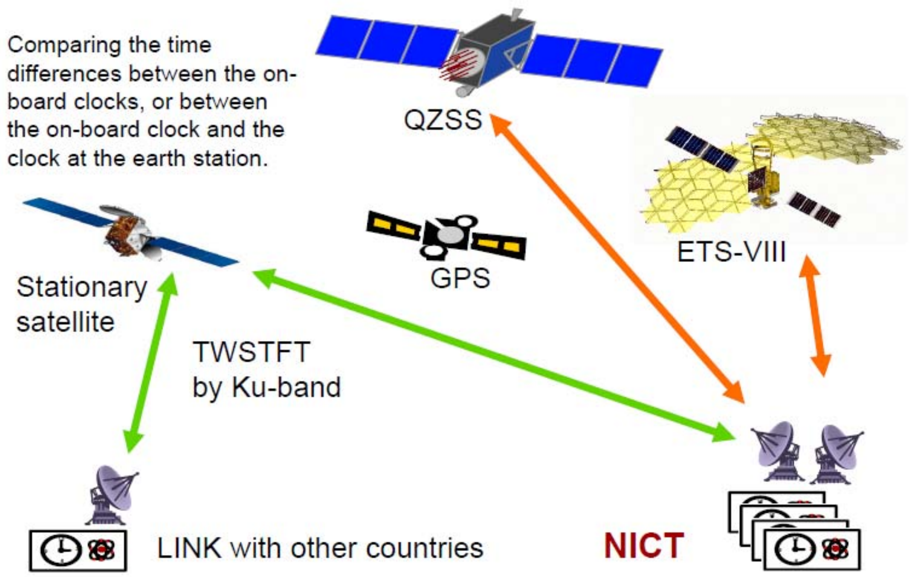


**Fig. 2. Time transfer systems at NICT**

## 5. DISSEMINATION

**5.1. STANDARD-FREQUENCY AND TIME-SIGNAL EMMISIONS**

NICT provides the dissemination service of standard-frequency and time-signal via LF band, as shown in Fig.3. The signals from the two LF stations, namely Ohtakadoya-yama station and Hagane-yama station, cover whole Japan. Table 1 shows the characteristics of the stations, Both stations operate 24 hours a day. A market of radio controlled watch and clock have been developed.

**5.2. FREQUENCY CALIBRATION SYSTEM FOR TRACEABILITY**

NICT have been conducting a frequency calibration service referenced to UTC(NICT). In order to fulfill the requirements of global MRA, NICT have established a quality system for the frequency calibration service, which was assembled by the accreditation body, National Institute of Technology and Evaluation. The conformity to ISO17025 was certified at the end of March 2001. BMC of the system is $1x10^{-13}$.

**Table 1. Characteristics of LF stations**

| | Ohtakadoya-yama | Hagane-yama |
|---|---|---|
| Frequency | 40 kHz | 60 kHz |
| E.I.R.P | 13 kW | 23 kW |
| Antenna | 250 m height | 200 m height |
| Latitude | 37°22' N | 33°28' N |
| Longitude | 140°51' E | 130°11' E |

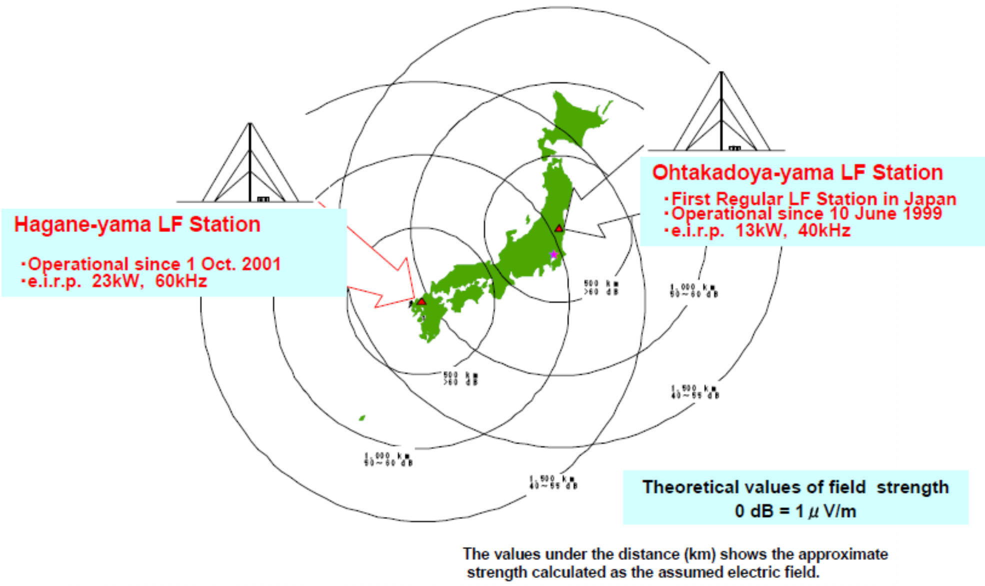


**Fig. 3. LF time and frequency service stations in Japan**
The values under the distance (km) shows the approximate strength calculated as the assumed electric field.

## 6. TRUSTED TIME STAMPING

Accurate and trusted time is required for safe use of electronic commerce or other important information exchanges. NICT has developed the time stamping platform systems for verifying new techniques under actual operation environment. Following experiments have been conducted in collaboration with time stamping service providers:

(1) using two different time stamping methods at the same time for making stronger against compromise of encryption algorithm
(2) new time transfer technique to ensure the time traceability
(3) validity term extension method with re-time-stamping
(4) validity term extension method with hysteresis signature techniques.

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