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SUMMARY OF TIME AND FREQUENCY ACTIVITIES AT CRL

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1. INTRODUCTION

On 1st April 2004, Communications Research Laboratory (CRL) merges Telecommunications Advancement Organization, and restarts as National Institute of Information and Communications Technology as part of government's administrative reforms. However, the structure for Time and Frequency research is unchanged. All of the activities described in this report are performed by Atomic Frequency Standards Group, Time and Frequency Measurements Group, and Japan Standard Time Group.

Another important event at CRL is the construction of a new building for Time and Frequency standard facility. In Japan, the importance of time and frequency standard service as social infrastructure is gradually understood. CRL has completed a new building for Time and Frequency facility with seismic isolation and high security in February 2004, and the above groups have moved to the new building..

2. ATOMIC FREQUENCY STANDARDS

2.1. OPTICALLY PUMPED STANDARD, CRL-O1

CRL-O1, the first optically pumped cesium primary frequency standard in CRL, has been in operation since April, 2000. The data of the accuracy evaluation of TAI scale unit has been sent to BIPM twice a year on average. In most cases, the total uncertainties of the standard are below 10^{-14}. In 2003, a paper on the accuracy evaluation of CRL-O1 has been submitted to Metrologia. In the course of writing the paper, and thanks to the referees' useful comments, many items of the uncertainty budget are revised. In the paper, typical type B uncertainty is estimated as 5.4×10^{-15}.

2.2. FOUNTAIN TYPE STANDARD

The development of a fountain standard in CRL is going on. Ramsey fringes of less than 1 Hz line width have been observed. A microwave frequency is stabilized to the central fringe and a stability of $\sigma_y(\tau) = 2 \times 10^{-12} / \tau^{-1/2}$ is obtained. Aiming a better stability, we are trying to improve the S/N ratio of the standard. Together with this improvement, the evaluation of the uncertainty budget will be conducted.

2.3. Ca^+ ION OPTICAL FREQUENCY STANDARD

CRL has commenced the research and development on the single Ca^+ ion optical region atomic frequency standard. Now we are developing a miniature trap, cooling laser systems and a 729 nm clock laser system. For the measurement of optical frequency, Menlo system's femtosecond laser optical comb system has been installed.

3. TIME KEEPING

CRL operates about twelve cesium atomic clocks to generate UTC(CRL), which is the source of Japan Standard Time (JST) and the national frequency standard. The improvement of timescale algorithm made in April 2003 has resulted in better stability of UTC(CRL), which has been kept within +/-15ns against UTC after the improvement. A new time keeping system is now being developed in the new building. The new time keeping system will be operated parallel with the current system and its performance will be evaluated during the transition period. After the evaluation, UTC(CRL) will be generated by the new system.

4. PRECISE TIME TRANSFER

CRL and major T&F institutes in the Asia-Pacific region, such as NMIJ in Japan, NML 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. The time transfer results of the links between CRL-TL, CRL-NMIJ, CTL-NTSC, have been used for the primary time transfer technique for the TAI calculation at BIPM from January 2002. To operate these links, we use the Atlantis modem which is commercially developed by AOA.

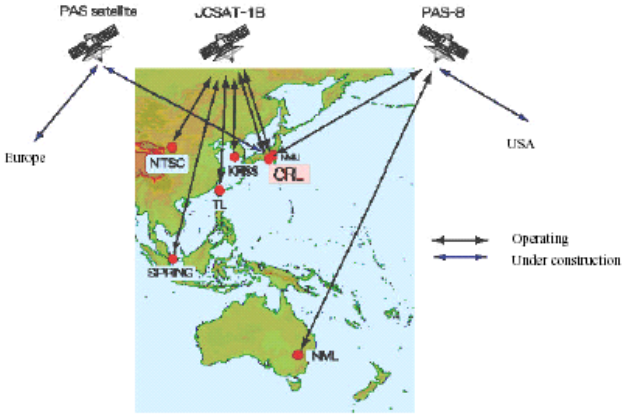

Fig. 1 Present state of the TWSTFT network in the

Besides that, CRL has developed a new time transfer modem for TWSTFT. Its main feature is the multi-channel operation which can realize simultaneous time transfer among the participating stations. At present, we are testing its performance using JCSAT-1B among CRL, NMIJ, TL, KRISS, SPRING, and NTSC, and using PAS-8 among CRL, NML, (TL), and (KRISS). For regular time transfer, 7 days/week time transfer using this multi-channel modem has started from latter half of March 2004.

Fig. 2 Multi-channel TWSTFT modem developed at CRL.

For the TWSTFT link with USA, the two-way time transfer has been experimentally started between CRL and USNO using Vandenberg Air Force Base (VDB) station of USNO from May 2003. CRL is planning to use the multi-channel modem developed by CRL for the link between CRL and VDB.

5. DISSEMINATION

5.1. STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

CRL 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 the whole Japan. Table 1 shows the characteristics of the stations. Both stations operate 24 hours a day. A new market of radio controlled watch and clock is rapidly growing, and more than ten million watches and clocks have been already sold in Japan in these five years.

Table 1 Characteristics of LF stations

	Ohtakadoya-yama	Hagane-yama
Frequency	40kHz	60kHz
E.I.R.P	15kW	23kW
Antenna	250m high	200m high
Latitude	37°22′ N	33°28′ N
Longitud	140°51′ E	130°11′ E

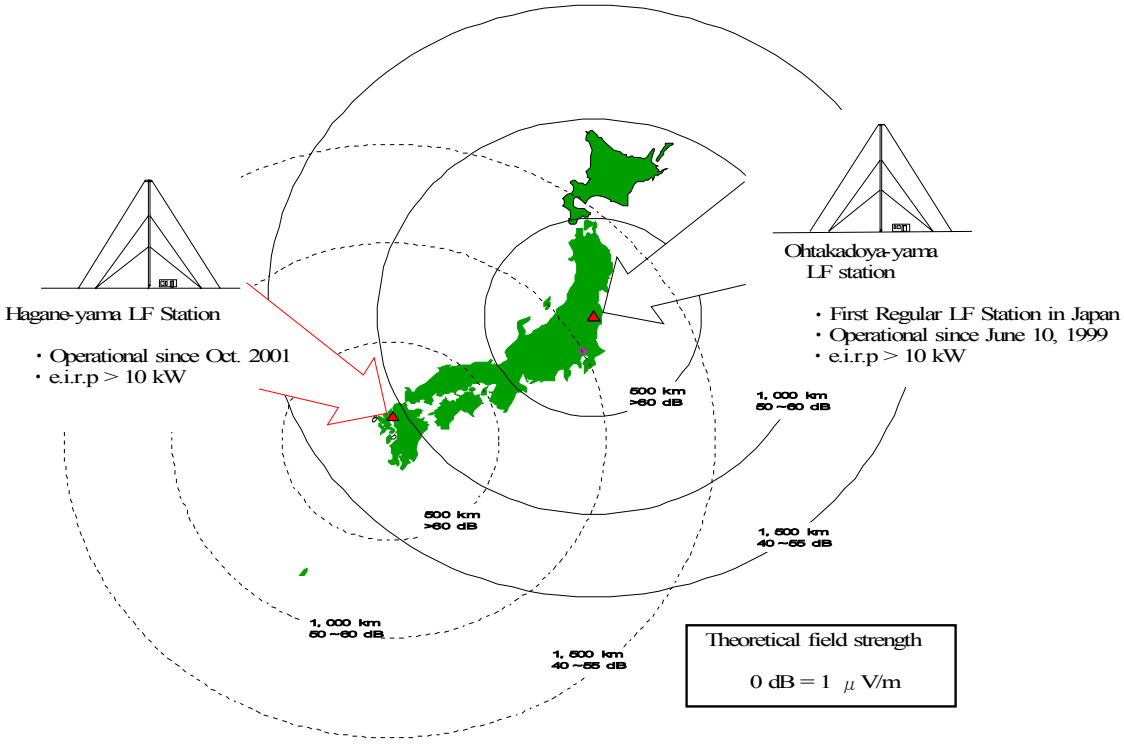

Fig.3 LF time and frequency service stations in Japan

5.2. FREQUENCY CALIBRATION SYSTEM FOR TRACEABILITY

CRL has been conducting a frequency calibration service referenced to UTC(CRL). In order

to fulfill the requirements of global MRA, CRL has established a quality system for the frequency calibration service, which was assessed by the accreditation body, National Institute of Technology and Evaluation, and the conformity to ISO17025 was certified at the end of March 2001. BMC of the system is $1x10^{-13}$. Besides that, CRL has developed a remote frequency calibration system, and is now evaluating the performance of system.

6. RELATED RESEARCH ON TIME AND FREQUENCY

In the field of the relativistic effects on time and frequency standards, following studies have been conducted recently:

(1) Detection of the gravitational red shift of several atomic clocks transported from CRL headquarters to two LF stations.
(2) Research on the astrometric gravitational lensing and reference frames.
(3) Observation of millisecond pulsars PSR J1937+21 and PSR J1713+07 by using Kashima 34 m antenna and Usuda 64 m antenna.