SUMMARY OF TIME AND FREQUENCY ACTIVITIES AT CRL

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1. INTRODUCTION

On 1st April, 2001, Communications Research Laboratory (CRL) became an independent administrative institution, as did almost all Japan's national research institutes as part of the government's administrative reforms. CRL's time and frequency activities now come under the Applied Research and Standards Division. All of the activities described in this report are performed within the division's Atomic Frequency Standards Group, Time and Frequency Measurements Group, and Japanese Standard Time Group.

2. ATOMIC FREQUENCY STANDARDS

2.1 OPTICALLY PUMPED STANDARD, CRL-O1

CRL-O1, the optically pumped cesium primary frequency standard, developed in collaboration with the National Institute of Standards and Technology (NIST) of the U.S., has been in operation since April, 2000. The accuracy of CRL-O1 has been regularly evaluated almost every two months. A typical value of the evaluated uncertainty is 2×10^{-14}. So far, type A uncertainty has been dominant in the uncertainty budget. Efforts to improve accuracy, e.g. by expanding the evaluation period, are now being planned.

2.2 FOUNTAIN TYPE STANDARD

Recent advances in laser cooling technology have enabled the development of a fountain standard that can achieve an outstanding uncertainty. Several research institutes are working on researching and developing fountain standards, and some have recently succeeded in putting them into operation. CRL is conducting research on the atomic fountain standard, and has succeeded in trapping cesium atoms using a standard MOT, and cooling them down to a few μK using the polarization gradient method. The moving molasses method has also been used to successfully launch the cold atoms, though the launching height is at present limited to 30 cm by the configuration of the experimental set up. Following this success with the small experimental set-up, a larger system is being set up with the aim of establishing the primary standard. The required high vacuum has been achieved with the system, and cesium atoms have been successfully trapped and launched.

3. TIME KEEPING

At the headquarters of CRL, about ten cesium atomic clocks are operated to generate UTC(CRL), which is used for Japanese Standard Time (JST) and for the national frequency standard. We use a special algorithm to generate UTC(CRL) as an ensemble time scale, and UTC(CRL) has been kept within 100 ns of UTC. We have started work on improving the algorithms used to calculate UTC(CRL) and TA(CRL) to enable us to combine all the timing data obtained at CRL, such as data from accuracy evaluation of primary frequency standards, atomic clocks, and millisecond pulsar timing.

4. PRECISE TIME TRANSFER

CRL is constructing a Two Way Satellite Time and Frequency Transfer (TWSTFT) network in the Asian-Pacific region to support next generation method of accurate and precise time transfer in collaboration with other time and frequency institutes in the region, such as NML in Australia, CSAO in China, TL in Chinese Taipei, AIST in Japan, KRISS in South Korea, and PSB in Singapore. Figure 1 shows the present state of the TWSTFT network in the Asia-Pacific region. CRL has been developing a new type of time transfer modem for the TWSTFT to reduce several of the technology's drawbacks, such as high running costs and operational difficulties. It will be completed before later half of 2001 and will be used in the Asia Pacific TWSTFT network.

We have also begun a study of the use of GPS carrier-phase time transfer as technique for precise time transfer.

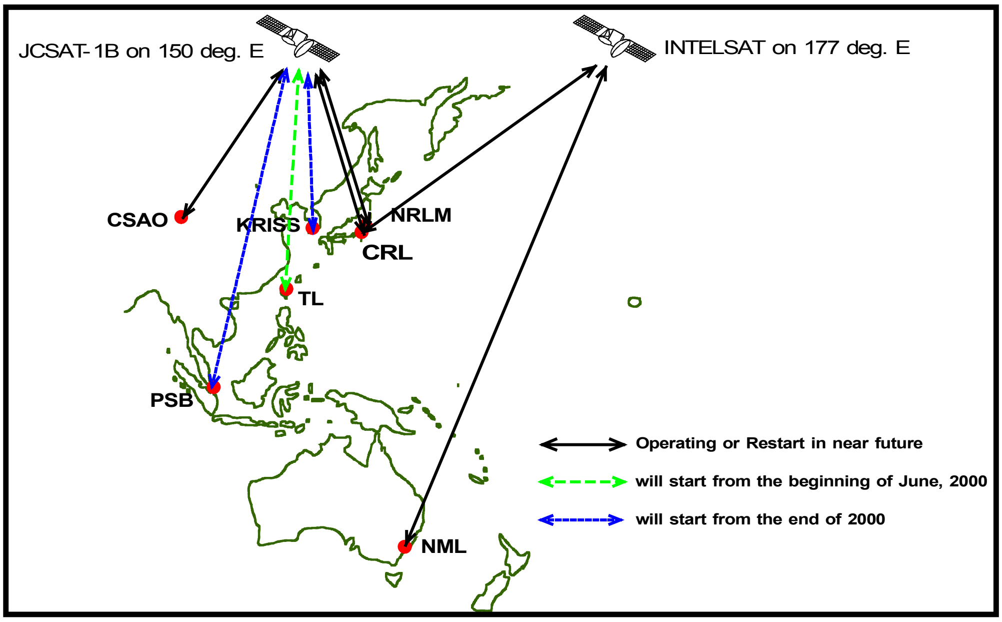

Figure 1 Present state of the TWSTFT network in Asia Pacific region

5. DISSEMINATION

5.1 RADIO BROADCASTING OF TIME AND FREQUENCY STANDARD SIGNALS

CRL decided to shift Japan's time and frequency service from the HF band to the LF band, and has constructed new LF stations so the change can be made. The locations of the stations are shown in Figure 2. The Ohtakadoya-yama Station, one of the new LF stations, has been built and has been operating since June 10, 1999. This station emits a center frequency of 40 kHz with an effective radiation power of about 15 kW. The station call sign is JJY. Construction of the second LF station started in 1999, and it will operate from October, 2001. The HF service ceased at the end of March, 2001.

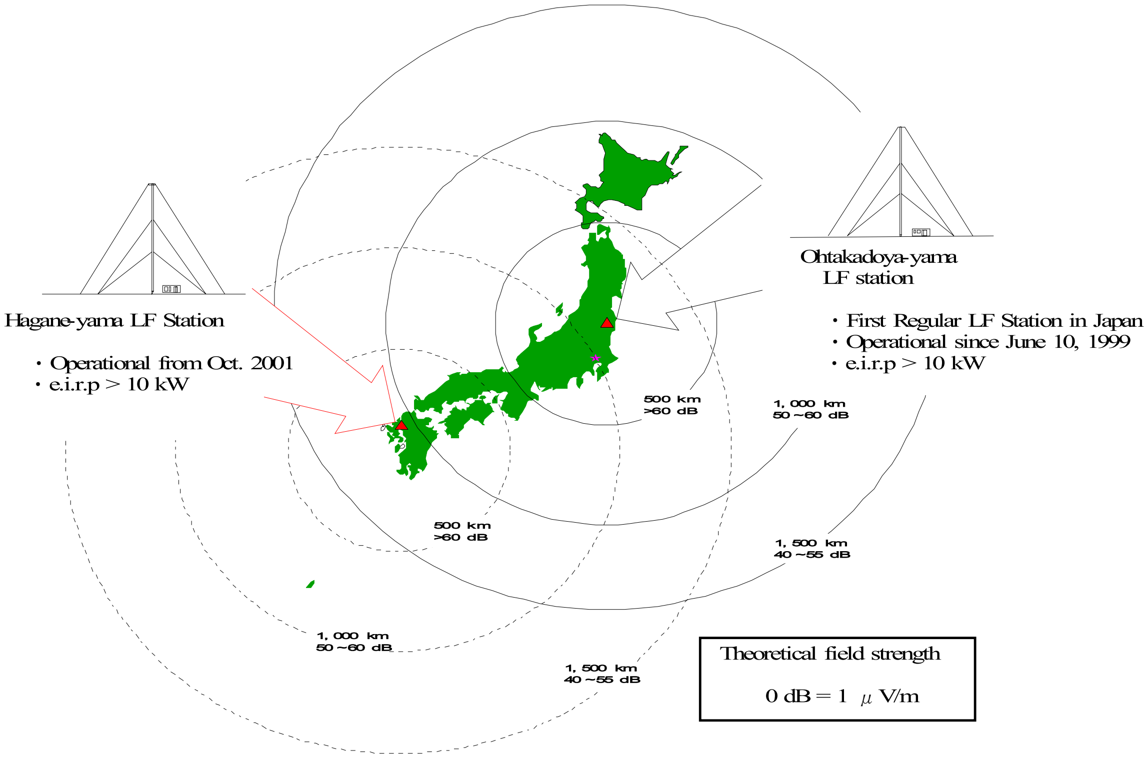

Figure 2 LF time and frequency service stations in Japan

5.2 DIGITAL TIME STAMPING

As the national time authority (NTA) in Japan, CRL has started to develop a trusted time serving system for time stamping authorities (TSA). This research and development work is highly significant for electronic commerce, and for the "electronic government" planned for 2003. CRL has a plan to develop an operational system until by the end of 2002.

5.3 FREQUENCY CALIBRATION SYSTEM FOR TRACEABILITY

CRL has been conducting a frequency calibration service referenced to the UTC(CRL). It has developed a frequency calibration system to meet the needs of the mutual recognition arrangement (MRA) in the field of metrology, CRL obtained the ISO 17025 certification for its calibration system at the end of March, 2001. The system has the capability of frequency calibration uncertainty within 1×10^{-13} by the frequency of UTC.

6. RELATED RESEARCH ON TIME AND FREQUENCY

6.1 MILLISECOND PULSAR TIMING

CRL has developed a millisecond pulsar observation system that uses an acoustic-optic spectrometer. We plan to use pulsar-timing data to construct a stable long-term time scale. We have conducted regular observations of PSR1937+21 using the S-band receiver of CRL 's 34-m antenna since 1997. Figure 3 shows the time residual of the arrival time of the PSR1937+21. The standard deviation of 2.4 microseconds has been obtained. Figure 4 shows the frequency stability of the time residual plotted in Figure 3.

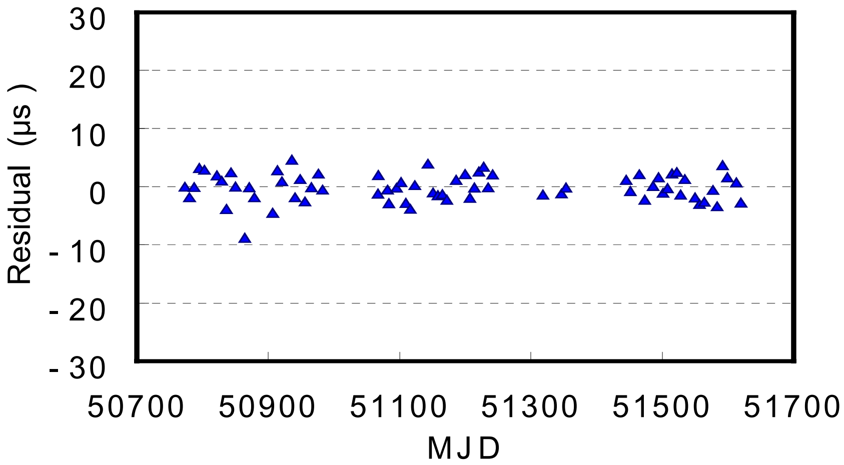

Figure 3 Timing residuals of arrival time of PSR 1937+21 observed by CRL's 34 m antenna using S-band receiver. Each mark denotes averaged value for one day observation data.

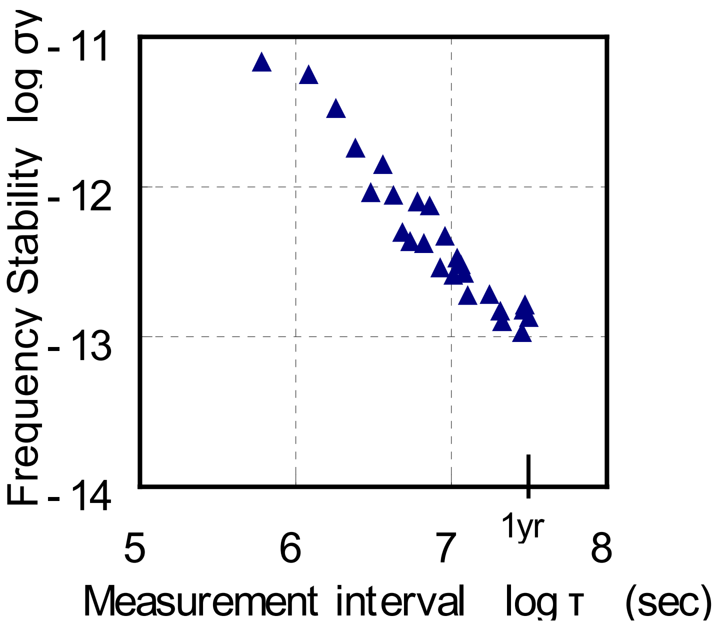

Figure 4 Frequency stability of the timing residual plotted in Figure 3.

6.2 RELATIVISTIC EFFECTS IN T&F STANDARDS

CRL has been conducting research on relativistic effects on time and frequency standards. The following studies have been conducted recently:

(1) analysis of the gravitational delay of TOA in pulsar timing,

(2) estimation of relativistic effects on inverse VLBI planetodesy,

(3) detection of the gravitational red shift of an atomic clock transported from CRL headquarters to Ohtakadoya-yama LF station.

6.3 GNSS

CRL has conducted basic research on the next generation global navigation system. The work includes developing a precise time and frequency comparison system for ETS VIII, a Japanese geostationary satellite that will be launched in 2003. Using a two-way time-transfer method and carrier-phase information, this precise time comparison system will attain a precision better than 10 ps for the measurement of time differences between on-board standards and ground reference clocks.

In the same research category, CRL is developing a breadboard model of a space-borne hydrogen maser. A small sapphire-loaded cavity is very effective for miniaturizing a maser. We analyzed the TE011 mode of a sapphire-loaded cavity, and established an optimized design principle for one. Based on the design principle, we have developed a small hydrogen maser with a sapphire-loaded cavity. Preliminary data show that the frequency stability of the maser is 1×10^{-14} for averaging time between 100 and 1000 s.

7. OTHER ACTIVITIES

CRL hosted a workshop on time and frequency called the Asia Pacific Workshop on Time and Frequency 2000 (ATF 2000). The workshop, held at CRL, ran from October 31 to November 2, 2000. About 80 people, 35 from foreign institutes, attended. CRL is planning to hold a similar workshop every two years.