OVERVIEW OF RESEARCH ACTIVITIES ON TIME AND FREQUENCY AT THE COMMUNICATIONS RESEARCH LABORATORY

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Abstract

Communications Research Laboratory (CRL) is a national institute, which is responsible for the national frequency standards in Japan. For this mission CRL has been conducting many research and development projects in the field of time and frequency standards. To introduce these projects, we will present following topics:
- Development of primary frequency standards, such as an optically pumped cesium-beam frequency standard and a fountain type cesium frequency standard,
- Time keeping at CRL,- Millisecond pulsar timing observations for long-term stability of time
- Millisecond pulsar timing observations for long-term stability of time scale,
- Construction of low frequency stations for the dissemination of the standard time and frequency,
-Precise time transfer using two-way satellite time-transfer and GPS carrier-phase method,
- Construction of the calibration system for traceability of the frequency standard in Japan,
- basic research on the next generation global satellite navigation system, such as the spaceborne hydrogen maser, and the precise time transfer method between satellite and ground station.
and
- research on the relativistic effects in the time scales and 4-dimensional reference frames.

INTRODUCTION

As the national institute responsible for the national frequency standards in Japan, CRL has been conducting many research and development projects in the field of time and frequency standards. Here we will introduce these projects.

DEVELOPMENT OF PRIMARY FREQUENCY STANDARDS

CRL and the National Institute of Standards and Technology (NIST) of the USA have collaborated on the development of the optically pumped cesium primary frequency standard CRL-O1 since January 1996. Based on the structure of NIST-7, several engineering improvements are added in CRL-O1, such as the computer-controlled master operating system and the improved microwave power servo system [1]. The evaluation operations are nearly automated. In August 1998 at NIST, CRL-O1 was evaluated in comparison with NIST-7 and frequency difference between the two frequency standards was 1 x 10-15. After that, CRL-O1 was transferred to Japan (Fig.1). At CRL, the achieved total uncertainty was 2.4 x 10-14, which is now limited by the frequency fluctuation of the reference standard used.

CRL have also conducted the basic research on Cs atomic fountain primary standard. So far, we have succeeded with the trap, laser cooling and launch of the Cs atoms.

TIME KEEPING AT CRL

At the headquarters of CRL, we are operating about 10 cesium atomic clocks to generate UTC(CRL), which is used for the Japanese Standard Time (JST) and also for the national frequency standard.
We use a special algorithm to generate UTC(CRL) as an ensemble time scale. UTC(CRL) has been kept within 100 ns compared to UTC.

MILLISECOND PULSAR TIMING OBSERVATIONS FOR LONG-TERM STABILITY OF TIME SCALE

CRL has developed a millisecond pulsar observation system which uses an acousto-optic spectrometer (AOS) aiming to apply the pulsar timing data for the construction of the long-term stable time scale [2]. We have detected several millisecond pulsars by using our wide detection bandwidth system and have started regular observations of PSR1937+21 with the 34 m telescope (Fig.2) since 1997. We also tested our observation system at the Usuda 64 m telescope of Institute of Space and Astronautical Science (ISAS) and succeeded in detecting two other highly stable millisecond pulsars, PSR1713+07 and PSR1855+09 [3].

CONSTRUCTION OF LOW FREQUENCY STATIONS FOR THE DISSEMINATION OF THE STANDARD TIME AND FREQUENCY

CRL decides to shift the radio frequency band from HF to LF for time and frequency service in Japan. To perform this direction, CRL has constructed new LF stations in Japan. The construction of Otakadoyayama Station, one of new LF stations, wascompleted and the station has been operational since June 10, 1999. This station emits the center frequency of 40 kHz with the radiation power more than 10 kW. The call sign of station is JJY.
The construction of the second LF station has been started in 1999 and it will be operational around middle of 2001.

NEXT GENERATION PRECISE TIME AND FREQUENCY TRANSFER

CRL has been making efforts to construct a Two-Way Satellite Time and Frequency Transfer (TWSTFT) network in Asian-Pacific region for next generation accurate and precise time transfer method.

Time-transfer links using this technique with National Measurement Laboratory (NML) in Australia, Shaanxi Astronomical Observatory (CSAO) in China,and National Research Laboratory of Metrology (NRLM) in Japan have been operating. CRL-NML LINK has started since October 1997. CRL-CSAO LINK has been established since the end of October 1998 on a regular basis. The National Research Laboratory of Metrology (NRLM) in Japan has started TWSTFT with CRL since March, 1999. We use INTELSAT 702 for CRL-NML LINK and JCSAT-3 for both CRL-CSAO and CRL-NRLM links. We are going to expand this TWSTFT network to other time and frequency institutes in this region,such as TL in Taiwan, PSB in Singapore and KRISS in South Korea and to connect European and North American TWSTFT network [4].

We have also started the study of GPS carrier phase time transfer.

CALIBRATION SYSTEM FOR TRACEABILITY OF THE FREQUENCY STANDARD IN JAPAN

CRL has been making frequency calibration service referenced to the UTC(CRL). CRL is going to obtain the ISO/IEC guide 25 accreditation according to the MRA which was signed among the directors of national metrology institutes on October 14, 1999.

BASIC RESEARCH ON THE NEXT GENERATION GLOBAL SATELLITE NAVIGATION SYSTEM

CRL has conducted the basic research on next generation global navigation system, such as the development of the spaceborne hydrogen maser and the precise time transfer system between satellite and ground station. Based on this research, the development of precise frequency/time comparison system for ETS VIII, a Japanese geostationary satellite which will be launched in 2002, is now going on. CRL is conducting the precise time and frequency transfer experiment between the cesium atomic clock on ETS-VIII and the ground reference clock. Using two-way time-transfer method and the carrier-phase information, it will attain a precision better than 10ps on the measurement of the time difference between on-board standards and the ground reference clocks [5].

As a part of the development of the spaceborne hydrogen maser, we have developed the sapphire cavity.

RELATIVISTIC EFFECTS IN THE TIME SCALES AND REFERENCE FRAMES

Recently, the importance of the understanding of the time scale as part of the four-dimensional reference frame is pointed out. Since the discovery of Time Geostationary Orbit in 1992 [6], we have conducted the theoretical research on relativistic effects in time scales and reference frames [7], [8].

REFERENCES

[1] A. Hasegawa et al., "An improved, optically pumped, primary frequency standard," Conference Digest of Conference on Precision Electromagnetic Measurements (CPEM) 1998, pp.177-178,1998.

[2] Y. Hanado, M. Imae, M. Sekido, H. Kiuchi, and S. Hama, "New Millisecond Pulsar Observation system at Communications Research Laboratory," Jpn. J. Appl. Phys. Vol. 33 pp.1681-1686, 1994.

[3] Y. Hanado, M. Imae, M. Hosokawa, M. Sekido, and Y. Shibuya, "Millisecond pulsar observation system at CRL," Proceedings of 30th Annual Precise Time and Time Interval (PTTI) Application and Planning Meeting, 1999, pp.89-97.

[4] M. Imae et al., "Two-way satellite time transfer activities in Asian-Pacific region," Proceedings of 30th Annual Precise Time and Time Interval (PTTI) Application and Planning Meeting, pp.355-363, 1999.

[5] M. Hosokawa et al., "Precise time transfer experiment using two way carrier phase method planned for ETS VIII satellite," Proceedings of 31st Annual Precise Time and Time Interval (PTTI) Application and Planning Meeting, submitted.

[6] M. Hosokawa and F. Takahashi, Time-geostationary orbits in the solar system, Publ. Astron. Soc. Japan 44, 159-163, 1992.

[7] M. Hosokawa, K. Ohnishi, and T. Fukushima, "Fluctuation of Extragalactic Reference Frame Due to Gravitational Lensing in Our Galaxy," Astron. J. 114, 1508-1516,1997.

[8] M. Hosokawa, K. Ohnishi, and T. Fukushima, "Uncertainty of pulsar time scale due to the gravitational time delay of intervening stars and MACHOs," Astron. Astrophys. 351-393, 1999.

Figure 1 CRL-O1

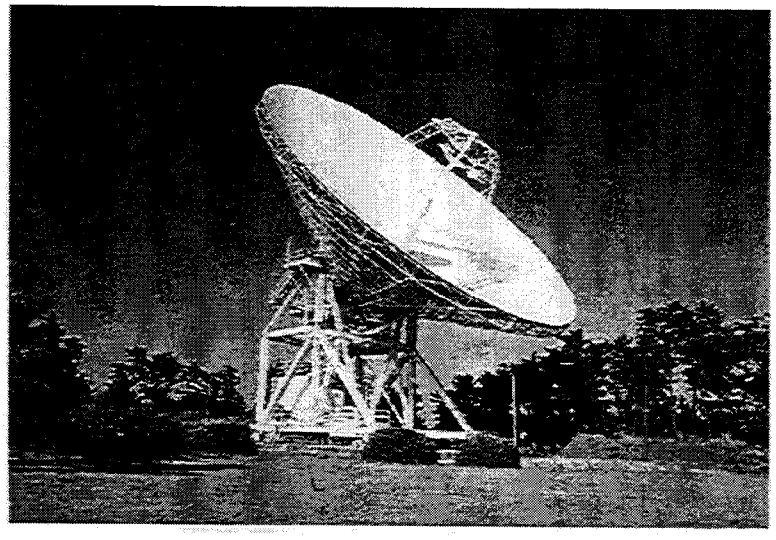

Figure 2 Kashima 34 m antenna

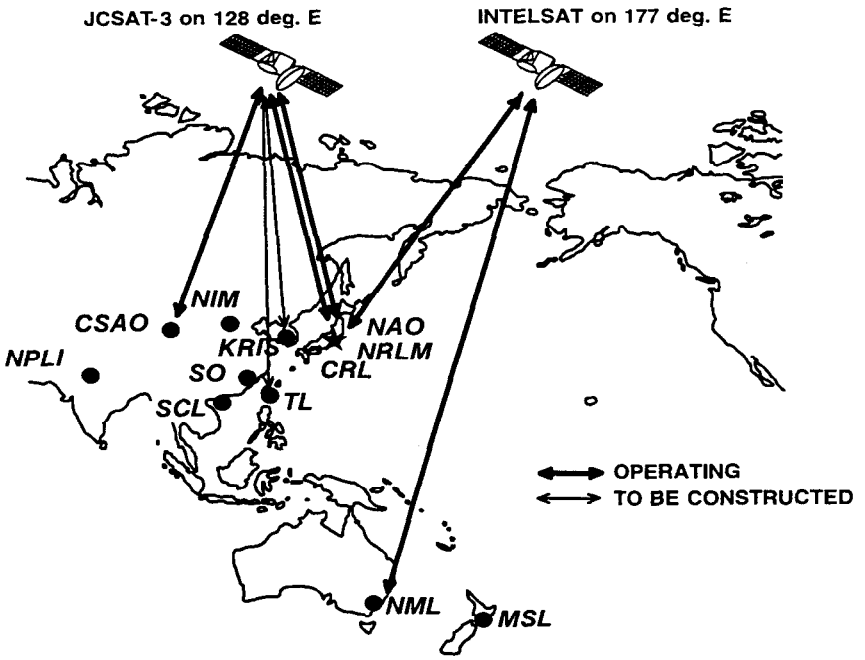

Figure 3 TWSTT network in Asia Pacific Region

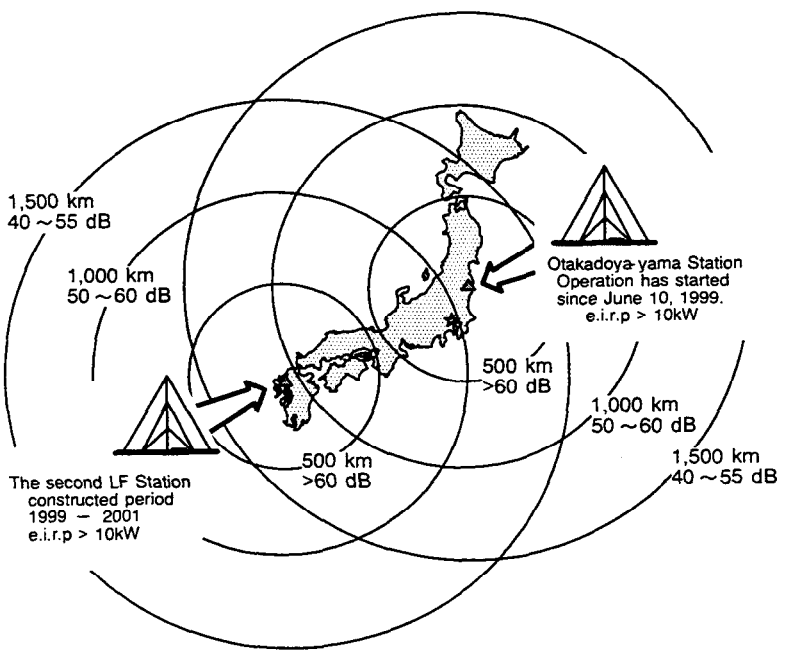

Figure 4 New LF station (Otakadoyayama Station)