TWO-WAY SATELLITE TIME TRANSFER ACTIVITIES IN ASIAN-PACIFIC REGION

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Abstract

Two-Way Satellite Time Transfer (TWSTT) is one of the most precise time transfer techniques, and time transfer using this method has been used between European and North American Time and Frequency laboratories on a regular bases. In the Asia-Pacific Region four Time and Frequency laboratories have been involved in establishing a precise time transfer network using the TWSTT technique.

After several continuous 24-hour TWSTT experiments between Communications Research Laboratory(CRL) in Japan and National Measurement Laboratory(NML) in Australia, a regular, twice weekly TWSTT link has been established since April 1998 using a Ku-band transponder on INTELSAT satellite 702 located at 177 deg. E.

CRL and Shaanxi Astronomical Observatory of Chinese Academy of Science(CSAO) have just established a precise time transfer link using the TWSTT technique from October, 1998. For this time transfer link we are using a Ku-band transponder on the JCSAT-3 satellite, which is owned by Japanese satellite communication company and is located at 128 deg. E. National Research Laboratory of Metrology(NRLM) in Japan is also planning to join the TWSTT link network with a link to CRL also using JCSAT-3 from March1999.

For the next step toward a global TWSTT network we are planning to connect the Asia-Pacific TWSTT link to European and North American time and frequency laboratories. Such a

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
DEC 1998		**00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Two-Way Satellite Time Transfer Activities in Asian-Pacific Region	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Communications Research Laboratory,4-2-1, Nukuikita-machi, Koganei-shi,Tokyo, 184-8795 Japan,**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA415578. 30th Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting, Reston, VA, 1-3 Dec 1998

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**9**	

network of precise time transfer links will not only by itself be useful in contributing to TAI and UTC but also provide an accurate time transfer reference for other precise time transfer techniques such as the GPS carrier phase method.

INTRODUCTION

The basic research on Two-Way Satellite Time Transfer(TWSTT) has been started from the 1960's[1-2] and remarkable progress was made in the 1970's and 1980's[3]. Due to its high potential for accuracy and precision, the TWSTT technique is expected to be one of the highly accurate time transfer methods for the next generation, and to investigate and to realize TWSTT network, the working group on TWSTT(presently TWSTFT) has been organized under the CCDS(present CCTF). Depending on this working group activities, Time and Frequency institutes in Europe and USA are making great efforts to realize this method as a practical tool to contribute to TAI[4-5,8-9].

In the Asian-Pacific region, the history of the research work in the field of TWSTT is also very long; several significant works were performed[3,6-8], but they could not be realized as a practical one.

Recently several Asian-Pacific Time and Frequency institutes are making an effort to establish a TWSTT network in this region and some links are already established and the time transfer using TWSTT have been performing on a regular basis. They are also planning to expand this network.

SITUATION OF T&F INSTITUTES IN ASIAN-PACIFIC REGION

In Asian-Pacific region more than ten Time and Frequency institutes which are contributing to TAI are distributed. Figure 1 shows their locations in this region. The numbers of atomic clocks for TAI in this region are about 40, and it corresponds to 15-20 % of all the clocks in the world. Also these institutes are making studies of construction of primary frequency standards, such as optically pumped Cs beam standards, atomic fountain type Cs standards and ion storage type frequency standards. Some institutes in this region recently started the uncertainty evaluation of primary frequency standards and they attained a stability at the level of $2\text{-}3 \times 10^{-14}$. Therefore it can be said that this region is one of most significant areas for the construction of TAI and UTC.

PRESENT TIME TRANSFER NETWORK FOR TAI

Figure 2 shows the GPS common-view time transfer network for the TAI organized by BIPM using GPS L1 single channel time transfer receivers. There are three node stations in the world for each area, and CRL is the node station for Asian-Oceania region. The delay calibration work of GPS receivers in this region which was organized by BIPM was performed in 1996, among

OP, NML, MSL and CRL. It is difficult to say the GPS time transfer link in this region is well enough calibrated, because it was only for three institutes and done only once. In addition this region is quite wide and the performance of GPS common-view method is not good enough for precise time transfer; therefore a new time transfer method should be considered.

TWSTT NETWORK AROUND ASIAN-PACIFIC REGION

The Major T&F institutes in Asian-Pacific Region are constructing a TWSTT network in this region under mutual cooperation. Main tools for this TWSTT network are the following:

Time transfer modem: TWT-100 "Atlantis Modem",
Earth station: 1.8 m dish Ku-band station which has 4 W of transmission power,
Satellite: INTELSAT 702 for CRL-NML link,
JCSAT-3 for links except for CRL-NML link.

JCSAT-3 satellite is owned by Japanese satellite communication company and located at 128 deg. E.

CRL-NML LINK

CRL(Communications Research Laboratory) and NML(National Measurement Laboratory) is conducting TWSTT using INTELSAT 702 satellite on 177 deg. E. The first TWSTT experiment between CRL and NML was performed in October 1997. CRL and NML have been performing TWSTT twice weekly on a regular basis. Figure 3 shows the time transfer results from June 1998 to November 1998. Two institutes are using a hydrogen maser as the reference clock for TWSTT to evaluate the performance of the system.

CRL-CSAO LINK

TWSTT link between CRL and CSAO(Shaanxi Astronomical Observatory in China) has been just started the end of October, 1998 on a regular basis using JCSAT-3 satellite with Ku-band. Figure 3 shows the preliminary results of this link. CSAO uses UTC(CSAO) and CRL uses a hydrogen maser as the reference clock for TWSTT.

NRLM

The National Research Laboratory of Metrology(NRLM) in Japan is preparing a TWSTT equipment, a TWSTT modem and a Ku-band earth station, to conduct a TWSTT between CRL using JCSAT-3. NRLM and CRL will make TWSTT starting from March, 1999.

TL and KRIS

The TWSTT experiments were performed between CRL and TL(Telecommunications Laboratory of Chaunghwa Telecom in Taiwan) and also between CRL and KRIS(Korean

Research Institute of Standard in Korea) in 1992[7-8]. But they were not continuous ones. TL and KRIS are planning to join the TWSTT Asian-Pacific network in near future. TL and KRIS are discussing with CRL to prepare the equipment for the TWSTT.

PROBLEMS TO BE SOLVED FOR HIGHER ACCURACY

TWSTT method has high potential for accurate time transfer in principle, but there also exists several problems to be solved to improve its accuracy and precision. They are :

1) Technical one

Calibration of internal delay change of the equipment including delays of earth stations.

To compensate this problem CRL is designing to develop a new modem which has a self-calibration function.

2) Operational one

It is difficult to make time transfer by full automatic mode due to the reason that one should transmit a signal to the satellite and it needs to confirm to the satellite operation center just before the signal transmission.

3) Satellite link fee

To perform the TWSTT requires payment for the satellite link and it is not cheap at present. This problem limits the frequency and duration of time transfer, which are one of the reason for the degradation of the total performance of TWSTT. There needs to be further efforts to realize TWSTT as an economical time transfer method. But one should remember that GPS is free to the users in fact, but the construction cost and operation cost exceeds more than 10 billion US$.

4) Existence of suitable communication satellite for TWSTT.

CONCLUSION ABOUT REALIZATION OF A GLOBAL TWSTT NETWORK

The TWSTT network among four major time and frequency institutes, CRL, NML, CSAO, and NRLM, in Asian-Pacific region will be constructed by March, 1999. To expand this network in this region TL in Taiwan and KRIS in Korea will join to this network in near future.

As a next step to realize a real global TWSTT network, we should connect this Asian-Pacific network to European and American ones.

Such a TWSTT network is useful not only for improvement of accuracy and stability of TAI, but also for comparison of another precise time transfer method, such as GPS carrier phase method.

REFERENCES

[1] J. M. Steele, W. Markowitz, and C. A. Lidback, "Telstar Time Synchronization," IEEE Trans. Instrum. Meas., Vol. 13, 1964.
[2] W. Markowitz, C. A. Lidback, H. Uyeda, and K. Muramatsu,"Clock Synchronization via Relay II Satellite," IEEE Trans. Instrum. Meas., Vol. 16, 1966.
[3] Y. Saburi, M. Yamamoto, and K. Harada, "High-Precision Time Comparison via Satellite and Observed Discrepancy of Synchronization," IEEE Trans. Instrum. Meas., Vol. 25, 1976.
[4] J. A. DeYoung, W. J. Klepczynski, A. D. McKinley, W. Powell, P. Mai, P. Hetzel, A. Bauch, J.A. Davis, P. R. Pearce, F. Baumont, P. Claudon, P. Grudler, G. de Jong, D. Kirchner, H. Ressler, A. Soring, C. Hackman, and L. Veenstra, "The 1994 International Transatlantic Two-Way Satellite Time and Frequency Transfer Experiment: Preliminary Results," Proc. of 26th PTTI, 1994.
[5] J. A. DeYoung, A. McKinley, J. A. Davis, P. Hetzel, and A. Bauch, "Some Operational Aspects of the International Two-Way Satellite Time and Frequency Transfer (TWSTFT) Experiment using INTELSAT Satellites at 307 Degrees East," Proc. of 27th PTTI, 1995.
[6] M. Imae, H. Okazawa, T. Sato, M. Uratsuka, K. Yoshimura, and Y. Yasuda,"Time comparison experiments with small K-band antenna and SSRA equipments via domestic geostationary satellite," IEEE Trans. Instrum. Meas., Vol. 32, 1983.
[7] F. Takahashi, K. Imamura, E. Kawai, C. B. Lee, D. D. Lee et al., "Two-way time transfer experiments using an INTELSAT satellite in an inclined geostationary orbit," IEEE Trans. Instrum. Meas., vol. 42, 1993.
[8] B.S.Engelkemier, K. Imamura, F. Takahashi, T. Yoshino, N. S. Chung, and C. S. Liao,"INTELSAT Two-Way Time Transfer Experiments Among Japan, Korea, and Taiwan," IEEE trans. Instrum. Meas. Vol.44, 1995.
[9] J. A. DeYoung, F. Vannicola, and A. D. McKinley,"A Comparison of the Highest Precision Commonly Available Time Transfer Method: TWSTT and GPS CV," Proc. of 28th PTTI, 1996.
[10] H. Ressler, D. Kirchner, and R. Robnik,"Satellite Earth Stations for Two-Way Satellite Time Transfer at the Technical University of Graz," Proc. of 11th EFTF, 1997.

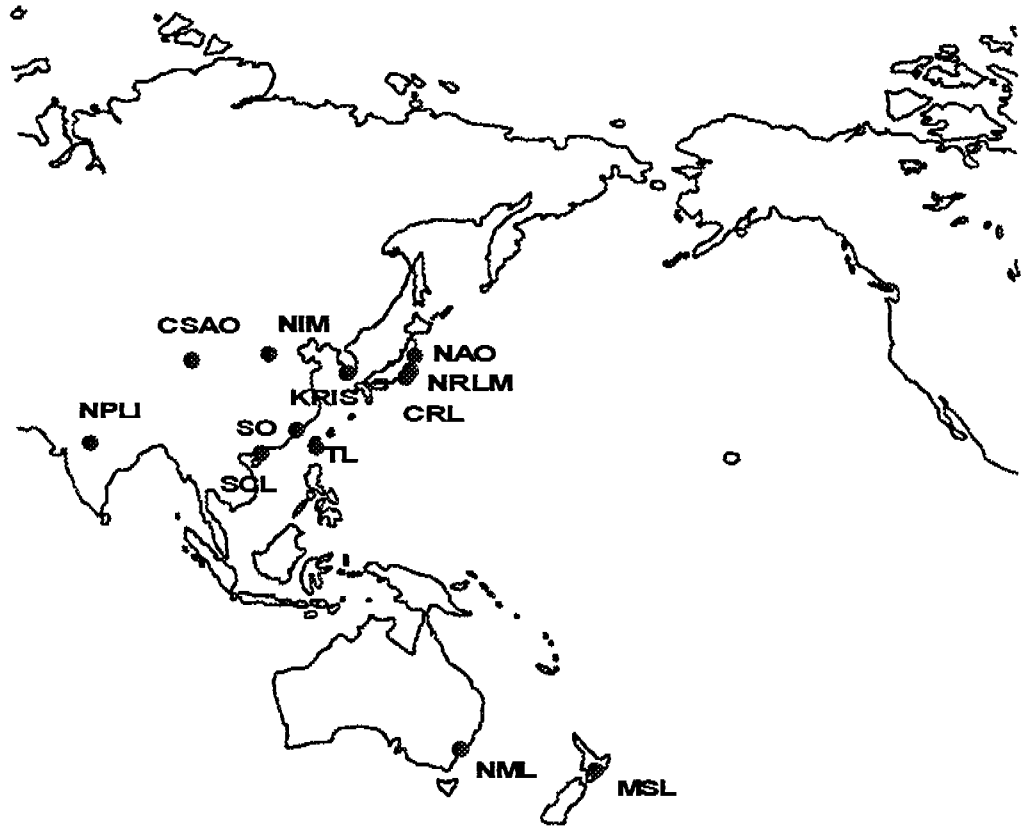

Figure 1. Locations of T&F institute in Asian-Pacific region

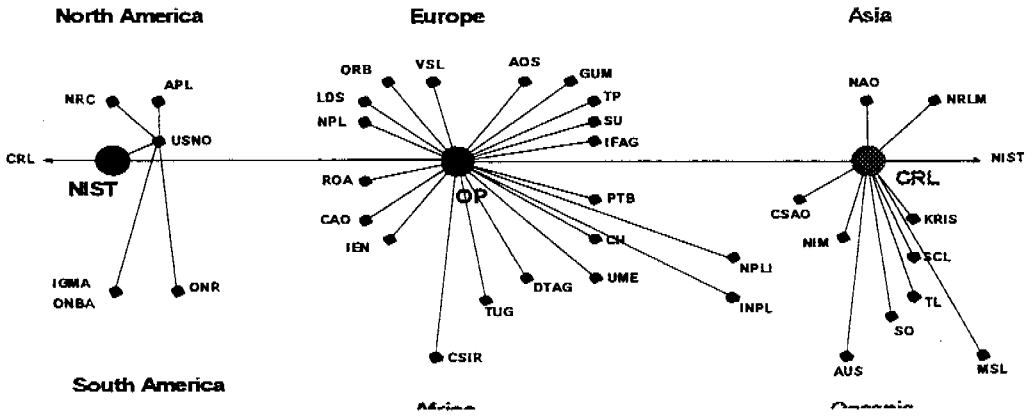

Figure 2. GPS common-view time transfer network

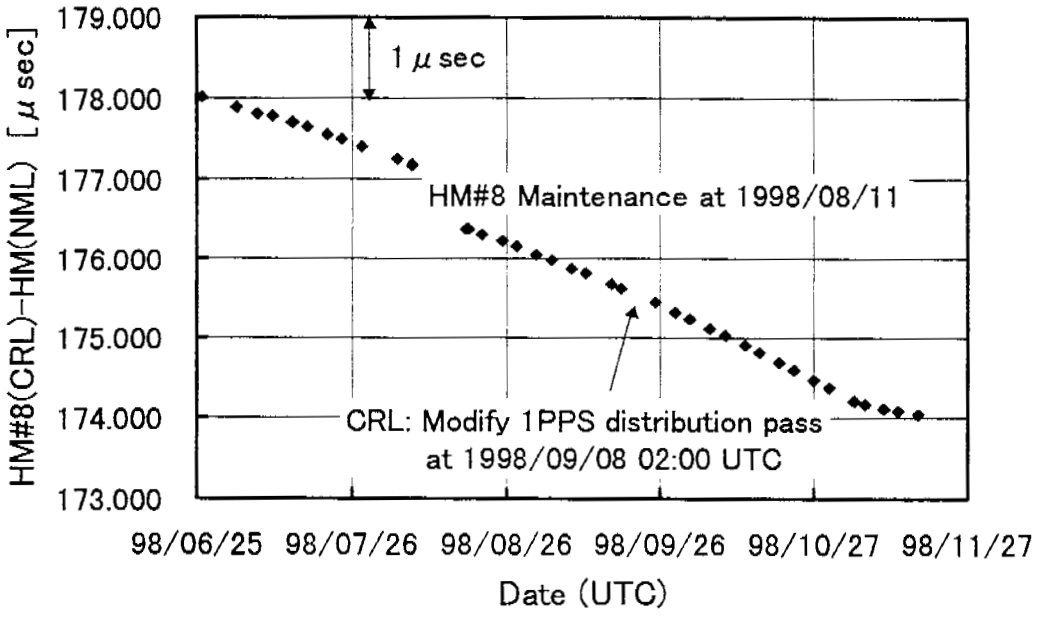

Figure 3. TWSTT results between CRL and NML

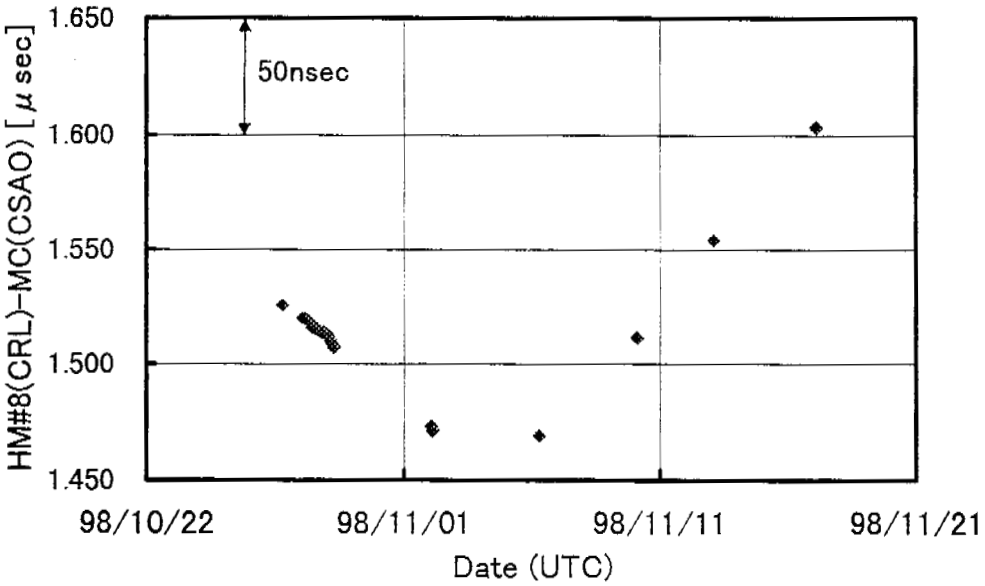

Figure 4. Preliminary TWSTT results between CRL and CSAO

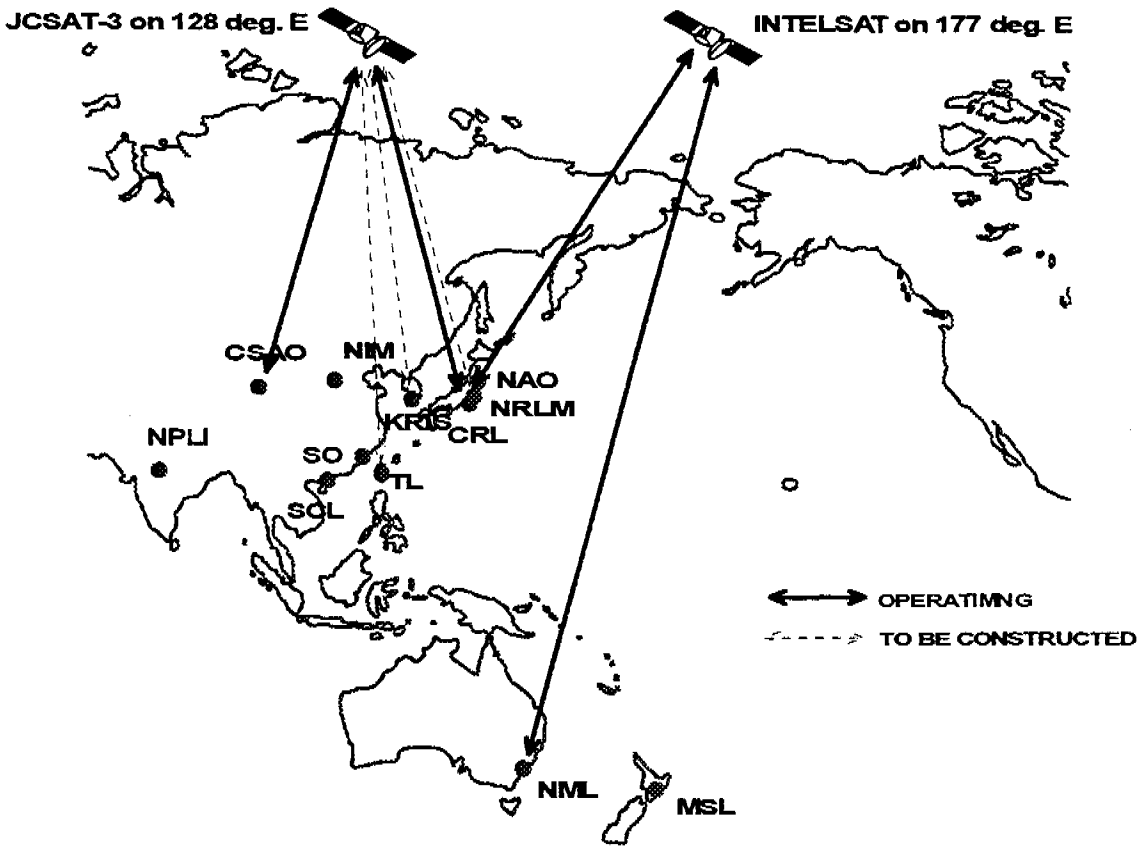

Figure 5. TWSTT network in near future

Questions and Answers

DEMETRIOS MATSAKIS (USNO): The link between Shaanxi and Europe that you are talking about is an important one because it has a possibility of contributing to TAI. I am very concerned about the initial data. I wonder if there are plans to upgrade that. Does Shaanxi have masers or a large ensemble of cesiums that could be a better flywheel?

MICHITO IMAE (CRL): At present they only have a HP-5071A. But they are now making an investigation for a primary frequency standard of the fountain type, under cooperation with Beijing University. So if they complete such a primary standard, we can use this. But unfortunately at present, they do not have a hydrogen maser.

DEMETRIOS MATSAKIS: And just one HP-5071.

MICHITO IMAE: No. They have maybe four or six.

WILLIAM KLEPCZYNSKI (ISI): I think they have six HP-5071s.

MICHITO IMAE: Yes.

WILLIAM KLEPCZYNSKI: Do you have INTELSAT-702? Will that have a spot beam coverage over North America?

MICHITO IMAE: You mean this one?

WILLIAM KLEPCZYNSKI: Yes.

MICHITO IMAE: Yes, this one has a North America spot beam.

WILLIAM KLEPCZYNSKI: Do you have a satellite that you think might be going from Asia to Europe?

MICHITO IMAE: It is difficult to keep the INTELSAT satellite above the Indian Sea, but we will try to keep the satellite.