Highlights Activities from July 2009 to August 2012 of the National Time and Frequency Standard laboratory of the Telecommunication Laboratories, CHT Co. Ltd., TAIWAN

ABSTRACT

Telecommunication Laboratories (TL) operates the Quality System in accordance with ISO 17025(since 2001) and the accreditation body is TAF (Taiwan Accreditation Foundation). TL has undergone peer assessment in 2001 and the technical assessors were from NMIA, Australia and NICT, Japan. In October 2004 and 2007, TL passed the audits of TAF CNLA to continue the ISO17025 certification and the technical assessors were from NIST (USA) and NICT (Japan), respectively. In October 2010, we passed the audit from TAF again and the technical assessor was from BIPM.

This article covers the four most important activities on time and frequency area undertaken in Taiwan from July 2009 to August 2012:

1. Reference Clocks and Time scales
   1.1 Reference clocks
   1.2 UTC(TL) and TA(TL)
2. Time transfer
   2.1 GPS time transfer
   2.2 Two-way satellite time and frequency transfer (TWSTFT)
3. Time Dissemination
   3.1 Speaking clock service
   3.2 Taiwan’s computer time service (TCTS)
   3.3 Network time protocol (NTP) service
4. Other research activities
   4.1 Fully utilization of TWSTFT network data by weighted least square method
   4.2 TL GPS Remote Time and Frequency Calibration System
   4.3 Digital standard time distribution architecture with its applications
   4.4 Precise Sagnac-effect correction on two-way satellite time transfer
   4.5 Forming a real-time time scale with Asia-Pacific TWSTFT network data
   4.6 Optical microwave generation, stabilization and distribution
   4.7 The Dual Pseudo-random Noise TWSTFT
   4.8 Ionospheric effects on next-generation two-way satellite time and frequency transfer

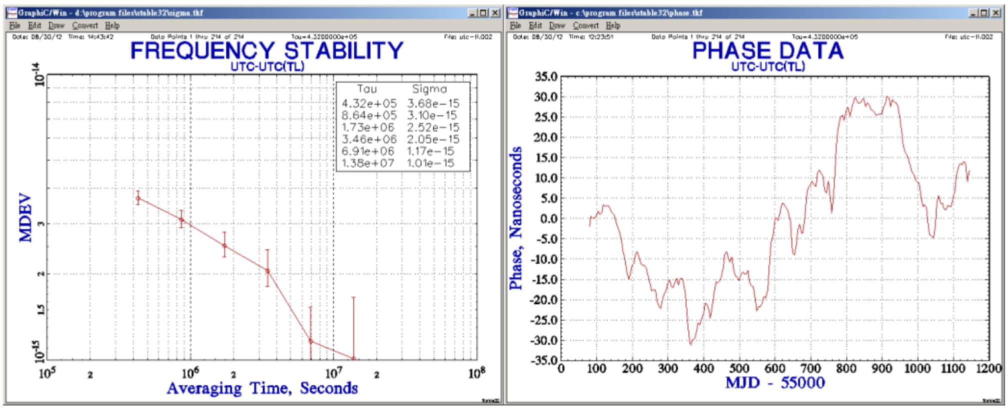
1.Clocks and Time scales

1.1 reference clocks

13 HP(Agilent) 5071A high performance cesium clocks and 3 active H-masers, which are located in the 4 EM shielding chambers with stabilize temperature (23±0.3°C) and humidity (50±5%) control. 2 microphase-steppers with mentioned clocks are used for generating the UTC(TL) and TA(TL), respectively.

1.2 UTC(TL) & TA(TL)

The atomic time scale TA (TL) is generated by our cesium-clock ensemble. UTC(TL) is physically generate by an micro phase stepper AOG-110, which frequency reference is a hydrogen maser. Both TA(TL) and UTC(TL) are generated by steering the AOG-110, we check the relative accuracy of UTC(TL) with TA(TL) daily and their real accuracies according to BIPM Circular T monthly report. Figure 1 showed the performance of UTC(TL) from July 2009 to August 2012, we kept the phase difference with UTC in ±35ns, and the MDEV is about 3.68e-10 when average time is



5 days.

Figure 1. UTC – UTC(TL), stability and phase difference

2. Time Transfer

2.1 GPS time transfer

One Topcon multichannel GPS C/A code receiver, two Ashtech Z12T dual frequency GPS receivers, one new purchased TTS-4 dual frequency GNSS receiver, and two new purchased PolaRx4 dual frequency GNSS receiver are used in TL for GPS/GNSS time transfer. Dual frequency data are adopted in GPS/GNSS system and the ionospheric delay could be obtained to reduce the uncertainty. Both GPS systems compare the UTC(TL) with GPS satellites time and generate CGGTTS format files everyday. All files are put in our ftp server ftp://ftp.stdtime.gov.tw/ which includes C/A code and P3 code GPS time transfer data. The Ashtech Z12T dual frequency GPS receiver also provides GPS carrier phase data, the RINEX format data files are put in the same ftp server as well. In the same time, the Z12T RINEX files are sent to BIPM and the IGS global data center CDDIS as TAIPPP and IGS station, the alphabetical character code is TWTF. Both new purchased GNSS receivers, TTS-4 and PolaRx4, provide RINEX and CGGTTS format data files everyday automatically and are going to put in our ftp server after the differential calibration with respect to TWTF is complete.

2.2 Two-way satellite time and frequency transfer (TWSTFT)

TL currently maintains four earth stations for TWSTFT experiments, as listed on the Table 1. The TL01 station is for the Asia-Pacific TWSTFT links. All TWSTFT measurements in the Asia-Pacific area are performed simultaneously by using the 8-receive-channel NICT modems. Hourly data, which are results of a quadratic fit over the 1-second measurements during 300-s duration sessions, are available. The regular Europe-Asia TWSTFT links, e.g., TL-PTB links, are performed hourly by employing SATRE modems with TL02 station. In the year 2012, the satellite for Europe-Asia TWSTFT links is Express AM-2, which only allows us to perform 10-hour experiments in a day. The frequency stability of PTB-TL link reached 2×10^{-15} at one-day averaging time. The TL03 station is for the dual pseudo-random noise codes (DPN) TWSTFT test link between NICT and TL. Since April 2012, TL has joined the Asia-USNO TWSTFT links through the Hawaii relay station, i.e., KPGO. The TL04 station is currently employed for the Asia-USNO TWSTFT links.

Table 1, TWSTFT links and facilities of TL in 2012

Earth Station	**TL01**	**TL02**	**TL03**	**TL04**
Link	Asia-Pacific	Eu-Asia	Prepare for DPN	Asia-USNO
Satellite	GE-23	AM2	GE-23	GE-23
Antenna Size	2.4 m	2.4 m	2.4 m	1.8 m
Transceiver	CODAN 5900	CODAN 5900	CODAN 5900	CODAN 5900
Band	Ku, band 1	Ku, band 1	Ku, band 3	Ku, band 1
Modem	NICT modem (multi-channel)	SATRE 66 (single channel)	AWG and Sampler	SATRE 63 (multi-channel)
Participants	NICT	PTB, NIM, NTSC, NICT, VNIIFTRI, NPLI	NICT	NICT, KPGO, USNO

3. Dissemination

3.1Speaking Clock Service

We had designed and set up a public voice time service system, it was called as 117 time service (the dialing number is 117). This system can provide accurate voice time to public users. The time difference between the voice time and UTC (TL) is less than 10 ms around Taiwan. The system have traced to UTC (TL) via IRIG-B code dissemination system by dedicated line and broadcasts through PSTN 24 hours a day automatically.

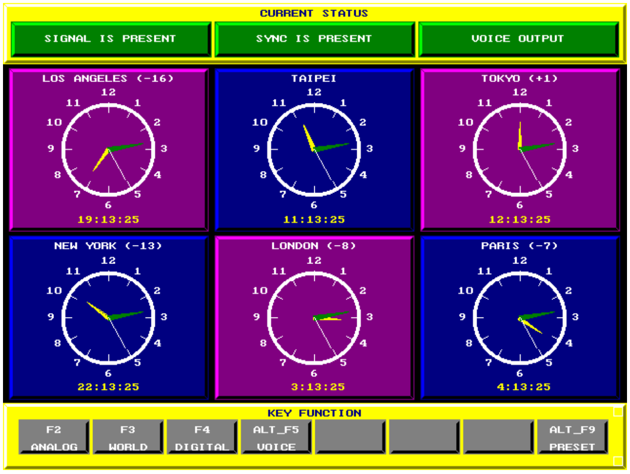


Figure 2 Status display of the speaking clock

To help ensure that 117-service never breaks the voice time service, we specially designed an automatic switch system in June 2006 and done in April 2007. The switch system can monitor the real time status of two 117 speaking clocks. The role of these two speaking clocks, one is operating in on-line situation and the other is actively standby. Once the switch system have found any status of failure from the on-line system, then, the switch system will immediately active the standby system to replace the on-line system and cut the troubled system off. Also the alarm will break out from the switch system. In addition, the switch system has special self-checking to enhance reliability.

Figure 3 Status display of the automatic switch system

3.2 TCTS Service

We developed the Taiwan's Computer Time Service (TCTS) system in 1998, an ACTS-like telephone line service system. It is synchronized to UTC (TL) with IRIG-B time code. The "European Telephone Code" is modified into TCTS time format to match our needs. Two modes, One-way and Loop-back, are operated. The propagation delay was measured precisely and compensated by Loop-back mode, whose accuracy can reach the range of 1 ms around Taiwan. Today, we have only launched a TCTS system with 2 lines because the users are decreasing day by day.

Figure 4 Status display of the TCTS service system

3.3 NTP Service

One of the most important time synchronization services TL provided for the populace is the Network Time Synchronization Service. The Network Time Synchronization Service uses Network Time Protocol (NTP) to synchronize clocks of computers in the Internet with national standard time. NTP builds a time tracking system in a hierarchical structure. The NTP timeserver with lower hierarchy is synchronized to that with higher one. NTP can estimate the network propagation delay and compensate the effect of delay for adjusting the local computer clock. In the Internet, the accuracy of NTP is about a few tens of milliseconds. Thus, it can provide an accurate time source for most information applications, including the Time Stamp Authority (TSA) application.

We have begun to provide the Network Time Synchronization Service since June 1998. We installed multiple NTP timeservers in our Lab. and revised a friendly client program implementing Simple Network Time Protocol (SNTP) for Windows OS environments. In addition, we also designed a system to monitor our NTP services and the monitoring program is used to count the number of NTP access to our NTP timeservers. Up to July 2009, the number of NTP requests is more than 2 hundred million (200,000,000) connections a day. NTP provides an authentication option to implement the security function. However, the present version client program does not implement any authentication function. To design a powerful authentication mechanism for our NTP system is under running.

Figure 5 real-time NTP request monitoring

3 Other Research Activities

4.1 Fully utilization of TWSTFT network data by weighted least square method

The two-way satellite time and frequency transfer (TWSTFT) is a precise time transfer technique and has being used to generate the TAI since 1999. Nowadays, TWSTFT links have formed a worldwide network and the large amount of TWSTFT data become highly redundant. To fully utilize the data of TWSTFT network and improve the TWSTFT results, a feasible method of processing data is proposed in this paper. According to the stability of each link, we assign a weighting value to each related equation and then solve the matrix equation with the weighted least squares method. We perform data analysis with practical time transfer data, and the results show that it is an effective method to improve the TWSTFT results.

4.2 TL GPS Remote Time and Frequency Calibration System

A new remote time and frequency calibration system using Global Positioning System (GPS) common-view or all-in-view method for the purpose of time synchronization and frequency syntonization is presented. The system integrates GPS timing receiver with measurement hardware and software. It can be used as Primary Reference Clock (PRC), remote time and frequency calibration, and monitoring the characteristic of the primary reference clocks for wireless and power system applications.

A series of experiments were executed to evaluate the performance of the system. The common view common clock test using hydrogen maser as reference was studied for the evaluation of the system noise level. The short-baseline test between Chunhwa Telecommunication Laboratories (TL) and HsinChu within 18.6 km, and mid-baseline test within 200 km between TL and Yunlin were also performed.

Experiment results show that the system works by making simultaneous all-in-view measurements at National Time and Frequency Standard Laboratory of TL and at under test sites in Taiwan with up to eight GPS satellites. The combined expand time uncertainty and frequency uncertainty of the designed system with a coverage factor of k=2 are equal to 94.52 ns and 1.0×10-12 respectively, which can meet ITU-T G.811 standard and requirements for the dominant wireless and power systems applications.

4.3 Digital standard time distribution architecture with its applications

An efficient and accurate two-layer standard time distribution architecture is proposed to implement digital time traceability. First, the system uses a clock calibration procedure based on two-way time transfer over a general dialup telephone modem and achieves a couple of milliseconds accuracy. Second, the system uses a delegation time stamping procedure that employs a forward secure proxy signature scheme to provide enhanced validity assurance and extends the RFC 3161 time stamp token to embed the standard time reading. These let users eliminate the blind trust on a commercial time stamping server's clock handling.

4.4 Precise Sagnac-effect correction on two-way satellite time transfer

This research describes how to eliminate the diurnal variations caused by the satellite motion in the

Two-Way Satellite Time and Frequency Transfer (TWSTFT) data. Through the analysis of the NICT-TL link, we demonstrate that a precise Sagnac correction is useful to improve the TWSTFT data. The time deviation (TDEV) at an 8-hour averaging time is reduced from 159 ps to 73 ps after the correction.

4.5 Forming a real-time time scale with Asia-Pacific TWSTFT network data

This research proposed a new scheme to generate a real-time paper time scale by utilizing the ensemble clock data and the two-way satellite time and frequency transfer (TWSTFT) data among the laboratories in the Asia-Pacific region. By integrating above data, with specific weighting methodology and using nero-fuzzy prediction, this research can form a reference time scale to analyze the time difference with local UTC in real-time. The proposed scheme is investigated by conducting a three-month long fuzzy predictor which based on the calculated clock ensembles from TWSTFT links among Asian timing laboratories. The performance is accredited with respect to time scale of the UTC(TL), as well as UTC.

4.6. Optical microwave generation, stabilization and distribution

In Taiwan, the demands of precise time synchronization are increasing recently, e.g., the next-generation telecommunication, the smart grid of power system, and the science study in some campus. Because an optical fiber has the characteristics of broad bandwidth and low transmission loss, a new trend is to perform the time transfer through the optical fiber link. In 2012, we have performed a preliminary experiment on two-way time transfer through a 25-km common-path optical fiber link. The fiber link achieved time deviation of less than 7 ps and frequency stability of 2×10^{-16} at one-day averaging time.

A particular idea is how to extend the technique of time and frequency transfer via optical fibers into the applications of frequency source stabilization. Optoelectronic oscillators (OEOs), based on optical fiber loops to act as a high-*Q* cavity, are capable of generating stable radio-frequencies (RF). The long-term frequency stability of the OEO is then limited by the cavity variation that is mainly induced by temperature sensitivity of the optical fiber. In 2011, we proposed a feasible method for monitoring the delay variation of fiber loops in a dual-loop OEO structure. Experimental results demonstrate a spread-spectrum probe signal is effective in measuring the loop delay without observable interference to the oscillating frequency. If the relationship between the free-running frequency of an OEO and the monitored delay is determined, the OEO can be stabilized by actively tuning the fiber delay according to the monitored data. Moreover, we also investigated the relationship between the phase shift of a reference injection-locked OEO and its fiber delay over a long period of time. With actively stabilized fiber delay, an OEO can be very steadily phase locked to the injection reference. A high performance OEO may act as a local oscillator that could lock the output of the absolute reference frequency, provided by the atomic transition.

4.7 The Dual Pseudo-random Noise TWSTFT

The measurement precision of TWSTFT is limited by the chip rate of the timing signal with the pseudo-random noise (PRN) code. In order to improve the time transfer precision and reduce the operational cost, the National Institute of Information and Communications Technology (NICT) has developed the Dual PRN (DPN) signal. The DPN is realized by modulating a PRN with two different subcarriers, and measuring the DPN group delay is equivalent to measure the propagation delay. The first international DPN experiment has been successfully performed, between NICT and TL, and lasted for 9 months in 2010. In this experiment, some discontinuities existed in the measured results due to the power blackout, rain fade, and some other unexpected events. After some tests and improvements, the data of the NICT-TL DPN experiment became more stable and reliable. The numerical results show that DPN results of NICT-TL experiment have higher precision and less diurnal as compared with the conventional TWSTFT results. The observation is real-time processing and the TDEV of current results can reach better than 10 picoseconds in 5-minute averaging time.

4.8 Ionospheric effects on next-generation two-way satellite time and frequency transfer

The next-generation two-way satellite time and frequency transfer (TWSTFT) is to compare clock difference at sub-nanosecond level. However, many uncertainties, including ionospheric effects, still have to be much well studied for farther reduction. A next-generation TWSTFT technique using dual pseudo-random noise (DPN) codes has high precision for clock comparison and can also provide opportunities to investigate the aforementioned ionospheric uncertainties.

Ionospheric effects on TWSTFT may include two main portions. One is ionospheric refraction caused by total electron content (TEC), and the other one is ionospheric diffraction and scattering caused by electron irregularities. TEC produces propagation delays of satellite signals. For example, Figure 6 demonstrates ionospheric delay corrections for the TL/NICT TWSTFT link. The delay corrections are larger in high solar activity year (e.g. 2001) than in low solar activity year (e.g. 2010), and they can affect the TWSTFT at sub-nanosecond level. By contrast, electron irregularities (e.g. ionospheric bubbles and traveling ionospheric disturbances) generate scintillations of satellite signals, and their impacts on TWSTFT are under study now.

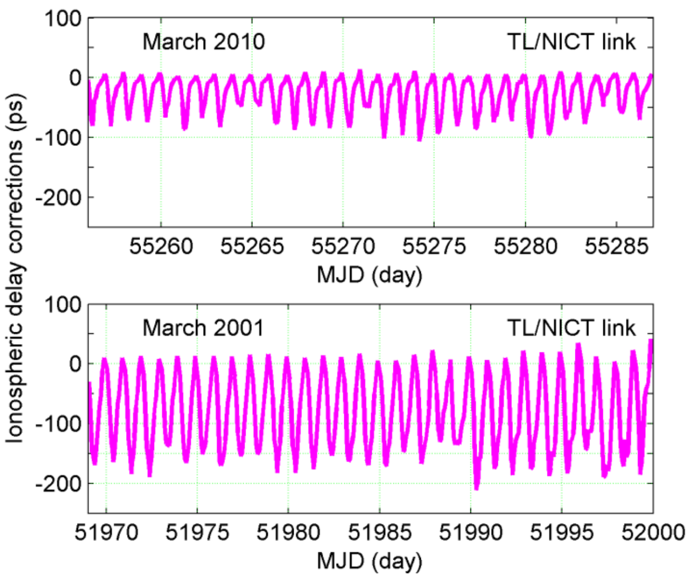


Figure 6. Ionospheric delay corrections during different solar activities

International Publications (from 2009 to 2012)

SCI Journal papers:

1. Chu, F. D., W. S. Chen, C. C. Lee, and J. Y. Liu, A climatological study of nocturnal equatorial F-region irregularities at the west Pacific longitudes by using phase fluctuations of global positioning system, *Journal of Atmospheric and Solar-Terrestrial Physics*, 71, 13, 1441-1449, 2009

2. Lee, C. C., F. D. Chu, W. S. Chen, J. Y. Liu, S. Y. Su, Y. A. Liou, and S. B. Yu, Spread F, GPS phase fluctuations, and plasma bubbles near the crest of equatorial ionization anomaly during solar maximum, *Journal of Geophysical Research*, 114, A08302, doi:10.1029/2009JA014195, 2009.

3. K. Y. Tu, C. S. Liao and S. Y. Lin, "Remote Frequency Control via IEEE 1588," *IEEE Transactions on Instrumentation and Measurement*, Vol. 58, No. 4, pp. 1263-1267, 2009.

4. W. H. Hsu, K. Y. Tu, J. S. Wu and C. S. Liao, "Frequency Calibration Based on Adaptive Neural-Fuzzy Inference System," *IEEE Transactions on Instrumentation and Measurement*, Vol. 58, No. 4, pp. 1229-1233, 2009.

5. Lee, C. C., Y. J. Chuo, and F. D. Chu, Climatology of total electron content near the dip equator under geomagnetic quiet-conditions, *Journal of Atmospheric and Solar-Terrestrial Physics*, 72, 207-212, 2010.

6. Wen-Hung Tseng, Shinn-Yan Lin, Kai-Ming Feng, M. Fujieda , and H. Maeno, "Improving TWSTFT Short-Term Stability by Network Time Transfer," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 57, no. 1, pp. 539–544, Jan., 2010.

7. Huang-Tien Lin, Chia-Shu Liao, Fang-Dar Chu, Yi-Jiun Huang, Wen-Hung Tseng, "Full utilization of TWSTT network data for the short-term stability and uncertainty improvement," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 7, pp. 2564-2569, Jul, 2011.

8. Chia-Shu Liao, Huang-Tien Lin, Fang-Dar Chu, Yi-Jiun Huang, Kun-Yuan Tu, Wen-Hung Tseng, "Formation of a real-time time scale with Asia-Pacific TWSTFT network data," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 7, pp. 2667-2672, Jul, 2011.

9. Wen-Hung Tseng, Kai-Ming Feng, Shinn-Yan Lin, Huang-Tien Lin, Yi-Jiun Huang, and Chia-Shu Liao, "Sagnac Effect and Diurnal Correction on Two-Way Satellite Time Transfer," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 7, pp. 2298-2303, Jul, 2011.

10. W. S. Chen, C.G. Lee, F. D. Chu, and S. I. Su, "Spread F, GPS phase fluctuations, and medium-scale traveling ionospheric disturbances over Wuhan during solar maximum," Journal of Atmospheric and Solar-Terrestrial Physics, Volume 73, Issue 4, Pages 528–533, March 2011

11. P. Y. Ting, F. D. Chu, S. C. Liao, and H. T. Lin, "A digital standard time dissemination architecture for trustworthy time stamping, "" *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 7, pp. 2584-2589, Jul, 2011.

12. I. Chun Chao, Kun-Yuan Tu, Shinn-Yan Lin, Fan-Ren Chang, "Design and Implementation of a Switching Controller for Transient Improvement in a Time Synchronization System," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 7, pp.2184-2190, Jul, 2011.

13. Te-Kwei Wang, Fan-Ren Chang, Shinn-Yan Lin:, "Multidevice Time Measurement System via a PTPD Network," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 7, pp. 2304-2307, Jul, 2011.

14. Wen-Hung Tseng, Yi-Jiun Huang, Tadahiro Gotoh, Thomas Hobiger, Miho Fujieda, Masanori Aida, Tingyu Li, Shinn-Yan Lin, Huang-Tien Lin, and Kai-Ming Feng, "First International TWSTFT Experiment by Employing Dual Pseudo-random Noise Codes," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 59, no. 3, pp. 531–538, March, 2012.

15. Huang-Tien Lin, Yi-Jiun Huang, Chia-Shu Liao, Fang-Dar Chu, and Wen-Hung Tseng, "Improvement of the Asia-Pacific TWSTFT Network Solutions by using DPN Results," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 59, no. 3, pp. 539–544, March, 2012.

16. Wen-Hung Tseng and Kai-Ming Feng, "Enhancing long-term stability of the optoelectronic oscillator with a probe-injected fiber delay monitoring mechanism," *Optics Express*, vol. 20, no. 2, pp. 1597–1607, Jan, 2012.

17. H. T. Lin, Y. J. Huang, W. H. Tseng, C. S. Liao, and F. D. Chu, "Recent Development and Utilization of Two-Way Satellite Time and Frequency Transfer," *MAPAN*, vol. 27, no. 1, pp. 13–22, March, 2012.

18. Wen-Hung Tseng and Kai-Ming Feng, " Impact of fiber delay fluctuation on reference injection-locked optoelectronic oscillators," Optics Letters, vol. 37, no. 17, pp. 3525-3527, Sep, 2012.

EI referenced papers:

1. K. Y. Tu and C. S. Liao, "Frequency Syntonization Using GPS Carrier-Phase Measurements Based on ANFIS," International Journal of Control and Intelligent Systems, ACTA Press, Vol. 37, No. 2, 2009

2. I. C. Chao, K. Y. Tu, S. Y. Lin and F. R. Chang, "Implementation of switching controller for precise network time synchronization," Conference on Precision Electromagnetic Measurements, DCC, Daejeon, Korea, pp. 40-41, 13 to 18 June 2010.

3. Wen-Hung Tseng, Shinn-Yan Lin, Kai-Ming Feng, Huang-Tien Lin, and Chia-Shu Liao," Precise Sagnac-Effect Correction on Two-Way Satellite Time Transfer," *Conference on Precision Electromagnetic Measurements(CPEM)* , 13-18 June, 2010, DCC, Daejeon, Korea

4. P.-Y. Ting, F.D. Chu, and C.S. Liao, " A digital standard time distribution architecture with its applications," *Conference on Precision Electromagnetic Measurements(CPEM)* , 13-18 June, 2010, DCC, Daejeon, Korea

5. H.T. Lin, C.S. Liao, F.D. Chu, Y.J. Huang, and W.H. Tseng, "Fully Utilization of TWSTT Network Data by Weighted Least Squares Method," *Conference on Precision Electromagnetic Measurements(CPEM)* , 13-18 June, 2010, DCC, Daejeon, Korea

6. C.S. Liao, H.T. Lin, F.D. Chu, Y.J. Huang, K.Y. Tu and W.H. Tseng," Forming a Real-Time Time Scale with Asia-Pacific TWSTFT Network Data," *Conference on Precision Electromagnetic Measurements(CPEM)* , 13-18 June, 2010, DCC, Daejeon, Korea

7. Yi-Jiun Huang, Wen-Hung Tseng, Shinn-Yan Lin, Huang-Tien Lin, Chia-Shu Liao, and Kai-Ming Feng, "The Dual Pseudo-random noise TWSTFT time transfer experiment between NICT and TL," *Proc. 2011 Joint IEEE International Frequency Control Symposium & European Frequency and Time Forum, (2011 joint IFCS/EFTF conference, paper 7060),* 2-5 May 2011, San Francisco, CA, USA, pp. 389-392, 2011. (EI, DOI: 10.1109/FCS.2011.5977305).

8. Huang-Tien Lin, Yi-Jiun Huang, Chia-Shu Liao, Fang-Dar Chu, Wen-Hung Tseng, and Wei-Chih Hsu, "Improvement of the Asia-Pacific TWSTFT Network Performance Utilizing DPN Results," *Proc. 2011 Joint IEEE International Frequency Control Symposium & European Frequency and Time Forum, (2011 joint IFCS/EFTF conference, paper 7173)*, 2-5 May 2011, San Francisco, CA, USA, pp. 645-648, 2011. (EI, DOI: 10.1109/FCS.2011.5977782).

9. Wen-Hung Tseng and Kai-Ming Feng, "Monitoring of Opto-Electronic Oscillator Fiber Delay by a Probe-Signal Method," *Proc. 2011 Joint IEEE International Frequency Control Symposium & European Frequency and Time Forum, (2011 joint IFCS/EFTF conference, paper 7190)*, 2-5 May 2011, San Francisco, CA, USA, pp. 174-177, 2011. (EI, DOI: 10.1109/FCS.2011.5977792).

10. F. D. Chu, et. al., "Characteristics of low latitude nocturnal ionospheric irregularities over India-Arab longitudes during solar maximum,"*The XXX General Assembly and Scientific Symposium of the International Union of Radio Science* (EI, DOI: 10.1109/URSIGASS.2011.6051000)

11. Jia-Lun Wang, P. C. Chang, Shinn-Yan Lin, Huang-Tien Lin, Chia-Shu Liao, "Remote time and frequency calibration system for telecommunication synchronization applications," *APNOMS 2011*: 1-6 (EI, DOI:10.1109/APNOMS.2011.6077032)

12. C. S. Liao, K. Y. Tu, F. D. Chu, and H. T. Lin, Y. J. Huang, "Formation of a Paper Neural-fuzzy Time Scale in the Eastern Asia" *Proc. 2011 Joint IEEE International Frequency Control Symposium & European Frequency and Time Forum, (2011 joint IFCS/EFTF conference, paper 7173)*, 2-5 May 2011, San Francisco, CA, USA, pp. 645-648, 2011. (EI, DOI: 10.1109/FCS.2011.5977782)

13. W. S. Chen, C.G. Lee, and F. D. Chu, "The occurrences of spread F and GPS phase fluctuations as well as medium-scale traveling ionospheric disturbances over Wuhan," The XXX General Assembly and Scientific Symposium of the International Union of Radio Science (EI, DOI:10.1109/URSIGASS.2011.6050963)

14. Miho Fujieda, Hideo Maeno, Dirk Piester, Andreas Bauch, Sung-Hoon Yang, Tomonari Suzuyama, Wen-Hung Tseng, Huanxin Li, Yuan Gao and Joseph Achkar, "Impact of the Transponder Configuration on the Asia-Europe TWSTFT Network," *Proc. 2011 Joint IEEE International Frequency Control Symposium & European Frequency and Time Forum, (2011 joint IFCS/EFTF conference, paper 7178)*, 2-5 May 2011, San Francisco, CA, USA, pp. 655-660, 2011. (EI, DOI: 10.1109/FCS.2011.5977786).

15. Wen-Hung Tseng and Kai-Ming Feng, "Influence of fiber delay fluctuation on a reference injection-locked optoelectronic oscillator," *2012 IEEE International Frequency Control Symposium, paper 7100*, 21-24 May 2012, Baltimore, MD, USA.

16. F. D. Chu, et. al., "A study of ionospheric delay corrections for next-generation two-way satellite time and frequency transfer," *2012 IEEE International Frequency Control Symposium,* 21-24 May 2012, Baltimore, MD, USA.

17. F. D. Chu, et. al., "A study of ionospheric effects on next-generation two-way satellite time and frequency transfer," *Conference on Precision Electromagnetic Measurements(CPEM)* , 2-6 July, 2012, Washington DC, USA

18. C. S. Liao, et. al., "Design and Implementation of a High Resolution Phase Comparator," *Conference on Precision Electromagnetic Measurements(CPEM)* , 2-6 July, 2012, Washington DC, USA

International conference papers：

1. Shinn-Yan Lin, Wen-Hung Tseng, Huang-Tien Lin, Kai-Ming Feng, Yi-Jiun Huang, and Kai-Ming Feng," Long-term Inconsistency between TWSTFT and GPS Time Transfer Results in PTB-TL and NICT-TL Time Links," *European Frequency and Time Forum,* Noordwijk, The Netherlands, 13-16 April, 2010

2. Huang-Tien Lin, Chia-Shu Liao, Fang-Dar Chu and Wen-Hung Tseng," Improvement of TWSTFT Short-Term Stability Utilizing Full Time Transfer Network Data," *European Frequency and Time Forum,* Noordwijk, The Netherlands, 13-16 April, 2010

3. Yi-Jiun Huang, Wen-Hung Tseng and Shinn-Yan Lin, " Integrated Doppler Correction to TWSTFT Using Round-Trip Measurement," *The 4rd Precise Time and Time Interval (PTTI) Systems and Applications Meeting*, Reston, Virginia, U.S.A., November 15-18, 2010.

4. Yi-Jiun Huang, Wen-Hung Tseng, Shinn-Yan Lin, Huang-Tien Lin, Fang-Dar Chu and Chia-Shu Liao, "The Multiple Access Interference Simulation on PRN-based Two-Way Satellite Time Transfer," *The 43rd Precise Time and Time Interval (PTTI) Systems and Applications Meeting*, Long Beach, California, USA, paper 19, November 14-17, 2011.

5. J. M Wu, et. al.," Absolute frequencies of ^{133}Cs $6S_{1/2}$-$8S_{1/2}$ two-photon transition stabilized diode lasers," *European Frequency and Time Forum,* Gothenburg, Sweden, April 24-26, 2012.