THE TIMING ACTIVITIES OF THE NATIONAL TIME AND FREQUENCY STANDARD LABORATORY OF THE TELECOMMUNICATION LABORATORIES, CHT CO. LTD., TAIWAN

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Abstract

The Telecommunication Laboratories (TL) has provided timing for Taiwan since 1969. Its Master Clock (MC) is the source of UTC (TL), TL's realization of Coordinated Universal Time (UTC), which has stayed within 30 ns of UTC during these years and within 15 ns in the past 12 months. The data used to generate UTC (TL) and TA (TL) are based upon 14 cesium and two hydrogen maser frequency standards in four electro-magnetic wave shielding rooms and TL's time scaling algorithm. TL disseminates time via speaking clock, Taiwan's computer time service (TCTS), telecom lease line, Network Time Protocol (NTP), GPS, and Two-Way Satellite Time and Frequency Transfer (TWSTFT).

To meet future needs of precision, accuracy, and robustness for UTC (TL), TL rebuilt the air conditioner system of the clock rooms and their monitor system. The new system could maintain temperature and humidity of clock rooms within 23 ± 0.3°C and 50 ± 5%, respectively. This paper also describes some of the changes being made recently for international and domestic time transfer in future development.

I. CLOCKS AND TIME SCALES

The most important duty of our laboratory is to keep the national standard time and frequency, UTC (TL), which is currently generated and maintained by our cesium clock ensemble and two hydrogen masers. Up to now, we have 14 5071a cesium clocks with high-performance tubes and 2 Kvarz CH1-75b active hydrogen masers, which are located in at the four EM shielding chambers with stabilized temperature (23 ± 0.3°C) and humidity (50 ± 5%) control.

The atomic time scale of TL, TA (TL), is generated by our 14-cesium-clock ensemble. To keep the best long-term accuracy, our clock ensemble excludes the hydrogen masers because of their larger long-term aging. The weighting function of TA (TL) is set to be proportional to inversely exponential with the index of each cesium clock's frequency deviation; we don't need to set any upper limit for the weighting function because the inversely exponential has an upper limit itself **[1-3]**. The coordinated time scale of TL, UTC (TL), is physically generated by a micro-phase stepper AOG-110, which is fed by the hydrogen

maser as its frequency reference. Both TA (TL) and UTC are used for steering the AOG-110. We check the relative accuracy of UTC (TL) with TA (TL) daily and check its actual accuracy according to BIPM's Circular T monthly reports. Figure 1 shows the performance of UTC (TL) in this year. We kept the phase difference related to UTC smaller than $\pm$ 15 ns, and the stability about 3×10^{-15} when the averaging time is 5 days.
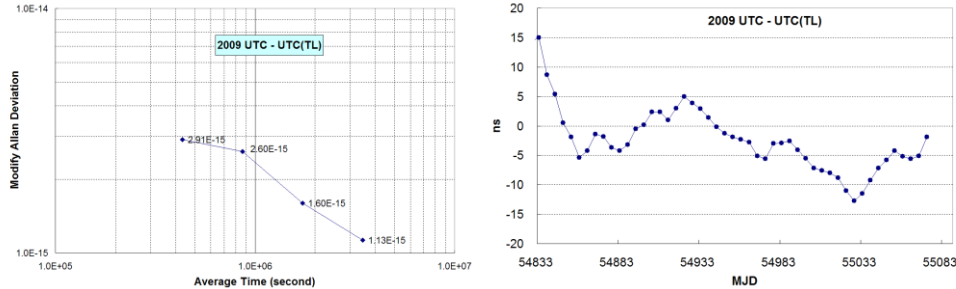

Figure 1. UTC – UTC (TL), stability and phase difference.

II. TIME TRANSFER

TWO-WAY SATELLITE TIME TRANSFER

TL maintains three earth stations for TWSTFT experiments, as listed on Table 1. The TL01 station is for the Asia-Pacific TWSTFT links. All TWSTFT measurements in this area are performed simultaneously by using the eight-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. In April 2009, the satellite was changed from JCSAT-1B to IS-8. The TL02 station is for the Asia-Europe TWSTFT links. The regular TL-PTB and TL-OP links are performed hourly by employing SATRE modems. The TL03 station is prepared for the Asia-US TWSTFT links through the Hawaii relay station. It can be expected that the global TWSTFT links would be established in the near future **[4]**.

GPS OBSERVATIONS

There are two formal GPS time transfer systems at TL, which are based on a Topcon multi-channel GPS receiver and an Ashtech Z12T dual-frequency GPS receiver and their related data processing software. Both systems compare the UTC (TL) with GPS satellites time every second and generate CGGTTS format files every day. All files are put in our ftp server as *ftp://ftp.stdtime.gov.tw/*, which can be used for GPS Common View and GPS All-in-View time transfer. Ashtech Z12T dual-frequency GPS receiver could also provide GPS carrier-phase data with the RINEX format, which are put in the same ftp server as well. At the same time, the Z12T RINEX files are sent to BIPM and CDDIS as the TAIPPP and the IGS station respectively, and the alphabetical code of the station is TWTF.

Figure 2 shows the time difference UTC (PTB) – UTC (TL) using different time transfer data, TWSTFT, GPS P3 All-in-View, and GPS carrier phase. The red dots use BIPM Circular T database from GPS P3 All-in-View, the light blue line is TWSTFT result; and the blue line and green line are GPS carrier-phase data calculated by TAIPPP and IGS **[5]**.

Table 1. TWSTFT links and facilities at TL.

| Earth Station	TL01	TL02	TL03
Labs to be linked	NICT, KRISS, NTSC, (NMIJ), (SG)	OP, PTB, (VSL)	Prepare for Hawaii
Satellite	(JCSAT-1B) → IS-8	IS-4	GE-23
Band	Ku	Ku	Ku
Antenna	Andrew 2.4 m	Andrew 2.4 m	Prodelin-1194 1.8 m
Modem	NICT modem	SATRE (066)	SATRE (073)
UP/Down Converter	Codan 5900 (8W) (5908 SSPA)	Codan 5900 (8W) (5908 SSPA)	Codan 5900 (8W) (5908 SSPA)
Power Supply Unit	Indoor (after May)	Outdoor	Indoor (after May)
IF Cable	Andrew SFJ1-50A	Andrew SFJ1-50A	Andrew SFJ1-50A
Counter	NICT internal	SR-620/ *SATRE internal*	SATRE internal
OP and Analyzing Software	Remote operating by NICT	Automation operating by TL	-
Others	Power Splitter	70 MHz BP filter and VHF switch	SATSIM (Satellite simulator)
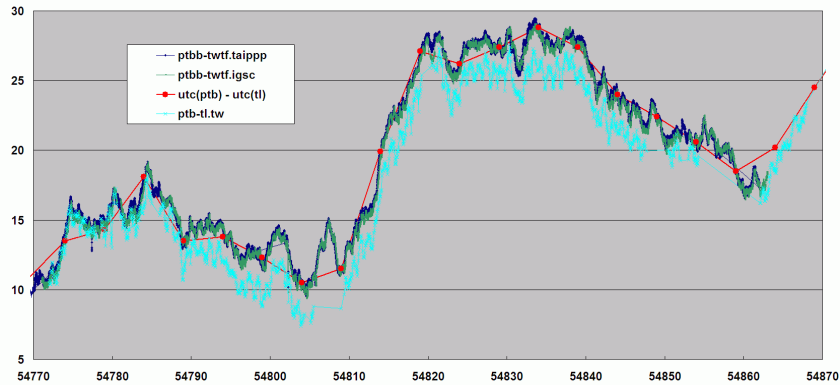
Figure 2. UTC (PTB) – UTC (TL) via different time transfer data.

III. TIME DISSEMINATION

NTP SERVICE

One of the most important time synchronization services we provide 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 the national standard time. NTP builds a time tracking system with a hierarchical structure. The NTP timeserver of a lower hierarchy is synchronized to that of a higher one. NTP can estimate the network propagation delay and compensate the effect of delay for adjusting the local computer clock. On 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 been providing the Network Time Synchronization Service since June 1998. We installed multiple NTP timeservers in our lab, and revised a client-friendly program implementing Simple Network Time Protocol (SNTP) for the Microsoft Win32 OS system. 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 2006, NTP requests is more than 1 hundred million (100,000,000) times a day. NTP also provides an authentication option to implement the security function. However, the client program of present version does not implement any authentication function. Design of a powerful authentication mechanism for our NTP system is still underway.

SPEAKING CLOCK SERVICE

We had designed and set up a public voice time service station; it is called the 117 time service (the dialing number is 117). This system can provide accurate voice time signal to public users. The time difference among voice time signal around the whole of Taiwan is less than 10 ms. The system can be traced to UTC (TL) via the IRIG-B code dissemination system by a dedicated lease lines and broadcast through PSTN 24 hours a day automatically.
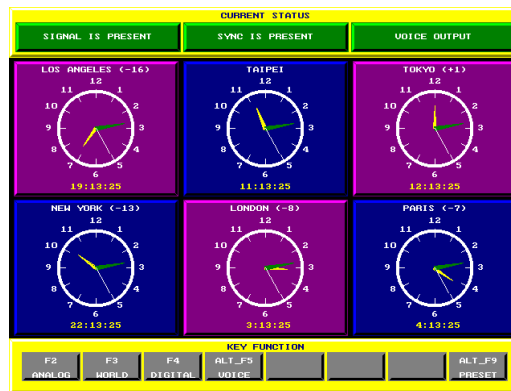
Figure 3. Status display of the speaking clock.

To ensure robustness of the 117 time service, we designed an automatic switch system in June 2006 and implemented it in April 2007. The switch system can monitor actual time status of the two 117 speaking clocks. Regarding the roles of these two speaking clocks, one is in online operation and the other is on standby. Once the switch system finds any status failure from the online speaking clock, then it will immediately switch to the standby one and cut off the signal from the original speaking clock. An alarm will also be triggered from the switch system. In addition, the switch system has a special self-checking function to enhance related reliability.

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 the IRIG-B time code. The "European Telephone Code" was modified in the TCTS time format to match our needs, such as including the Lunar Calendar especially. Two modes of One-way and Loop-back are in operation. The propagation delay was measured precisely and compensated by the Loop-back mode, whose accuracy can reach to the range

of 1 ms around Taiwan island. At this time, we only run the system with four lines, 5 baud rates via the telephone line for the public, because the users are decreasing gradually.

TIME AND FREQUENCY CALIBRATION

The capabilities of time and frequency calibration of our laboratory registered in the BIPM database are listed on Table 2. The established highest frequency range up to now is 300 MHz. In order to meet increasing industrial requirements for calibrations in the microwave range, we are planning to set up a related system in the near future.

Table 2. Time and frequency calibration.

System	Code	Range	uncertainty	Equipments
Phase difference	KJ01-1	-1000 to 1000 s	1 ns	SR620 universal counter, UTC (TL)
frequency	KJ02-2	1.0 MHz to 300MHz	3.0×10^{-12}	SR620 universal counter, UTC (TL)
Phase comparator	KJ02-3	1, 5, 10 MHz	3.0×10^{-13}	SR620 universal counter, HP5071A
Frequency and phase	KJ02-4	5, 10 MHz	5.0×10^{-14}	A7 frequency and phase comparator, UTC (TL)
Remote calibration	KJ02-5	5, 10 MHz	$2. \times 10^{-12}$	GPS receiver, UTC (TL)

GPS REMOTE TIME AND FREQUENCY CALIBRATION SYSTEM

TL has developed a low-cost GPS time and frequency calibration system that can provide remote time and frequency devices with functions of trace back to TL by using the GPS Common View or All-in-View methods. The system consists of a GPS receiving module, a time-interval counter, and a PC controller. The Thunderbolt GPS-disciplined clock is used as the GPS receiving module, the time-interval counter is a HP53131A, and a personal computer is utilized as a post-processing platform controlling the GPS module and the counter. The C language was adopted here in developing programs for data collecting and processing.

A series of measurements were executed to evaluate the performance of the system. The zero-baseline common-clock test using a hydrogen maser as its reference was carried out for evaluating the system noise level. The accuracy calculated from experimental data of the zero-baseline common clock test in a half-day can reach a few parts of 1.0×10^{-13}. We also compared our system to the other GPS time and frequency transfer system used for the TL TAI link, NMIA Topcon and Ashtech Z12T; the standard deviation of double phase difference between systems are 3.63 ns and 1.71 ns respectively **[6]**.
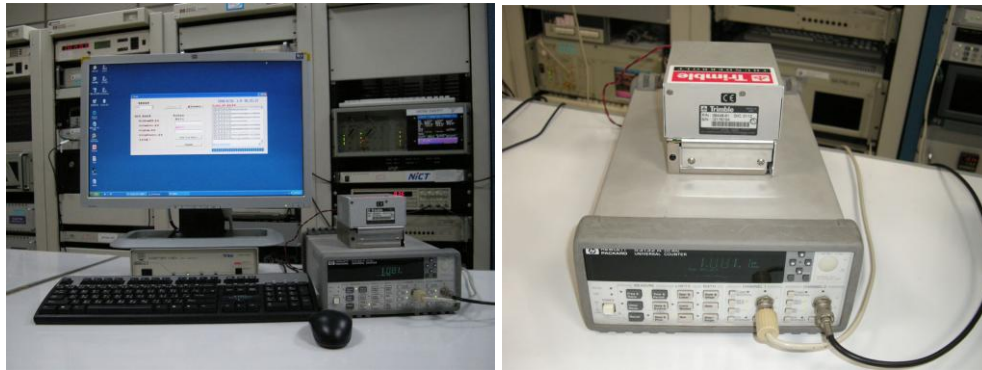
Figure 4. The GPS remote time and frequency calibration system.

IV. ACKNOWLEDGMENTS

Many thanks to all staff of the TL Time Service; their hard work makes our services keep operating and improving.

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