The Calibration Device for TWSTFT station at TL

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***Abstract*—Because of the nanosecond time transfer capability of the Two-Way Satellite Time and Frequency Transfer (TWSTFT)[1], it is important to understand the quality of the delay difference between transmission and receiving (Tx/Rx) paths inside TWSTFT earth station. An effective technique using Satellite Simulator to separately calibrate the absolute Tx/Rx delays at each station was developed by VSL (de Jong and Polderman, 1994[2] and TUG (Kirchner et al., 1995[3]).**

In order to investigate the rigorous calibration method in absolute mode, TL had installed a calibration device, the satellite simulator developed by TimeTech[4], on a Ku-band 1.8 m earth station. By using this device, we performed two serial measurements to obtain the delay values of some internal loops in earth station, and then calculated the difference of the transmission and receiving delays of the TWSTFT earth station. The system structure of the calibration device and the measurement results are illustrated in this paper.

The measurement results show that the calibration device at TL is suitable to monitor the change of the Tx/Rx delay difference precisely. In order to have further understanding of the delay measurement of the TWSTFT earth station, more experiments would be performed at TL in the near future.

I. INTRODUCTION

The Two Way Satellite Time and Frequency Transfer (TWSTFT)[1] method has currently become one of the major techniques to compare atomic clocks of different metrology institutes located far away. The time-transfer data obtained from several regular experiments in Europe, North America and Asia have been contributed to calculate the international atomic time (TAI).

Because high precision can be achieved by TWSTFT, the measurement of the delay difference between transmission and receiving (Tx/Rx) paths inside the TWSTFT earth station becomes crucial. One method to accomplish the calibration is: a portable earth station collocated with both stations to perform the common-clock measurements, and the relative delay difference of each of the two stations can be calculated. The other method is using the technique of separate calibration at each station of the absolute Tx/Rx delays with Satellite Simulator. This method was developed by VSL (de Jong and Polderman, 1994[2]) and TUG (Kirchner et al., 1995[3]).

In order to investigate the rigorous calibration method in absolute mode, TL had purchased and installed a calibration device, the satellite simulator developed by TimeTech[4], on a Ku-band 1.8 m earth station. Two Serial measurements for obtaining the delay values of some internal loops in earth station were performed, and the differences of the transmission and receiving delays of the TWSTFT earth station were calculated and shown in this paper. The system structure of this calibration device and the measurement results are also illustrated.

II. MEASUREMENT SET-UP

For convenience of explanation, we would introduce the structure of the calibration device briefly.

This device includes 3 parts: SATSIM antenna, outdoor unit, and indoor unit. Fig.2.1 shows the block diagram of the calibration device. The cables and the transfer switches of this device are arranged to route the signal path in various ways through all combinations of cables, amplifiers and converters. For the determination of different loop delays in the local station, there are 7 modes (from Mode-S1 to Mode-S7) to be selected.

Let's take Mode-S2 for example, it is selected to determine the sum of the delay values of the Tx and Rx cable (i.e., $T_{TX\text{-}cable}+T_{RX\text{-}cable}$), and the cable connection is shown in Fig.2.2.

The connections of Mode-S6 and Mode-S7 are shown in Fig 2.3 and Fig.2.4. The delays measured with Mode-S6 (Fig 2.3) include the components of Ref-cable, cable to SATSIM antenna, radio link to antenna feeder, down-converter, and Rx-cable. Mode-S7 (Fig 2.4) determines the sum of the delays including: Tx-cable, up-converter, antenna feeder, radio link to SATSIM antenna, radio link to antenna feeder, down-converter, and Rx-cable. The delay components of each mode are summarized in Table-1:

Table I. The components of the measured delays with different modes

Modes	The components of the measured delays
S1	Normal TWSTFT operation
S2	$T_{TX\text{-}cable}+T_{RX\text{-}cable}$
S3	$T_{REF\text{-}cable}+T_{TX\text{-}cable}$
S4	$T_{REF\text{-}cable}+T_{RX\text{-}cable}$
S5	$T_{REF\text{-}cable}+T_{CableToAnt}+T_{CableFromAnt}+T_{RX\text{-}cable}$
S6	$T_{REF\text{-}cable}+T_{CableToAnt}+T_{RadioToRx}+T_{DownConv}+T_{RX\text{-}cable}$
S7	$T_{TX\text{-}cable}+T_{UpConv}+T_{RadioToAnt}+T_{RadioToRx}+T_{DownConv}+T_{RX\text{-}cable}$

Where

$T_{TX\text{-}cable}$: delay of TX cable,

$T_{RX\text{-}cable}$: delay of RX cable,

$T_{REF\text{-}cable}$: delay of Ref cable,

$T_{Cable\ toAnt}$: delay of the cable to SATSIM antenna,

$T_{CableFromAnt}$: delay of the cable from SATSIM antenna,

$T_{RadioToAnt}$: delay of radio link to SATSIM antenna,

$T_{RadioToRx}$: delay of radio link to K-star receiver,

(Radio link includes antenna feeder, air gap between horn and antenna unit)

$T_{DownConv}$: down-converter delay,

T_{UpConv}: up-converter delay,

The following equations show the procedure to get the calibration result "CALR":

CALR (=Calibration result, ns)

= **TX** – **RX** (=transmit/receiver difference at station)

With these measurement results of different modes, the TX/RX delays can be calculated:

$T_{REF\text{-}cable}=(S3+S4-S2)/2$,

$T_{CableToAnt} = T_{CableFromAnt} = (S5-S4)/2$

RX = $S6-T_{REF\text{-}cable} - T_{CableToAnt}$

= $S6-(S5+S3-S2)/2$

TX =S7-**RX**

Finally, the value of [**TX-RX**] can be obtained.

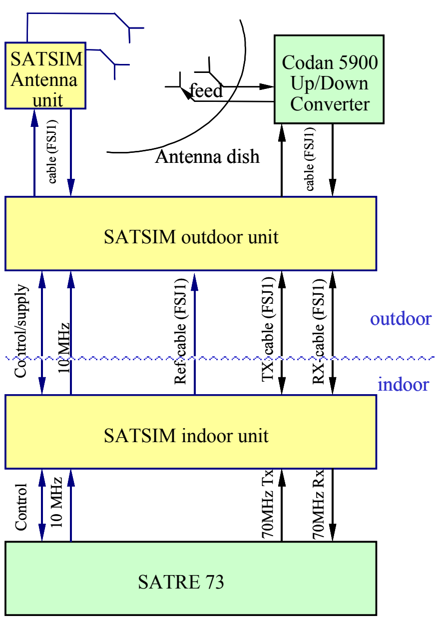

Fig. 2.1 The block diagram of the calibration system

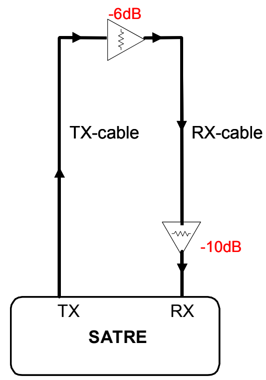

Fig. 2.2 Connections of Mode-S2.

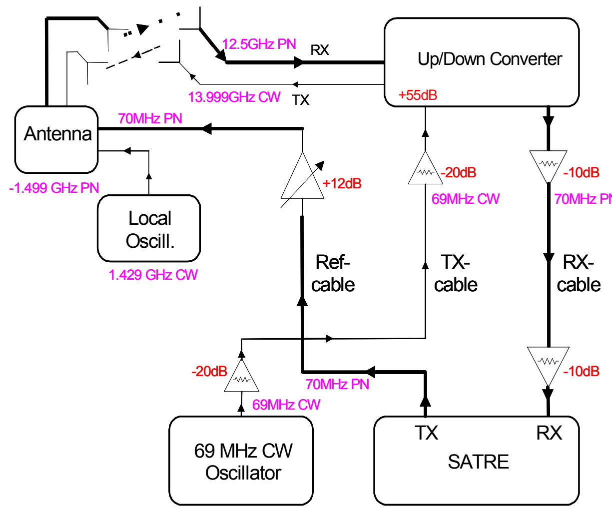

Fig. 2.3 Connections of Mode-S6

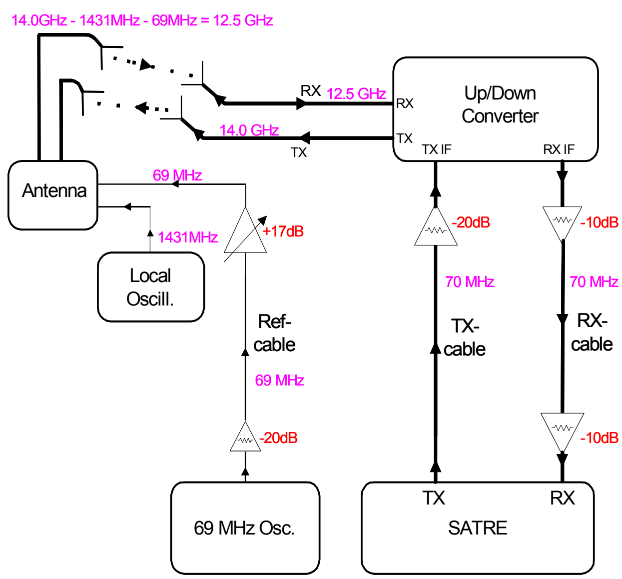

Fig.2.4 Connections of Mode-S7

Ref: *"Satellite-simulator / SATRE calibrator", SA-TIM-MA-1005, TimeTech GmbH 2002*

III. MEASUREMENT RESULTS

After the installation of the calibration device at TL, two serial experiments with different schedules were performed to verify the performance of the calibration device. The first experiment with an hourly schedule has lasted for one month. The time period of each measurement mode was about 5 minutes (including the preparation time of about 1 minute), so it took 34 minutes to run through 7 modes.

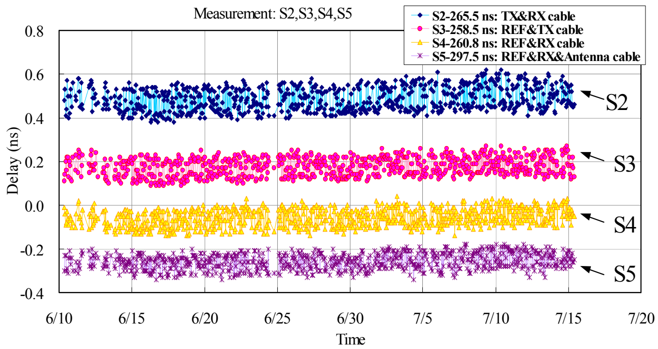

Fig. 3.1 Measurement results of Mode-S2, S3, S4, and S5.

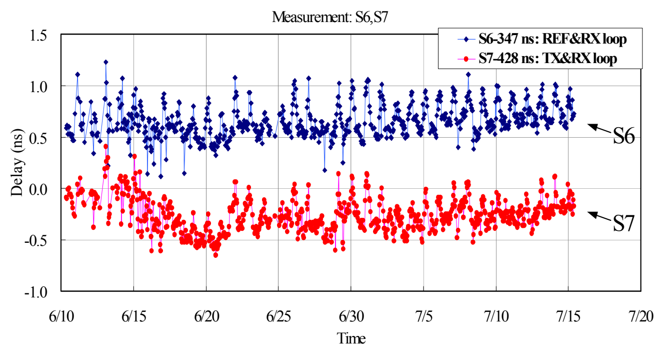

Fig. 3.2 Measurement results of Mode-S6 and S7.

Fig. 3.1 shows the measurement results with different cable connections from Mode-S2 to Mode-S5. The delay values of these measurements are very stable. Fig. 3.2 shows the results of Mode-S6 and Mode-S7. The delay values of TX and RX can be calculated with the equations introduced in section II, and parts of the calculated results are illustrated in Fig.3.3. By contrast with the variations of outdoor temperature shown in the same figure, the influence of temperature to the measurement results is obvious.

From Table-1, one can see that measurements Mode-S2 ~ S5 mainly include the cable-delay values, while Mode-S6 and S7 include the cables, radio link and converter delays. We conclude, from the above measurement results, that the up/down converters (including low noise amplifier) are sensitive to temperature changes and this is the major reason of the delay variations in Fig.3.3. Fig.3.4 is the calculated results of [TX-RX] values. To reduce the temperature effect on the TWSTFT results, the use of an indoor-type converter or temperature control box for outdoor-converter would be necessary.

For the second experiment, the scheduler function of SATRE modem was adjusted and a 15-minute schedule was adopted. Fig.3.5 shows the calculated results of TX-RX, and the influence of outdoor temperature on the TX-RX results is still obvious. The measurement period goes through a Typhoon hit from August 03 to 05, and its unstable measurement results in Fig.3.5 are easily distinguished. The instability of the measurement results during the typhoon period is evidently caused by antenna vibration in the strong wind. After the effect of the Typhoon was removed, the stabilities of TX-RX with different schedules are shown in Fig.3.6. TDEV values vary at tau= 10 hours in both cases, and these variations should be due to the daily temperature transition between day and night.

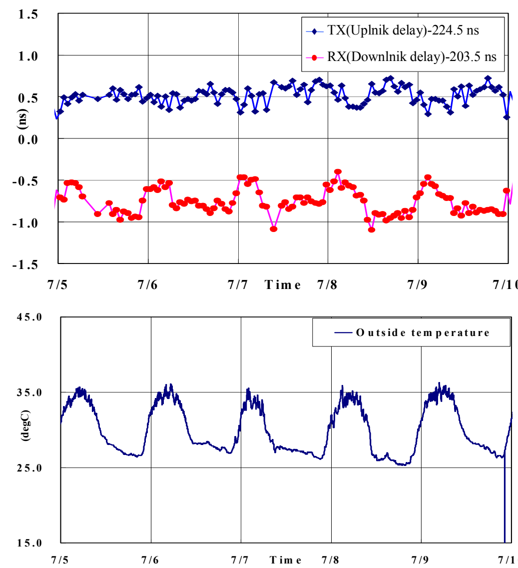

Fig. 3.3 The variations of Tx/Rx delays and temperature.

IV. CONCLUSIONS

In order to investigate the rigorous TWSTFT calibration method in absolute mode, TL had installed a calibration device, the satellite simulator developed by TimeTech, on a Ku-band 1.8 m earth station. Two serial experiments, with hourly (preset) and 15-minute schedules, were performed to verify the performance of this device. Measurements with 15-minute schedule can be applied right before or after a practical TWSTFT session, and the real-time variations of a TWSTFT earth station will be effectively monitored. Some practical and interesting measurement results are observed and illustrated in this paper. In the future, more experiments with the calibration device at TL will be performed in order to have further understanding of the TWSTFT earth-station delay measurements.

References

[1] D. Kirchner, "Two-Way Time Transfer via Communication Satellites," in Proc. of the IEEE, 79, pp.983-990, 1991.

[2] G. de Jong and M. Polderman, "Automated delay measurement system for an earth station", Proc. 26th Precise Time and Time Interval Meeting, pp. 305-317, 1994.

[3] D Kirchner, H. Ressler, and R. Robnik, "An automated signal delay monitoring system for two-way satellite time transfer terminal", Proc. 1995 joint Meeting EFTF-IEEE IFCS, pp. 75-79, 1995.

[4] "Satellite-simulator / SATRE calibrator", SA-TIM-MA-1005, TimeTech GmbH 2002.

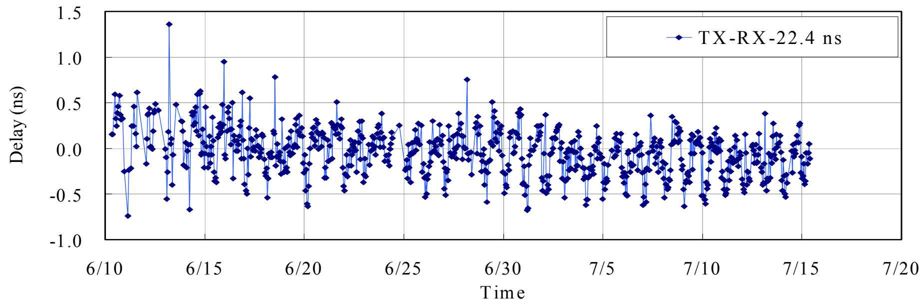

Fig. 3.4 The calculated results of [TX-RX] with hourly schedule.

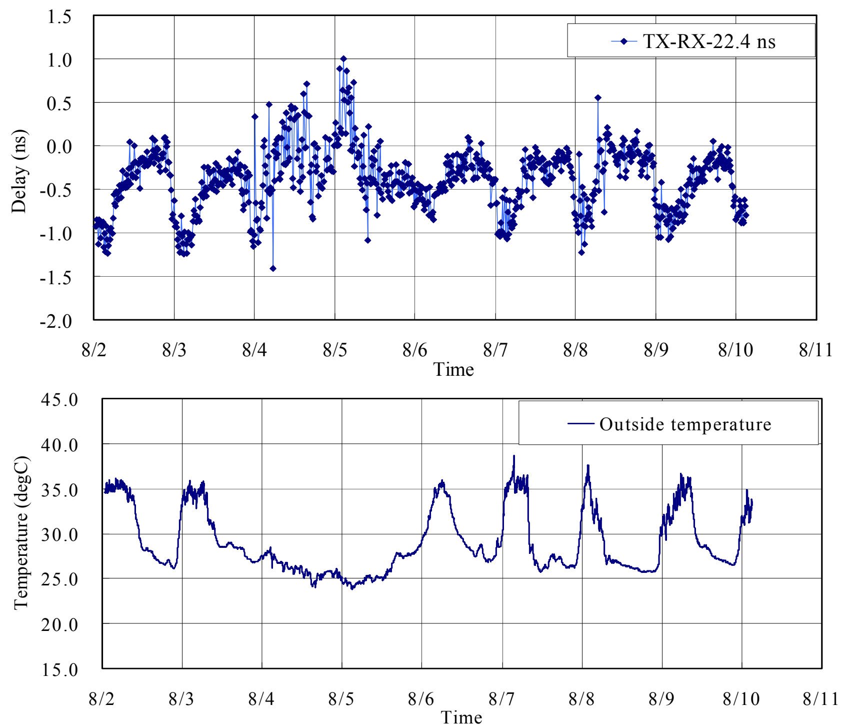

Fig. 3.5 The calculated results of [TX-RX] with 15-minute schedule, and temperature variations.

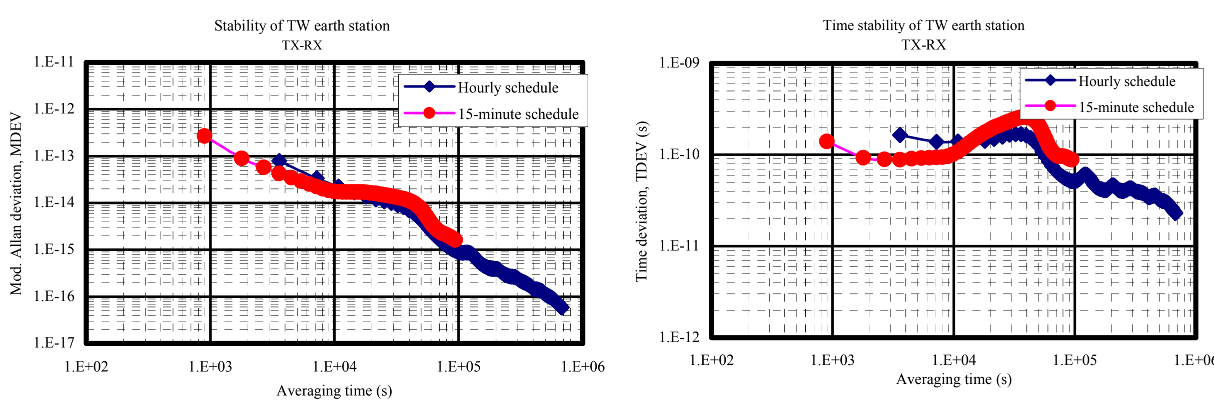

Fig. 3.6 The stabilities of [TX-RX] with hourly and 15-minute schedules