# Optimizing Satellite Earth Station Architecture to Enhance TWSTFT Measurement Accuracy

Tien-Kuan Tseng (1), Wen-Hung Tseng (1), Mamoru Sekido (2) , Michael Wouters (3) , Huang-Tien Lin (1)
National Time and Frequency Standard Laboratory, Telecommunications Laboratories, Chunghwa Telecom Co., Ltd., Taoyuan, Taiwan, nm3634932@cht.com.tw
Space-Time Standards Laboratory, National Institute of Information and Communications Technology, Koganei, Tokyo/Japan
Standards for Time and Frequency, National Measurement Institute Australia, Lindfield, NSW 2070, Australia

Two-Way Satellite Time and Frequency Transfer (TWSTFT) is a well-established microwave-based technique used for comparing remote clocks between National Metrology Institutes (NMIs) and Designated Institutes (DIs). This paper examines the application of TWSTFT using the Software-Defined Ranging System (SRS), developed by the National Institute of Information and Communications Technology (NICT). The Korea Research Institute of Standards and Science (KRISS), NICT, and the Telecommunication Laboratories (TL) have established regular time and frequency comparison links using the SRS modem and have continuously evaluated their performance.

The SRS utilizes both code and carrier phase measurements, aiming to improve conventional TWSTFT systems that primarily rely on pseudo-random noise (PN) codes. Despite its advantages, the measurement precision remains constrained by the signal bandwidth and the earth station equipment. During previous tests, it was observed that the measurements from the original earth station at TL did not meet expectations. To address this issue and improve the measurement precision, TL have constructed a new earth station employing a different architecture.

In the architecture of the original TL03 earth station, which is equipped with a 1.8-meter antenna dish, both the downconverter and upconverter were located indoors. When the antenna receives a signal from the satellite, the earth station amplifies it using a low-noise block (LNB) and down-converts it to the L-band. The signal is then transmitted through an approximately 40-meter cable to the indoor downconverter. This configuration leads to considerable signal loss during the reception process. Figure 1(a) illustrates the architecture of the original TL03 satellite earth station.

A newly established earth station, designated TL01, features an upgraded 2.4-meter satellite dish and an outdoor downconverter, as illustrated in Figure 1(b). This configuration is specifically designed to minimize transmission loss by positioning the downconverter closer to the antenna, thereby reducing cable length and enhancing overall signal performance. Notably, the new earth station has been equipped with low-noise equipment, including a low-noise amplifier (LNA) and both up and down converters, to further reduce signal degradation. Additionally, it should be noted that the SRS modem does not consistently synchronize with the laboratory's reference 1 PPS signal. To mitigate this issue at TL, we employ an external time interval counter to measure the delay times of the 1 PPS input and output of the SRS modem in relation to TL's reference 1 PPS. Based on these monitoring results, we apply any necessary corrections to the SRS measurement reference values. This strategy not only reduces time step discrepancies but also improves measurement quality.

Figures 2(a) and 2(b) present the results of the two-way time transfer between TL and NICT. The time differences between UTC(TL) and UTC(NICT) were measured using the TL01 and TL03 earth stations respectively. The results indicate that TL01 achieves a reduction in diurnal variation of approximately 0.5 ns compared to TL03. The Modified Allan Deviation was used to characterize the frequency stability of the two link setups. As shown in Figures 2(c) and Figures 2(d), TL01 demonstrates an improvement in frequency stability of about 30% at an averaging time of 1200 s.

## References

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## Figures

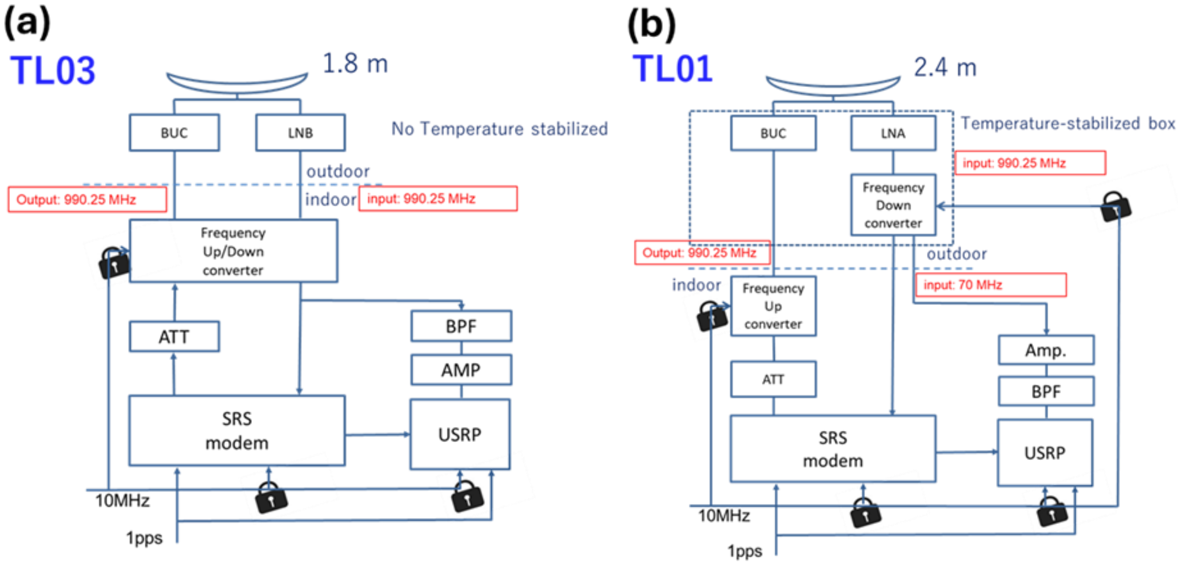


**Figure 1.** (a) The original satellite earth station TL03 architecture. (b) Improved TL01 satellite earth station architecture. LNA: low-noise amplifier, ATT: Attenuator, LNB: Low Noise Block Converter, USRP: Universal Software Radio Peripheral, BUC: Block Up-Converter, AMP: Amplifier, BPF: Band-Pass Filter.

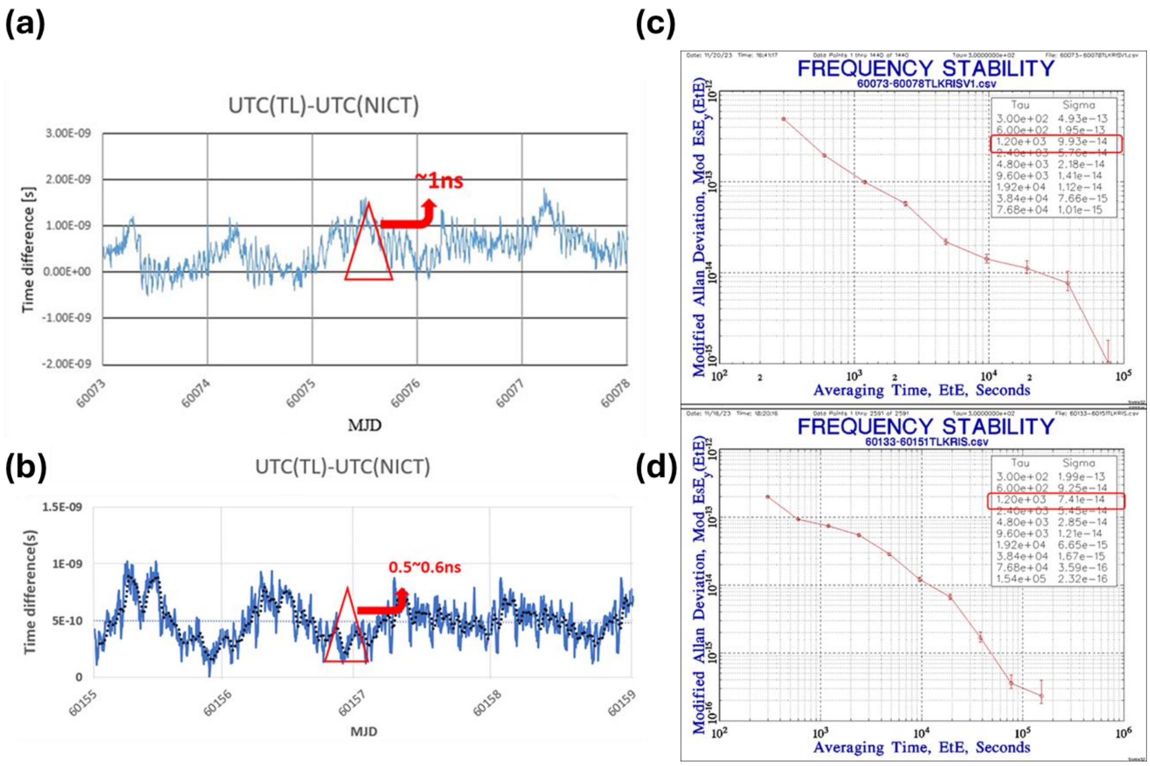


**Figure 2.** (a)Time difference between TL03 and NICT. (b)Time difference between TL01 and NICT. (c) Frequency stability (modified Allan deviation) between TL03 and NICT. (d) Frequency stability (modified Allan deviation)between TL01 and NICT.