

On Developing and Utilizing the Next-Generation Modems and Technologies for Two-Way Satellite Time and Frequency Transfer (TWSTFT) Used in UTC Generation

The Consultative Committee for Time and Frequency

realizing

- that TWSTFT is one of the primary techniques used in comparing remote frequency standards and for UTC generation over the inter-continental baselines
- that a growing number of NMIs is interested in contributing to the calculation of UTC with TWSTFT, reinforcing the necessity to continue developing this network and the required technology
- that the current generation of TWSTFT modems used in these applications will reach End-Of-Life before the end of the decade
- that the current generation of TWSTFT modems and technologies are not capable of comparing the next generation of high-performance frequency standards
- that transition to a new generation of hardware and technology will require several years and careful planning in order to ensure the continuity of the UTC TWSTFT links

considering

- that tests of a new modem [1] in Asia and in Europe showed encouraging results on a limited period of time, with enhanced performance with respect to that of the current generation of modems, as well as a demonstration of Carrier-Phase measurement capacity [2]
- that other types of new TWSTFT modems and technologies (such as Dual Pseudo-Random Noise Code, DPN) are currently being developed and tested, and should be available (either as prototypes or commercial items) within a few years [3] [4]
- that the pilot study on using the Software Defined Radio (SDR) TWSTFT receiver [5] for UTC has successfully accomplished its goal of having SDR TWSTFT links used in UTC generation [6], and was closed during the 28th meeting of the CCTF WG on TWSTFT (23rd and 26th Feb., 2021)
- that development of the corresponding transmitter modules for the SDR TWSTFT receiver is ongoing, with preliminary results being presented in conferences [7], paving the way to an autonomous Rx/Tx solution
- that these new modems are good candidates for realizing the high-performance trans-continental time and frequency links that are made necessary by the perspective of the redefinition of the SI second
- that development and tests are still needed to decide what is the way forward

recommends that the laboratories operating TWSTFT stations

- continue to support research and development on the next-generation of modems and technologies
- continue to participate in the evaluation of the new modems and TWSTFT carrier-phase capability
- continue to support continuous operation of the international TWSTFT network

- continue to research and develop methods and procedures for efficient calibration of the current- and next-generation modems and TWSTFT links
- share the data with the BIPM, and report on the tests to the TWSTFT Working Group

recommends that the BIPM

- continues to support studies on Next-Generation modems and technologies
- ensures that the UTC calculation process is able to cope with additional TWSTFT links realized with these new modems

recommends that the Members taking part to the development of a modem take advantage of the flexibility of digital techniques to allow interoperability when possible

References

[1] Satellite Ranging System (SRS) Modem developed by NICT, see Fujieda, M., Tabuchi, R., & Gotoh, T. (2020). DEVELOPMENT OF A NEW DIGITAL TWSTFT MODEM. *International Journal of Electrical Engineering*, 27(4), 141-145.

[2] Thai, T. T. et al. (2021). Code- and carrier-phase based TWSTFT Experiment Between InRiM, LNE-SYRTE and PTB, presented at the Precise Time and Time Interval Systems and Applications (PTTI) meeting, January, 2021.

[3] Modem developments by BIRMM, presentation by S. Zhang to the 28th meeting of the CCTF WG on TWSTFT

[4] Modem developments by VNIIFTRI, presentation by A. Naumov to the 28th meeting of the CCTF WG on TWSTFT

[5] Use of software-defined radio receivers in two-way satellite time and frequency transfers for UTC computation, Jiang *et al* 2018, *Metrologia* **55** 685.

[6] First Calibration of the UTC TWSTFT Link between OP and PTB Using a Travelling SDR Receiver. Achkar J, Huang Y-J, Piester D, Staliuniene E, Arias F. Calibration report, BIPM reference number 0517-2020.

[7] ITX Module developed by INRiM and SKK, see M. Siccardi, T. T. Thai, D. G. Rovera and I. Sesia, "A TWSTFT Transmitter Prototype Compatible with SDR Receivers and SATRE Modems," 2020 Joint Conference of the IEEE International Frequency Control Symposium and International Symposium on Applications of Ferroelectrics (IFCS-ISAF), Keystone, CO, USA, 2020, pp. 1-3, doi: 10.1109/IFCS-ISAF41089.2020.9234873