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Secretary of the CCTF WG on TWSTFT

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## **REPORT OF THE 8th MEETING OF THE CCTF WORKING GROUP ON TWO-WAY SATELLITE TIME AND FREQUENCY TRANSFER**

held at the BIPM, Sèvres near Paris,  
on 5 and 6 October 2000

The 8th meeting of the Consultative Committee for Time and Frequency (CCTF) Working Group (WG) on Two-Way Satellite Time and Frequency Transfer (TWSTFT) was held on 5 and 6 October 2000 at the Bureau International des Poids et Mesures (BIPM), Sèvres near Paris. An additional session of the participating stations was held on 5 October at the end of the general session. The meeting was organized by the Time Section of the BIPM and was chaired by Dr W.J. Klepczynski of ISI, Inc. The list of participants is given in the Appendix to this report. Dr T.J. Quinn, Director of the BIPM, welcomed participants with an opening address. Other contributions to the meeting are available on the [http://www.bipm.fr/pdf/cctf/wg\\_twstft.html](http://www.bipm.fr/pdf/cctf/wg_twstft.html)

### **Summary of the meeting**

The meeting was devoted to an overview of current TWSTFT operations, studies of uncertainties of TWSTFT links, the possible extension of TWSTFT observations to five or seven days per week, calibrations of TWSTFT stations, expansion of TWSTFT links to the Pacific Rim region including links with Europe and North America, and the introduction of further TWSTFT links into TAI. Electronic versions of all reports/presentations are available at the BIPM website (see above).

**Reports from Participating Stations.** The participating stations presented reports on their work. The ROA TWSTFT station is now operational and will soon start to send data to the BIPM on a regular basis. The IEN TWSTFT station is completely automated, and INTELSAT approval of the IEN VSAT antenna was obtained in May 2000. In July 2000 the NIST undertook the first TWSTFT comparison of the NIST and PTB caesium fountains. It plans to continue to use TWSTFT for comparisons of NIST and PTB caesium fountains when they are operating simultaneously. The NIST will use TWSTFT as its main link to TAI as soon as some issues concerning reliability are resolved. The NPL's primary station NPL01 is almost completely automated, and the back-up station NPL02 provides a secondary TWSTFT link with the USNO. The OCA TWSTFT data are now sent to the BIPM on a regular basis and this station is expected to be fully automated before the end of 2000. In the Pacific Rim region the CSAO and TL stations should soon be operational.

**BIPM TWSTFT Monthly Reports.** J. Azoubib highlighted that the variances of all the studied links show that TWSTFT has a clear advantage over GPS common-view for averaging times

of up to a few tens of days. He noted that at some stations the GPS equipment is subject to systematic errors. He stressed that the use of TWSTFT significantly improves transatlantic links because, unlike GPS, TWSTFT is unaffected by ionospheric delays. This is particularly important during the present period of high solar activity.

Analyses of the current performance of TWSTFT show that clocks located on different continents can be compared at their full level of performance within five-day intervals, without being affected by time-transfer measurement noise. Thus, if TWSTFT were used for all TAI links, the stability of TAI would be improved for periods of up to 10 days. The introduction of a number of TWSTFT links into TAI has already increased robustness of TAI construction: TAI no longer relies on a single technique, because TWSTFT links are backedup by GPS links and vice versa, and for the first time two transatlantic links are included, each of which being performed by two independent techniques.

***USNO Time Transfer Monthly Reports.*** On behalf of K. Senior, D. Matsakis presented a summary of the USNO Time Transfer Reports. The USNO is carrying out comparisons of the TWSTFT, GPS common-view and GPS carrier-phase (CP) techniques. Although recognizing the qualities and future potential of GPS CP he said that for the time being TWSTFT gives the best performance.

***Comparisons with other techniques.*** Several participants presented the results of comparisons of the TWSTFT, GPS common-view and GPS CP techniques (refer in particular to the presentations from the NIST, USNO and BIPM).

***Study of uncertainty of TWSTFT links.*** Several detailed studies on uncertainties were presented during the meeting.. Of particular interest were the presentations by D. Kirchner and T. Parker.

***Calibration of TWSTFT link with a portable X-band station.*** In May 2000 USNO carried out a calibration of the PTB-USNO link using a portable X-band station. Simultaneous X- and Ku-band sessions were recorded on two days. The data are being evaluated at the USNO, and calibrations of other links with this X-band station are planned.

***Calibration of TWSTFT link with GPS.*** It was stressed that frequent calibration of TWSTFT equipment using GPS should be organized. In addition each calibration of TWSTFT equipment by a portable TWSTFT station should be confirmed by GPS. G. de Jong has recently discovered that AOA TTR6 receivers use a trigger level of 1.4 V instead the 0.5 V used by older models. This may complicate GPS calibrations and must be taken into account.

***Relocation of NPL station.*** In March or April 2001, the NPL Time Section will move to a new building. A procedure will be put in place to ensure the continuity of time operations. The BIPM and WG will be kept informed.

***Future of TWSTFT.*** D. Kirchner shared his views on possible future developments of TWSTFT. Among them are: more frequent, fully automated measurements, higher chip rate (20 MHz, SATRE modem is ready), exchange of 1 s data via satellite (SATRE and other

modems are available), use of carrier phase for TWSTFT (SATRE is available), development of a small and self-contained (hardware, software) station that is simple to operate.

**New modems at NRL.** R. Beard reported that new modem has been developed at the NRL and will be adapted for use in mobile applications, for example for a ship to use as a back-up system for GPS. The possible implementation of MITREX code is considered too costly.

**IGS Analysis Centre Workshop 2000.** F. Arias reported that this workshop took place during 25-29 September at the USNO. Three main themes dominated the meeting: the IGS/BIPM Timing Pilot Project; the IGS near-real-time products and their applications; and potential interactions between the IGS and various GNSS systems (GPS, Galileo, GLONASS).

## **Actions**

The WG decided the following actions:

- **Extension of the number of weekly TWSTFT sessions.** A group comprising J. Davis, B. Klepczynski, T. Parker and S. Shemar under the leadership of G. de Jong will investigate if the TWSTFT acquisition time can be reduced from 60 s to 30 s and TWSTFT sessions can be reduced from 120 s to 60 s to allow seven sessions a week. A report will be prepared for the PTTI meeting of participating stations.
- **Payment of INTELSAT.** G. de Jong will coordinate payment of INTELSAT, addressing related issues concerning INTELSAT's privatization in April 2001.
- **Pacific Rim/Europe TWSTFT link.** A working group on this issue was set up, with Z. Li as chairman and M. Imae, G. de Jong, B. Klepczynski, T. Parker and S. Shemar as members. A short report will be prepared for the PTTI meeting of participating stations.
- **Filtering of outliers.** It was decided that during treatment of TWSTFT 1 s data, observations that deviate by more than  $3\sigma$  from the quadratic fit to the data will be eliminated, but only one at a time.
- **GPS calibrations.** Frequent (thrice yearly) GPS calibrations of TWSTFT equipment should be organized. The involvement of regional organizations such as EUROMET is welcomed.
- **TWSTFT calibrations.** The TWSTFT community should dedicate a portable TWSTFT station for frequent calibrations. A de-Jong-type satellite simulator should also be used more frequently for calibration. TWSTFT calibrations should always be confirmed by GPS calibrations.

- **Log files.** It is recommended that log files be implemented on ftp sites to record the evolution of TWSTFT stations.
- **Empty data files.** Because an empty TWSTFT file is ambiguous it is recommended that an entry such as “no measurements” be made.
- **E-mail dispatching software.** The USNO plans to equip the TWSTFT community with software allowing the distribution of e-mail to the community. The software would also allow consultation of all exchanged messages.
- **Theoretical uncertainty of TWSTFT.** A draft table showing a theoretical estimation of different sources of uncertainties in TWSTFT will be prepared by J. Davis and W. Lewandowski for the PTTI meeting of participating stations.
- **Studies of TWSTFT.** Further investigations should be carried out to study the improvements brought into TAI by the use of TWSTFT. These studies should be completed in advance of the next meeting of the CCTF.
- **USNO TWSTFT calibrations using US X-band satellite.** The continuation of the calibrations by the USNO, including TAI TWSTFT links, is most encouraged.
- **Introduction of new TWSTFT links into TAI.** The WG recommends the introduction of further TWSTFT links, including Pacific Rim links, into TAI.

### **Dieter Kirchner**

The WG expressed its gratitude to Dr Dieter Kirchner, scientist and engineer. Dr Kirchner is one of the pioneers of the TWSTFT technique and remains one of the main contributors to its development. The WG expressed the hope that the TWSTFT community will continue to benefit from his expertise, despite the TUG ceasing operation.

### **Forthcoming meetings**

It was agreed that the next meeting of participating stations will be held during the PTTI'2000 conference at the end of November 2000. The next full meeting of the Working Group will be held at the CSAO, Lintong, China, at the end of October 2001.

## APPENDIX

### List of participants

F.E. Arias, BIPM,  
J. Azoubib, BIPM,  
F. Baumont, OCA/CERGA,  
R. Beard, NRL,  
J.A. Davis, NPL,  
G. de Jong, NMI VSL,  
W. Hanson, NIST,  
P. Hetzel, PTB,  
Z. Jiang, BIPM,  
D. Kirchner, TUG,  
W.J. Klepczynski, ISI, Inc.,  
H. Konate, BIPM,  
W. Lewandowski, BIPM,  
Z. Li, CSAO,  
S.Y. Lin, TL,  
D. Matsakis, USNO,  
P. Moussay, BIPM,  
J. Palacio, ROA,

T. Parker, NIST,  
G. Petit, BIPM,  
Z. Piwowarczyk, GUM,  
T. J. Quinn, BIPM,  
S. Shemar, NPL,  
P. Uhrich, BNM-LPTF,  
B. Yujing, CSAO.

*Excused:*

F. Cordara, IEN,  
M. Imae, CRL,  
V. Pettiti, IEN,  
W. Schaefer, TimeTech.