18th Meeting of the CCTF

Report on time activities at the BIPM Time, Frequency and Gravimetry section for the period October 2006-May 2009

Elisa Felicitas Arias

TAI generation at the BIPM follows the workplan presented at the 16th and 17th meetings of the CCTF (2004, 2006), as well as the adopted recommendations. Current clock comparisons for the generation of TAI are based on GPS satellite all-in-view using single and dual frequency receivers and TWSTFT links. The software that produces *Circular T* allows link comparison, whose results are made available through the internet. Campaigns for characterizing the delays in GNSS equipment in laboratories have been organised without interruption during the period of this report. In conformity with recommendation CCTF 4(2006), a strategy for using the GNSS carrier phase for time transfer in TAI has been implemented. Within the frame of a pilot experiment, more than twenty laboratories are participating to a campaign since April 2008 (refer to working document CCTF/09-19).

Regular updates of key comparison CCTF-K001.UTC have been published monthly in the BIPM Key Comparison Data Base (KCDB). Following the decision made at the 17th Meeting of the CCTF (2006), and in cooperation with the CCTF Working Group on the MRA, the section worked on the implementation of the key comparison in frequency CCTF-K002.UTC. A proposal for the calculation of the frequency offset and its uncertainty submitted by the BIPM to the working group has been accepted, and the format if its presentation in the KCDB will be decided in the next months (refer to working document CCTF/09-18).

Work has started on the improvement of the algorithm ALGOS for computing EAL (refer to working document CCTF/09-24).

The information provided on the ftp server of the section has been completed with a page dedicated to the characterization of time transfer equipment delays in laboratories (http://www.bipm.org/jsp/en/TimeCalibrations.jsp).

Activities of some section members continued on the establishment of space-time references, mainly in cooperation with the IERS.

The staff of the section has evolved since the previous meeting of the CCTF. Gianna Panfilo has been recruited as physicist in August 2007 and Aurélie Harmegnies as assistant in November 2008.

1. International Atomic Time (TAI) and Coordinated Universal Time (UTC)

Reference time scales TAI and UTC have been computed regularly and have been published in the monthly *Circular T*. Definitive results for 2006 and 2007 have been available in the form of computer-readable files in the BIPM home page and on printed volumes of the *BIPM Annual Report on Time Activities*, the volume for 2008 is under preparation at the moment of this report and will be distributed during the Summer 2009. The current format of this publication includes part of the information in the traditional printed publication, completed by tables accessible through the BIPM web site.

1.1. EAL stability

Some 87 % of the clocks used in the calculation of time scales are either commercial cæsium clocks of the HP/Agilent 5071A type or active, auto-tuned hydrogen masers. To improve the stability of EAL, a weighting procedure is applied to clocks where the maximum relative weight each month depends on the number of participating clocks. About 15 % of the participating clocks have been at the maximum weight, on average, during 2008. This procedure generates a time scale which relies upon the best clocks.

The stability of EAL, expressed in terms of an Allan deviation, has been about 0.4×10^{-15} for averaging times of one month. Slowly varying long-term drifts limit the stability to around 2×10^{-15} for averaging times of six months.

1.2. TAI accuracy

We have regularly used results of frequency measurements of primary frequency standards to improve the accuracy of TAI.

Since October 2006, individual measurements of the TAI frequency have been provided by twelve primary frequency standards, including eight Cs fountains (IT-CSF1, LNE-SYRTE FO1, LNE-SYRTE FO2, LNE-SYRTE FOM, NIST-F1, NMIJ-F1, NPL-CSF1 and PTB-CSF1):

- IT-CSF1 is the caesium fountain operated at the INRIM, Torino (Italy). Eight measurement reports over 10-20 days have been produced in the period. Its type B relative standard uncertainty as stated by the INRIM is $0.4\text{-}0.7 \times 10^{-15}$.
- KRISS-1, is the optically pumped caesium beam frequency standard recently developed and evaluated at KRISS, Daejeon (Korea). Three first measurement reports have been provided in the last half of 2008 with periods between 10 and 20 days. The type B relative standard uncertainty of KRISS-1 is stated by the KRISS as 9.5×10^{-15}.
- NIST-F1, which is the caesium fountain developed at the NIST, Boulder (USA). In the period covered by this report, it provided sixteen measurements with periods between 10 and 30 days. The type B relative standard uncertainty is stated by the NIST as 0.3×10^{-15}.
- NMIJ-F1 is the caesium fountain developed and operated at NMIJ/AIST, Tsukuba (Japan). Fourteen measurements have been reported since October 2006 over periods of 10-30 days. The type B relative standard uncertainty of NMIJ-F1 is stated by the NMIJ as 4×10^{-15}.
- NPL-CSF1 is the caesium fountain developed at the NPL, Teddington (UK). Four measurements have been reported in the over periods of 25-35 days. The type B relative standard uncertainty of NPL-CSF1 is stated by the NPL as 1.8×10^{-15}.
- PTB-CS1 and PTB-CS2 are classical primary frequency standards operating continuously (CS1 stopped 2 months) as clocks at the PTB, Braunschweig (Germany). The type B relative standard uncertainty is stated as 8.0×10^{-15} for PTB-CS1 and as 12.0×10^{-15} for PTB-CS2 during the period of this report.

- PTB-CSF1 is the caesium fountain developed at the PTB. Five reports covering 15 to 25 days of measurement have been provided in the period. The type B relative standard uncertainty of PTB-CSF1 is stated by the PTB as 1.0×10^{-15}.
- SYRTE-JPO is the optically pumped caesium standard operated at the LNE-SYRTE, Paris (France). It provided thirty-one measurements in the period of this report, over periods between 10-30 days. The type B relative standard uncertainty of this primary standard is stated by the LNE-SYRTE as 6.3×10^{-15}.
- SYRTE-FO1 is the caesium fountain operated at the LNE-SYRTE. Sixteen measurements were provided over periods of 10 to 30 days. The type B relative standard uncertainty of SYRTE-FO2 stated by the LNE-SYRTE is $0.4\text{-}0.6 \times 10^{-15}$.
- SYRTE-FO2 is the double rubidium-caesium fountain operated at the LNE-SYRTE. Twenty measurements were provided over periods of 5 to 30 days. The type B relative standard uncertainty of SYRTE-FO2 stated by the LNE-SYRTE is $0.4\text{-}0.6 \times 10^{-15}$.
- SYRTE-FOM is the mobile caesium fountain operated at the LNE-SYRTE. Sixteen measurements were provided over periods of 10 to 30 days. The type B relative standard uncertainty of SYRTE-FO2 stated by the LNE-SYRTE is $0.7\text{-}1.2 \times 10^{-15}$.

The global treatment at the BIPM of individual measurements led to a relative departure *d* of the duration of the TAI scale interval from that of Terrestrial Time TT (the SI second on the geoid) ranging since October 2006 from $+5.7\times 10^{-15}$ to $+1.0 \times 10^{-15}$, with an uncertainty of 0.3 - 1.1×10^{-15}.

Starting in October 2006, monthly steering corrections of maximum value 0.6×10^{-15} have been applied to the frequency of EAL, with a total correction amounting -10.1×10^{-15} over the period October 2006-April 2009. Figure 1 shows the values of the relative departure *d* since 2002. For the period of this report the values of *d* increase at a rate of about 1.2×10^{-16} /month indicating that the steering strategy is becoming less effective.

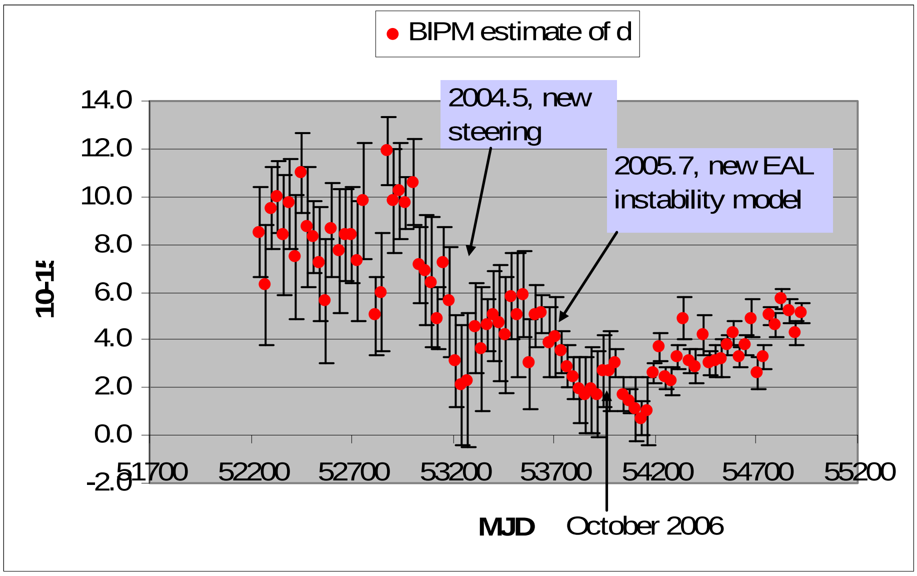

Fig 1. Relative departure *d* of the duration of the TAI scale unit from the SI second on the geoid in the period January 2002 – April 2009.

2. Time links

TAI relies at present on 68 participating time laboratories equipped with GNSS receivers and/or operating TWSTFT stations.

As decided at the 17^{th} meeting of the CCTF in 2006, the GPS common-view method for clock comparison has been replaced by the GPS all-in-view taking advantage of the increasing quality of the IGS products (clocks and IGS time). Clock comparisons are possible with C/A code measurements from GPS single- frequency receivers; with dual-frequency, multi-channel GPS geodetic type receivers (P3); and two-way satellite time and frequency transfer through geostationary telecommunications satellites (TWSTFT). The GPS single-channel single frequency receivers that allowed 25% of the links in 2006 represent today only 6%, most of them replaced by either multi-channel single- or dual-frequency receivers. 54% of the links in TAI come from multi-channel receivers, and 22% from dual-frequency receivers providing P3 links. Ten TWSTFT links are officially used for the computation of TAI, representing 15% of the time links. More TW links exist in the Asia-Pacific region, not already officially introduced in the calculation, and some European laboratories are close to contributing.

The international network of time links has been modified with the introduction of the GPS all-in-view method. The previous pattern of stars within a continent and long distance links between pivots in different continents necessary to the common views has changed to a one cross-over laboratory (PTB at present) for all UTC(k) comparisons. This scheme is common to the GPS and TWSTFT links.

Following the recommendation CCTF 4(2006) the section started a pilot experiment, TAIPPP, where time laboratories contribute GPS phase and code data and where the BIPM uses the Precise Point Positioning technique to generate monthly solutions, in slightly deferred time after the regular TAI computation. The call for participation was released in January 2008, and the experiment started in April. The number of laboratories regularly participating today is 25. Comparison of the TAIPPP links with others obtained by TWSTFT and P3 are published monthly on the ftp server of the section. Details of the TAIPPP experiment, including results are provided in the working document CCTF/09-19.

Results of link comparisons by the different techniques and methods are made available on the BIPM website.

2.1. Global Positioning System (GPS)

The BIPM TFG section continues publishing twice a year, GPS international common view schedules. These schedules are not necessary in the case of satellite tracking with GPS multi-channel receivers, and neither at the BIPM for comparing clocks with the GPS all-in-view method. However, the schedules are useful for common-view comparison between laboratories.

All GPS links are corrected by using precise satellite ephemeredes produced by the International GNSS Service (IGS). Time links calculated with GPS single-frequency observations are corrected by using the ionospheric maps produced by the IGS analysis centre CODE (Centre for Orbit Determination in Europe). The rapid IGS products have the continuity, stability and rapid availability adapted to the all-in-view time transfer for TAI on a monthly basis.

The BIPM publishes an evaluation of the daily time differences [*UTC – GPS time*] in its monthly *Circular T*. These differences are obtained by smoothing GPS data, taken at the Observatoire de Paris (France) from a selection of satellites at high elevation. The standard deviation characteristic of individual measurements is about 2-3 ns.

Campaigns for characterizing the delays of GPS equipment in participating laboratories are regularly organized by the BIPM, the result being the differential calibration of about 65% of the GPS equipment in contributing laboratories. Most GPS equipment providing data for P3 official links in TAI has been calibrated.

To the measurement of relative delays of the Ashtech Z12-T and Septentrio PolaRx2, we have now added the GTR-50 and other receivers based on Javad chips. We have started the measurement of relative delays for these receivers in contributing laboratories.

The realization of a chain for measuring the absolute delays in GNSS equipment started in September 2008 in the frame of a PhD in a cooperation established between the BIPM, the CNES and the Observatoire de Paris.

2.2. Global Navigation Satellite System (GLONASS)

GLONASS international common-view schedules had been interrupted in October 2008, since there are no single-channel receivers tracking GLONASS satellites.

Within the period of this report, work has been developed on the characterization of the delays of GLONASS equipment in the frame of a PhD in a cooperation between the BIPM and the Astrogeodynamical Observatory Borowiec (AOS, Poland). The first measurement campaign has started, and a TTS-3 GPS/GLONASS BIPM travelling receiver has visited the time laboratory in VNIIFTRI (Russian Federation). GLONASS data taken by time laboratories are collected and studied at the BIPM, but they are not yet used in the current TAI computation. When a number of GLONASS equipment will be calibrated, we will start a pilot experiment for including GLONASS observations for clock comparison in TAI.

The BIPM publishes an evaluation of the daily time differences [*UTC – GLONASS time*] in *Circular T*. These differences are obtained by smoothing GLONASS data, which had been taken at the AOS. The standard deviation characteristic of individual measurements is about 15 ns. The combined standard uncertainty of the daily GLONASS values is, however, not better than several hundred nanoseconds, because no absolute measurements of the GLONASS equipment delay are available.

2.3. Two-way time transfer

The introduction of TWSTFT increases the robustness of the construction of TAI by adding a technique independent from GPS.

The TWSTFT technique is currently operational in twelve European, two North American and seven Asia-Pacific time laboratories. Ten TWSTFT links are routinely used in the computation of TAI; four others are in preparation for their introduction or re-introduction into TAI, or are used for particular studies as the T2L2 experiment. The TWSTFT technique applied to clock comparison in TAI is reaching its potential capabilities with the sessions scheduled every two hours.

Results of time links and link comparison using GPS single-frequency, dual-frequency and TW observations are published monthly on the ftp server of the TFG section (tai.bipm.org/TimeLink/LkC).

3. Algorithm for TAI

The effect of the linear prediction algorithm has been studied for different types of clocks in TAI. ALGOS predicts the clock frequency with a linear model that is well adapted to the caesium clock, but not to the H-maser clock. A test version of EAL without H-masers has been calculated to evaluate the effects of the equal modelling of the clock frequencies. A new mathematical expression for the prediction of the H-maser frequency is proposed taking into account the drift. Tests over a 3-year period have been performed applying the linear prediction to the caesium clocks and the quadratic prediction to the H-masers. A version of EAL on the basis of the proposed frequency prediction for H-masers, but with the classical clock weighting has been evaluated. The results seem to indicate that non-modelling of the frequency drift of H-masers could be responsible for 20% of the drift of EAL. In this test one month of past data has been used to evaluate frequency drift but longer periods will be tested. EAL still shows a significant drift; further work needs to be done on EAL weighting algorithm (for more details see CCTF/09-24).

4. Key comparisons

The key comparison in time CCTF-K001.UTC with results for laboratories in member states and associates signatories of the CIPM Mutual Recognition Arrangement (MRA) has been regularly published in the key comparison data base (KCDB) after the publication of *Circular T*.

Following the decision of the CCTF at its 17th meeting in 2006, the BIPM has cooperated with the CCTF WG on the MRA, and implemented the calculation of the frequency offsets and their uncertainties for the new key comparison CCTF-K002.FREQ (for more details see CCTF/09-18).

5. Other research studies

5.1. Space-time references

Since 1 January 2001 the BIPM and the U. S. Naval Observatory (USNO) have been working together to provide the Conventions Centre of the IERS. A web and ftp site for the IERS Conventions has been established at the BIPM (http://tai.bipm.org/iers/) and a user discussion forum has been set-up (http://tai.bipm.org/iers/forum/) for users to offer comments related to the future updates of the IERS Conventions (the forum has been discontinued in December 2008). Updates to the Conventions (2003) have been regularly posted on the web site http://tai.bipm.org/iers/convupdt. These updates consider several new models for effects that affect the positions of Earth's points at the mm level, which is now significant. These modifications are studied with the help of the Advisory Board for the IERS Conventions updates, including representatives of all groups involved in the IERS. An international workshop on the IERS Conventions was held at the BIPM in September 2007, gathering some 65 participants from some 15 countries.

Activities related to the realization of reference frames for astronomy and geodesy are developed in cooperation with the IERS.

5.2. Pulsars

Collaboration is maintained with radio-astronomy groups observing pulsars and analyzing pulsar data provided that it is of interest for us; for example, to study the potential capability of millisecond pulsars as a means of sensing the very long-term stability of atomic time. The Time section provides these groups with its post-processed realization of Terrestrial Time, computed every year, the more recent one is TT(BIPM08) available in January 2009. A collaboration continues with the Observatoire Midi-Pyrénées (OMP), Toulouse, on a programme of survey observations.

6. Publications of the staff

1. Arias E.F., Guinot B., 2006, Avenir du Temps Universel Coordonnée (UTC), *Navigation*, **54**, 214, 59-78.
2. Jiang Z., Vitushkin L. , Becker M., Francis O., Jousset P., Ferry M., Dupont F., Deroussi S., Métivier L., Pajot G., Lee C., TsaiC.-L., Falk R., Wilmes H., Kopaev A., Ruess D., Ullrich C., Meurers B., Mrlina J., Palinkas V., Kostelecky J., Pereira F., van Ruymbeke M., Naslin S., Relative campaign during the International Comparison of Absolute Gravimeters ICAG-2005 and the strategy of data treatment combined with the absolute results, *Proc. IGFS2006, 1st Symposium of the International Gravity Field Service*.
3. Lewandowski W., International Atomic Time Scales and Related Time Transfer, *MAPAN – J. Metrol. Soc. India,* 2006, 4, 223-227
4. Matsakis D., Arias E.F., Bauch A., Davis J., Gotoh T., Hosokawa M., Piester D., 2006, On optimizing the configuration of time-transfer links used to generate TAI, *Proc. of the EFTF 2006*, 448-454.
5. Matsakis D., Lee M., Dach R., Hugentobler U., Jiang Z., GPS Carrier Phase Analysis Noise on the USNO-PTB Baselines, *Proc. FCS 2006*, 631-636.
6. Nawrocki J., Rau Z., Lewandowski W., Małkowski M., Marszalec M., Nerkowski D., Steering UTC(AOS) and UTC(PL) by TA(PL), *Proceedings of the 38th Annual Precise Time and Time Interval (PTTI) Applications and Planning Meeting,* 2006, Reston, VA.
7. Petit G., Defraigne P., Warrington B., Uhrich P., Calibration of dual frequency GPS receivers for TAI, *Proc. 20th EFTF*, 2006, 455-459.
8. Petit G., Jiang Z., Using a redundant time link system in TAI computation, *Proc. 20th EFTF*, 2006, 436-439.
9. Vitushkin L., Jiang Z., Becker M., Francis O., Jousset P. et al., The Seventh International Comparison of Absolute Gravimeters ICAG-2005 at the BIPM. Organisation and

preliminary results, *Proc. IGFS2006 ,1st Symposium of the International Gravity Field Service*.

10. Arias E.F., Time scales and relativity, *Proc. International School of Physics 'Enrico Fermi', Course CLXVI, Metrology and Fundamental Constants, 2007*, 367-392

11. Jiang Z., Dach R., Petit G., Schildknecht T., Hugentobler U., Comparison and combination of TAI time links with continuous GPS carrier phase results, *Proc. EFTF-IFCS 2007*, 440-447.

12. Jiang Z., Petit G., Redundancy in the TAI TWSTFT time transfer network, *Proc. EFTF-IFCS 2007*, 468-475.

13. Jiang Z., Petit G. Defraigne P., Combination of GPS Carrier Phase data with a Calibrated Time Transfer Link, *Proc. EFTF-IFCS 2007.*

14. Ma L.-S., Bi Z., Bartels A., Kim K., Robertsson L., Zucco M., Windeler R.S., Wilpers G., Oates C., Hollberg L., and Diddams S.A., Frequency Uncertainty for Optically Referenced Femtosecond Laser Frequency Combs, *IEEE Journal of Quant. Electr.*, **43**, N° 2, 139.

15. G. Panfilo and P. Tavella. Algorithms for the atomic clock prediction within the GALILEO system, *Proc. 1st Colloquium Scientific and Fundamental Aspects of the Galileo Programme.* 1-4 October 2007, Toulouse, France.

16. Petit G., From atomic clocks to coordinate times, in *Highlights of Astronomy*, 2007, in press.

17. Petit G., The long-term stability of EAL and TAI (revisited), *Proc. EFTF-FCS'07 meeting*, 2007

18. Robertsson L., On the diffraction correction in absolute gravimetry, *Metrologia,* 2007**, 44**,35-39

19. Arias E.F., A successful example of international coordination for metrology: the international time scales, *Proc. Int. Symposium, Terrestrial Gravimetry, Static and Mobile Measurements TGSMM-2007,* State Research Centre of Russia Electropribor St Petersburg, 2008, 7-14.

20. Jiang Z., Becker M., Vitushkin L., The local gravity field at BIPM, *Proc. Int. Symposium Terrestrial Gravimetry: Static and Mobile Measurements TGSMM-2007,* State Research Centre of Russia Electropribor, St Petersburg, 2008, 152-157.

21. Krivtsov E., Yankovsky A., Vitushkin L., Francis O., Investigations of characteristics of gravimetric sites intended for high-accuracy measurements, *Proc. Int. Symposium Terrestrial Gravimetry: Static and Mobile Measurements TGSMM-2007,* State Research Centre of Russia Electropribor, St Petersburg, 2008, 158-166.

22. Lewandowski W., Matsakis D., Panfilo G., Tavella P., Analysis of correlations, and link and equipment noise in the uncertainties of [*UTC – UTC*(*k*)], *UFCC,* 2008, 750-760

23. Lewandowski W., Impact of atomic clock and time-transfer noises in the formation of the International Atomic Time, (invited) *Proceedings of the Fluctuations & Noise SPIE Meeting,* Florence, Italy, 2007).

24. Lewandowski W., Tisserand L., Determination of the differential time corrections for GPS time equipment located at the OP, NTSC, HKO, TL, SG, AUS, KRIS, NMIJ, and NICT, *Rapport BIPM*-2008/02, 27 pp

25. Lewandowski W., Tisserand L., Determination of the differential time corredtions for GPS time equipment located at the OP, TCC, ONBA, IGMA and CNMP, *Rapport BIPM*-2008/03, 18 pp

26. Lewandowski W., Tisserand L., Determination of the differential time corrections for GPS time equipment located at the OP, CNM, NIST, USNO and NRC, *Rapport BIPM*-2008/04, 21 pp

27. Lewandowski W., Tisserand L., Determination of the differential time corrections for GPS time equipment located at the OP, PTB, NPL and VSL, *Rapport BIPM*-2008/01, 19 pp

28. Petit G., Jiang Z., GPS All in view time transfer for TAI computation, *Metrologia*, 45, n°1, 35-45, 2008**.**

29. Vitushkin L., Orlov O., Nalivaev V., Test measurements of free-fall acceleration using the FG5-108 gravimeter with a compact diode-pumped solid-state Nd:YVO_4/KTP/I_2 laser at a wavelength of 532 nm, *Proc. Int. Symposium Terrestrial Gravimetry: Static and Mobile Measurements TGSMM-2007,* State Research Centre of Russia Electropribor, St Petersburg, 2008, 143-146

30. Vitushkin L., Wolf P., Vitushkin A., A proposal for the measurement of the gravitational constant using the attraction between two freely moving discs, *Proc. Int. Symposium Terrestrial Gravimetry: Static and Mobile Measurements TGSMM-2007,* State Research Centre of Russia Electropribor, St Petersburg, 2008, 259-263

31. Vitushkin L., Measurement standards in gravimetry, *Proc. Int. Symposium Terrestrial Gravimetry: Static and Mobile Measurements TGSMM-2007,* State Research Centre of Russia Electropribor, St Petersburg, 2008, 98-105

32. Petit G., Jiang Z., Precise point positioning for TAI computation, *IJNO* Article ID 562878, doi:10.1155/2008/562878, 2008.

33. Petit G., Klioner S., Does relativistic time dilation contribute to the divergence of Universal Time and Ephemeris Time?, *AJ* **136**, 1909-1912, 2008.

34. Jiang Z., Towards a TWSTFT network time transfer, *Metrologia,* 2008, **45(**6), S6-S11

35. G. Panfilo and P. Tavella. Atomic clock prediction based on stochastic differential equations. *Metrologia*, 2008, **45**(6), 108-116.

36. E. Bibbona, G. Panfilo and P. Tavella. The Ornstein-Uhlenbeck process as a model of a low-pass filtered white noise. *Metrologia,* 2008, 45(6), 117-126.

37. Jiang Z., Petit G., Combination of TWSTFT and GNSS for Accurate UTC Time Transfer, Metrologia 2009, **46**(3), 305-314

38. Petit G., Arias F., Use of IGS products in TAI applications, *J. Geodesy*, 2008, 83: 327-334, 2009.

39. Souchay J., Andrei A., Barache C., Bouquillon S., Suchet D., Baudin M., Gontier A.-M, Lambert S., Le Poncin Lafitte C., Taris F., Arias E.F., The construction of the Large Quasar Astrometric Catalogue, *A&A*, 2009, 494, 799-815.

40. Arias E.F., Bauch A.,Metrology of Time and Frequency, in *Handbook of Metrology*, Wyley-VCH, 2008, in press.

41. Niessner A., Mache W., Blanzano B., Koudelka O., Becker J., Piester D., Jiang Z., Arias E.F., Calibration of the BEV GPS receiver by using TWSTFT, *Proceedings of the PTTI Annual Meeting 2008*.

42. Petit, G., Relativistic aspects in astronomical standards and the IERS Conventions, Proc. Journées SRST 2008, in press.

43. E. F. Arias and G. Panfilo. Algorithms for TAI. Submitted to the *special issue of UFFC,* 2009.

44. Petit G., The TAIPPP pilot experiment, *Proc EFTF-IFCS 2009*, in press.

45. Petit G, Bernier L-G., Uhrich P., Time and frequency transfer by geodetic GPS: comparison of receivers and computation techniques, *Proc EFTF-IFCS 2009*, in press.

46. G. Panfilo and E.F. Arias. Studies and possible improvements on EAL algorithm. *Proc EFTF-IFCS 2009*, in press (also submitted to the special issue of UFFC).