Report to the 18th Session of the Consultative Committee for Time and Frequency from the National Measurement Institute, Australia

June 2009

1. UTC(AUS) and standard ensemble

UTC(AUS) is realised using a single Cs beam standard from a small ensemble at NMIA. The realisation was switched from a standard-performance 5071A (clock number 360340) to a high-performance unit (352269) on MJD 54868. NMIA's present policy is to maintain UTC(AUS) within one microsecond of UTC, by applying occasional rate corrections to the clock itself.

The ensemble also includes two hydrogen masers developed at NMIA in the 1970s (405401 and 405402). Modifications have recently been made to the RF dissociation region in the hydrogen source for both masers, which we hope will reduce maintenance requirements and extend the period of continuous operation.

2. Optical frequency comb

NMIA has operated a commercial fibre-based optical frequency comb since 2006. The comb is used for optical frequency measurements of reference laser sources, in particular to establish a traceability chain for dimensional measurements in the Length project.

A validation of the measurement capability of the comb was completed in 2007 in collaboration with NMIJ. A separate fibre comb developed at NMIJ was shipped to NMIA, enabling a direct comparison between the two combs locked to a common reference. Measured frequencies were consistent at the level of 8×10^{-17}. Frequency differences between the two combs showed an Allan deviation of 4×10^{-13} at 1 s and 3×10^{-16} at 10 000 s, consistent with results reported by other institutes. In practice, frequency measurements are therefore limited by the accuracy and stability of the local realisation of UTC.

NMIA is also an active participant in the international Avogadro collaboration, contributing precise measurements of the mass and volume of a near-perfect silicon sphere in preparation for a potential redefinition of the kilogram. The optical system for the volume interferometer has been upgraded over the past year, with the reference laser now directly locked to the frequency comb. Similar work is in progress for interferometric dimensional measurements in other metrology areas, including for nanometrology and the NMIA calculable capacitor.

3. Time transfer collaboration with the University of Western Australia

The Frequency Standards and Metrology Group at the University of Western Australia (UWA) is well-known for its development of ultra-stable cryogenic oscillators. TWSTFT and GPS carrier-phase time transfer links between clock ensembles at UWA and NMIA were commissioned in 2007. The comparison between the two methods provides important verification of performance. In particular, a number of tests have been undertaken to test the sensitivity of TWSTFT time transfer to variation of parameters such as the transmit power or frequency; much of this data is currently being evaluated.

Comparisons began in the second half of 2007, with GPS data continually recorded and TWSTFT sessions typically occurring twice weekly. Results are generally similar to those reported by other institutes; for example, the TDEV of TWSTFT data is approximately 200 ps at 1 s. Both GIPSY and the Bernese software have been used for GPSCP data processing, showing differences typically up to several hundred picoseconds. The difference between TWSTFT and GPSCP results shows evidence for a residual drift of order 25 ps/day. This is still under investigation, but appears consistent with the specified stability of the SATRE time-transfer modems used.

The UWA-NMIA links have been established in preparation for participation in the Atomic Clock Ensemble in Space (ACES) mission. UWA and NMIA currently form the only ACES User Group in the southern hemisphere.

4. $^{171}Yb^{+}$ trapped-ion frequency standard

Work on the NMIA 12.6 GHz $^{171}Yb^{+}$ trapped-ion microwave frequency standard continued slowly, as permitted by the other responsibilities of the Time and Frequency group. A new design for magnetic shielding and control coils was prepared to minimise magnetic field gradients throughout the trap volume, with a corresponding uncertainty is 1×10^{-15} inside the CrCu non-magnetic vacuum chamber. A number of other uncertainty contributions were evaluated at or below this level, including shifts due to imperfections of the applied microwave field, pressure shifts from residual background gases, the blackbody radiation, and the AC second-order Zeeman shift due to the RF trapping field.

In 2008 the decision was taken to suspend further work on this experiment. In collaboration with the University of Western Australia (UWA) in Perth, we are currently exploring opportunities to continue development of these standards, particularly to enable Australian participation in the flight phase of the ACES mission.

5. GPS time transfer activities

NMIA has been developing GPS time-transfer systems for many years, based on OEM receivers and CGGTTS processing software running on a PC. These systems enable a wide range of applications, not only to support Australian calibration laboratories through traditional time and frequency transfer but also through the addition of custom hardware for extra functionality. In this way, GPS time-transfer becomes a tool to project the accuracy and reliability of national standards into activities that are widely spread both topically and geographically, and this capability continues to become more important as Australian clients recognise the value of accurate and reliable time.

To give one example, these systems are used to establish traceability of NTP servers at locations around Australia, both for NMIA's own reference network of NTP servers but also for clients requiring traceability for NTP on their own LAN. Key clients for these systems include Australia's largest telecommunications company, a state railway company, and a Federal Government service providing notarisation and timestamping. To take a second example, as reported to the last CCTF NMIA has also developed 'speaking clock' systems integrated with GPS transfer, used to provide Australia's principal public telephone time system since 2006. Because the timing is done in hardware, and this timing is linked to UTC(AUS) by GPS transfer, we are able to issue remote calibration reports on the output of the speaking clock systems. This in turn supports a range of lower-level calibration activity by other laboratories, for example calibration of stopwatches in medical testing facilities.

Continuing development of these systems has focussed on reducing the size and cost of these systems to extend the range of applications. The current version adopts a low-cost Trimble Resolution T receiver and a compact rack-mounted form factor which still allows for an integrated rubidium frequency standard.

A transportable system developed at NMIA in 2002 with support from TL has also been used to characterize receiver internal delays for APMP economies around the Asia-Pacific region for a number of years, and this campaign will continue into the future. Current work in this area is aimed at formalising the protocol for the comparisons, to standardise measurements and to assist in formal recognition of the results alongside the reference campaigns overseen by the BIPM.

NMIA has operated the SYDN node of the IGS network since 2004, using a Javad receiver and a custom fibre link to the antenna on a geodetic monument. This station was recently upgraded to report GLONASS observations and will shortly participate in the TAIPPP pilot project.

6. NTP

NMIA has maintained a network of NTP servers throughout Australia for many years. Access is controlled owing to past abuse, as previously reported to CCTF.

Although it is possible in principle to use NTP to establish a traceable comparison between the client and the reference NTP server, difficulties arise in practice. The key measurement is of the round-trip delay from client to server and back to client, from which the uncertainty of the synchronization can be obtained. However, only the client has sufficient information to reconstruct the entire timing sequence; to support traceability, the client must therefore record and archive full NTP system logs in a way such that their integrity can be easily defended, which can require significant effort.

Because this effort is too great for many clients, NMIA has been developing simple extensions to the NTP protocol. These allow the client to relay additional information to the server, so that the record keeping and analysis can now be done on the server side. This allows the NMIA to effect remote calibration of the client PC clock, with sufficient information for formal reporting including uncertainties. Because the records are being maintained by a third-party (NMIA), the integrity of the records is also more easily defended. This service is under development to support clients requiring legal or metrological traceability for computer time at low accuracy, for example for notarisation of documents, timestamping of transactions, and speed and road safety applications using ‘point to point’ enforcement.

7. Regional activities

NMIA continues to actively support the Asia-Pacific Metrology Programme (APMP), including co-ordinating comparisons, participating in peer reviews, review of submitted CMCs and related activities. NMIA organised and hosted the 2007 APMP meetings in Sydney, including meetings of the APMP Technical Committees and a joint workshop between TCTF (Time and Frequency) and TCL (Length) on optical frequency metrology.

8. Structure of the Time and Frequency Group

The Physical Metrology Branch of NMIA is led by Dr Peter Fisk. The Time and Frequency group is led by Dr Bruce Warrington, with scientists Dr Michael Wouters and Dr Malcolm Gray and project officers Mr Anura Gajaweera, Mr Stephen Quigg and Mr Malcolm Lawn (shared with nanometrology).