Status Report: Time and Frequency Activities at NML Australia

Peter Fisk[1], Bruce Warrington, Michael Wouters, Malcolm Lawn,
John Thorn and Stephen Quigg

National Measurement Laboratory, CSIRO Australia
PO Box 218, Lindfield NSW 2070, Sydney, Australia

Abstract

The Australian National Measurement Act requires CSIRO to maintain, or cause to be maintained, Australia's standards for measurement of physical quantities. The CSIRO National Measurement Laboratory (NML) discharges CSIRO's responsibilities under the Act. This paper presents an update on some of the activities of the Time and Frequency Section of NML since the most recent ATF meeting at CRL in 2000.

1. Introduction

The Time and Frequency Section of NML (presently six staff) is responsible for maintaining Australia's national standards for time of day and for frequency, disseminating time and frequency information nationally and internationally by a variety of methods, and carrying out research in the field of time and frequency standards**.** These activities have been described in detail previously [1]; this paper will present a short summary, together with recent developments since the time of the last ATF meeting at CRL in 2000.

2. Standards for Time and Frequency

2.1. Australia's national standards

NML presently maintains an ensemble of four commercial cesium beam standards and two hydrogen masers on site in Lindfield, Sydney. The 1 pulse-per-second (pps) output of one of the cesium standards (an HP5071A) is designated as UTC(AUS), the official Australian realization of Coordinated Universal Time (UTC). The rate of this cesium standard is adjusted from time to time in order to maintain UTC(AUS) within 1μs of UTC. A 10 MHz output from the same standard is designated as the National Frequency Standard. Traceability of Australian time and frequency to the Système Internationale (SI or metric) second is maintained by continuous international time transfer. The SI second is realized at NML with an uncertainty smaller than 2 parts in 10^{13}, and UTC with an accuracy of better than 200 ns.

2.2. Australia's contribution to UTC

Australia contributes to UTC by NML reporting GPS time receiver and clock data to BIPM. UTC(AUS) is linked via GPS common-view (GPSCV) time transfer to the international network of clocks from which UTC is derived. Clock data (values of UTC(AUS) – clock) are currently submitted from clocks located at NML laboratories in Sydney and Melbourne, at the Tidbinbilla deep space tracking station near Canberra and at the Telstra laboratories in Melbourne. Australia's local atomic time scale TA(AUS) is also reported to BIPM. Reporting of clock data to BIPM is essential for maintaining international traceability of Australian time and

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[1] peter.fisk@csiro.au

frequency. NML collects and transmits this data to BIPM following BIPM's standard protocols and data formats. The history of UTC(AUS) and TA(AUS) since December 2000 is shown in Figure 1.

3. Time and Frequency Dissemination in Australia

NML monitor a variety of signals at the Sydney site and around Australia to support dissemination of UTC(AUS) by comparison of remote clocks with the national standard [1]. These signals include GPS (with monitoring of integrity of GPS signals as received at several locations), the synchronization pulse in television broadcasts and the high-frequency broadcast station Radio VNG near Sydney. Clients from around Australia submit devices for calibration at NML, providing legal traceability to the national standards by direct comparison. NML also maintain Network Time Protocol servers for distributing time through national computer networks, and have recently commissioned a direct telephone dial-up service.

3.1. Network Time Protocol (NTP)

NTP continues to increase in importance as a means of disseminating time information. Accurate computer timing is essential for a wide range of purposes, including banking, electronic commerce and computer-based document exchange.

The size of Australia presents a challenge for time dissemination through computer networks, since the accuracy of synchronization achievable is reduced as network distances increase. NML presently maintains Stratum 1 servers in Adelaide, Sydney, Melbourne and Perth, with further servers planned for other state capital cities to provide improved accuracy and redundancy for clients across the country. Servers outside Sydney use a rubidium frequency standard (or a cesium standard in the case of Melbourne) as the local reference, which is continuously compared to UTC(AUS) by CVGPS time-transfer. Software developed at NML continuously monitors the performance of the NTP servers, providing an essential record for legally traceable time dissemination.

Figure 2 shows traffic on three of these NTP servers, and indicates a sharp increase in the number of users over time. Since many of the computers requesting time information from a server will in turn distribute this information to their local networks, it is likely that the dissemination of UTC(AUS) by this means may be much wider than the data indicate.

4. Research Activities

Research undertaken at NML includes the development of microwave frequency standards based on electromagnetically-trapped $^{171}Yb^{+}$ ions [2], development of reliable and remotely operable single- and dual-frequency GPS time-transfer systems [3], and evaluation of two-way satellite time transfer (TWSTT) links, summarized in Table 1. The primary purpose of the time-transfer experiments is to compare the performance of GPS and TWSTT over very long and trans-equatorial baselines and over a period of several years.

4.1. Two Way Satellite Time Transfer (TWSTT): Ku band

Ku-band time-transfer sessions have operated twice weekly between CRL in Tokyo and NML in Sydney without major interruption since the last ATF meeting in 2000 [4, 5]. This link operated initially using Intelsat 702 at 176° E, changing to PanAmSat PAS-8 at 166° E in May of this year. Jacques Azoubib at BIPM has recently completed a calibration of the PAS-8 link, and we understand that the data should shortly be used in the computation of TAI.

Successful time transfer sessions were also conducted with the US Naval Observatory earth station at Vandenburg Air Force Base in California between August 2001 and March 2002. Continuous operation of this service would provide an alternative link from the Asia-Pacific region to the Americas and thus to Europe, since the Vandenburg station is separately linked to the main USNO site in Washington DC.

4.2. Two Way Satellite Time Transfer (TWSTT): C band

Since the last ATF meeting in 2000, C-band time-transfer sessions between ground stations at NIST in Fort Collins, TL in Taoyuan and NML in Sydney have been conducted at various times using two different satellites. A link between NIST and NML was operated between July and November 2001 using Intelsat 701 at 180° E, until the satellite capacity ceased to be available. A link between TL and NML was successfully established using the same satellite in December 2001 only to encounter the same difficulty. Since September 2002, all three stations have been intercompared using New Skies 513 at 183° E [6].

There are two principal difficulties with these C-band links. The first is that the elevation of the satellite is very low as seen from NIST in Fort Collins (about 7° for NSS 513, or even lower for IS 701). The second is that NSS 513 is in an inclined orbit, and variations in apparent position can cause significant variation in received signal amplitudes as none of the ground stations is capable of automatic tracking. Data processing from the recent three-way comparison is currently in progress at the time of writing, and the evaluation of the performance of these links for high-precision time transfer is continuing.

5. Conclusion

On a national scale, NML continues to face increasing client demand for accurate, legally traceable time and frequency information realised at the client's premises. This continues to drive the development of remotely operable, low cost software-based solutions such as NML's GPSCV timing systems and NTP servers. On a wider scale, the development of high-accuracy and high-stability frequency standards in laboratories around the Asia-Pacific region will test the ability to compare these standards across large distances, and continued research into methods of time transfer is an important challenge for this region.

References

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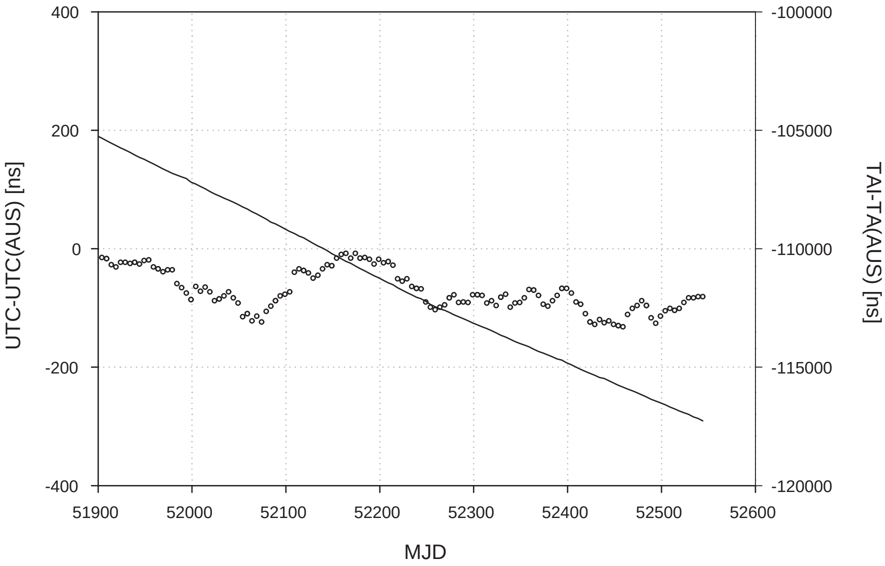
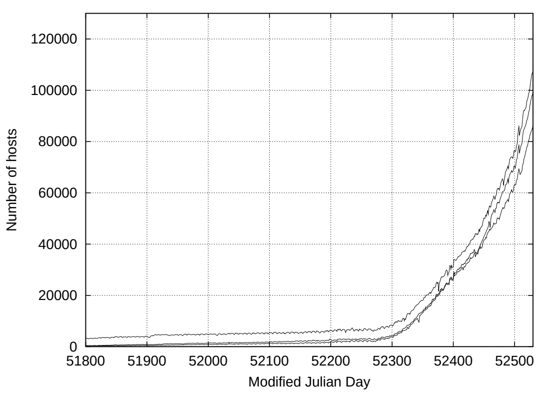


Figure 1: History of UTC(AUS) (points, left scale) and TA(AUS) (line, right scale) since December 2000.



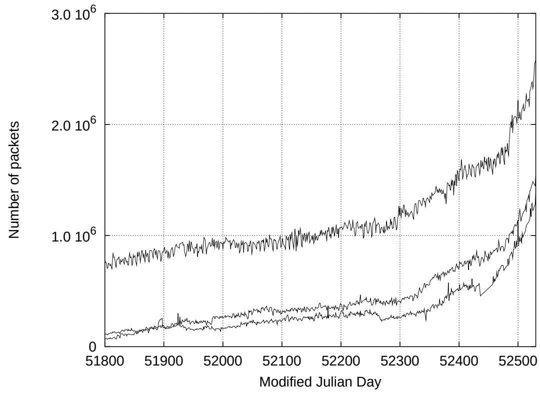


Figure 2: Total number of hosts accessing NTP services (left) and total number of NTP requests processed (right) over a 24-hour period. The upper, middle and lower curves are for servers in Sydney, Melbourne and Perth respectively.

Table 1: Parameters of two-way satellite time transfer links operating at NML.

	Ku band	**C band**
Earth stations:	NML, Sydney, Australia CRL, Tokyo, Japan USNO, Vandenburg AFB, USA	NML, Sydney, Australia TL, Taoyuan, Taiwan ROC NIST, Fort Collins, USA
Satellite:	Intelsat 702, 176° E; PanAmSat PAS-8, 166° E	Intelsat 701, 180° E; New Skies NSS 513, 183° E
Tx power:	4 W	10 W
Antenna diameter:	2.2 m	4.6 m
Modem:	ATLANTIS	MITREX