TIME AND FREQUENCY ACTIVITIES AT THE CSIR — NATIONAL METROLOGY LABORATORY

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Abstract

The Time and Frequency Laboratory of the CSIR-National Metrology Laboratory (CSIR-NML) is responsible for the maintenance and development of the national standards in time and frequency. Specific responsibilities include time and frequency, phase angle, fast electrical-pulse characterization, and time-interval measurements. The fiber-optics laboratory also resides within the Time and Frequency Laboratory. This paper will discuss the various activities within the Laboratory.

INTRODUCTION

The CSIR is empowered by the Measuring Units and National Measuring Standards Act, 1973 (Act 76 of 1973), as amended, to keep and maintain all national measuring standards for South Africa. It performs this duty through the CSIR – National Metrology Laboratory (CSIR-NML).

The Time and Frequency Laboratory of the CSIR-NML is responsible for the maintenance and development of the standards in time and frequency. Specifically, the laboratory is responsible for the following standards: time, frequency, phase angle, pulse rise-time and pulse characterization, and time interval. Fiber-optic measurements also reside under the laboratory.

The national measuring standard for time in South Africa consists of two commercial cesium beam atomic clocks. Time transfer is performed using single and multi-channel Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS) receivers The CSIR-NML is the only contributor in Africa of time transfer data to the Bureau International des Poids et Mesures (BIPM).

In addition to its standards activities the Time and Frequency Laboratory also offers time services in the form of a dial-in Telephone Time Service (TTS), as well as an Internet time service. These services are provided free to any user in Southern Africa.

Recent developments at the CSIR-NML include the development and deployment of multi-channel GPS receivers, the deployment of a multi-channel dual frequency GPS / GLONASS receiver and the re-development of the TTS.

LABORATORY LAYOUT

The Time and Frequency Laboratory consists of four rooms on the top floor of one of the buildings of the Pretoria campus of the CSIR. These four rooms house the clock room, a calibration room, a computer room and a fiber-optics laboratory respectively. The rooms are all air-conditioned. The temperature in all rooms are kept at (23 ± 2)°C and the humidity at (50 ± 15)%RH.

The calibration room houses the measurement standard for phase angle, a high bandwidth oscilloscope, a fast electrical pulse generator, and several general-purpose instruments. The clock room houses the clocks, the satellite receivers, a TV receiver, and monitoring equipment. The control room houses the time services, monitoring equipment, and a **Web** server. The fiber optic room houses the fiber optic measurement standards and related equipment. A small section of this room is designated as a development laboratory.

The satellite and television antennas are housed on the roof of the building. The lift tower provides excellent visibility with a mask of less then 5° in all directions. Several steel towers are situated elsewhere on the roof to give visibility to a number of other antennas. Access to the antennas is gained by access holes through the roof of the clock room and control room respectively.

The main satellite receivers reside in the clock room. Several experiments with GPS receivers are ongoing at present and most of these are performed in the control room.

TIME STANDARDS

The National Measurement Standard for Time in South Africa is a commercial cesium-beam atomic clock. This clock is maintained in continuous operation in the clock room of the Time and Frequency Laboratory.

CLOCKS

At present the clock room contains two commercial cesium clocks. One is designated as the master clock, and it is used as the primary reference clock for South Africa. The time and frequency accuracy of the master clock is disseminated to industry through time services and the issue of a monthly Time and Frequency Bulletin [1]. The status of the clocks is monitored on an ongoing basis, and the time transfer values logged to computer. Performance graphs of the clocks are drawn on a weekly and monthly basis, and paper copies of these graphs are archived.

SATELLITE RECEIVERS

The clock room also contains the satellite receivers used for international traceability. At present each clock is monitored by two GPS receivers, an Allan Osborne & Associates (AOA) receiver (either TTR5 or TTR5A) and a locally developed Motorola UT+ based receiver. In addition to these receivers, a dual system GPS (single frequency C/A code) / GLONASS (dual frequency C/A and P code) receiver (3S Navigation R100/30T) is used to monitor the master clock.

DISTRIBUTION EQUIPMENT

Distribution amplifiers are used to distribute the standard frequencies through the Time and Frequency rooms, and to other laboratories in the building requiring traceable signals. The satellite receivers all receive either 5 or 10 MHz signals, and a one pulse per second (1PPS) from the relevant clock in the clock room.

The calibration room, control room, and fiber-optic room receive 10 MHz signals, mainly for use as the external frequency reference for counters and signal generators. A 1 MHz signal is distributed to the control room, where it is used in the generation of lower frequency signals for the Telephone Time Service. 1 MHz and 5 MHz signals are distributed to the calibration laboratory where they are used as required.

A pulse distribution system for the 1PPS signal from the master clock distributes pulses to the calibration and the control room.

The Radio Frequency laboratory and the DC / Low frequency laboratory situated in the same building, each receives a 10 MHz feed, for use as an external clock reference.

OTHER EQUIPMENT

In addition to monitoring the transmissions from GPS and GLONASS, the vertical synchronization pulse from local television broadcasts is monitored. These values are measured every hour, at designated times, and then published (for office hours) in the monthly Time and Frequency bulletin. A project for making these values available in real time on the Internet is currently underway. Local accredited laboratories make use of these values to perform time transfer measurements; using CSIR-NML developed Auto Television Time Transfer Control Units (Auto-TTCUs).

TIME SERVICES

At present the Time and Frequency laboratory has two time services available to users in Southern Africa. These are the Telephone Time Service (TTS), a telephone-based service that can synchronize a wide range of instruments via a modem and computer, and the Internet time service, which provides synchronization via the Internet.

TELEPHONE TIME SERVICE

The TTS has been available to users in Southern Africa since the early 1990's. The service was started mainly as a replacement for the ZUO transmitter that was decommissioned in the late 1980's. At the time the laboratory was faced with financial pressures, and the service was offered on a pay-per-use basis. The structure of payment for this service was revised numerous times to attract new users, but the user basis dwindled nonetheless.

The service was upgraded in 1998 to be fully Y2K-compliant At the time it was also decided to make the service available free of charge, and to comply fully with the specifications of the International Telecommunication Union (ITU) [2], which states that any time service should transmit Coordinated Universal Time (UTC). Up to that time the service was transmitting South African Standard Time. The protocol adopted is a variation of the National Institute of Standards and Technology (NIST) Automated Computer Time Service (ACTS) protocol, and is used with permission. The number of users for this service is increasing rapidly. Major users are accredited laboratories, radio stations, the telecommunication authority, sporting clubs, and users that do not want to connect to the Internet due to security concerns.

INTERNET TIME SERVICE

In 1996 it was decided to offer an Internet-based time service. At present the laboratory provides two Internet Time servers, serving the Network Time Protocol (NTP) and the Time protocol. The number of users for this service is expanding on a daily basis, with most of the local Internet Service Providers (ISPs) making use of the servers.

The main server (tick.nml.csir.co.za) is running at Stratum 1, connected to the 1PPS output of the master clock. The other server (tock.nml.csir.co.za) is running at Stratum 2, using the Stratum 1 server as its primary synchronization source.

TIME AND FREQUENCY BULLETIN

The monthly Time and Frequency bulletin has been available since December 1994. The bulletin contains information on the measurements performed in the laboratory, notes on GPS performance and other information. It is available free of charge to anyone that wishes to receive a copy. All copies from January 1996 are also available on the Internet [3].

The measured values of CSIR - GPS as the time interval difference between the 1PPS of the master clock and the 1PPS of GPS as tracked by the 3S Navigation R100/30T receiver is reported. An All-in-View Common-View methodology is followed. All measurements above a mask angle of 15° are used. The daily value is the result of a linear fit to approximately 500 data points, reported to 0 h UTC each day.

CSIR - GLONASS measurements are reported as the least-squares linear interpolation of all measured values in a month, reported to 0 h UTC each day. The number of GLONASS observations is far less than those for GPS, and the calculated random uncertainty of the measured values is larger.

The computed values of UTC – UTC (CSIR) are reported for the previous month. The corrections for UTC (CSIR) are obtained from the BIPM Bulletin "T" [4]. The results are reported to 0 h UTC each day.

The bulletin also contains notes on GPS performance extracted from the United States Naval Observatory (USNO) series 4 bulletins [5]. A number of users in South Africa make use of stand-alone GPS equipment, and this information is used to ensure that no unusable satellites were used for measurements.

Television synchronization pulse measurements are reported for three local transmissions. The offset between the vertical synchronization pulse and the master clock 1PPS is measured and reported on the hour, every hour during the day.

In addition to these measurements, the calculated drift rate of the master clock is reported, as well as information on the TTS, the GPS common-view tracking schedule, leap second announcements, and the relation between the International Atomic Time (TAI), UTC, and GPS time scales.

OTHER RESPONSIBILITIES

In addition to the responsibilities in time and frequency, the laboratory is also responsible for the national measurement standards for phase angle and for fast electrical pulse characterization, time interval, and fiber-optic measurements.

PHASE ANGLE

The national measurement standard for phase angle is a Clarke-Hess model 5500 phase standard, with a set of model 5002 phase bridges. The phase bridges are calibrated periodically and used to verify the phase standard annually. The laboratory also has a capability for phase measurement, utilizing commercial phase angle meters.

FAST ELECTRICAL PULSE CHARACTERIZATION

Fast electrical pulses are characterized using a high bandwidth oscilloscope, verified using a fast electrical pulse generator. As with phase angle, commercial equipment is being used.

TIME INTERVAL MEASUREMENT

The time-interval measurement and generation capability is based on commercially available equipment. For measurement of single shot events the laboratory can generate and measure signals of down to some tens of ps.

FIBER OPTICS

The fiber-optics laboratory was integrated with the Time and Frequency Laboratory in 1999, due to the similarity between measurements performed in the two laboratories. The services offered by the fiber-optics laboratory include calibration of fiber optic power meters, fiber-optic attenuators, Optical Time Domain Reflectometers (OTDR), wavelength meters, and optical delay lines.

FUTURE WORK

At present the focus in the Time and Frequency Laboratory is the reduction of time transfer uncertainties. To further reduce these uncertainties a geodetic quality GPS receiver will be acquired, and a project started to perform carrier-phase measurements using this receiver.

Further development of the Motorola-based GPS receivers are underway. The new M12 Oncore receiver from Motorola is being evaluated as a replacement for the current UT+ Oncore receivers. There are some drawbacks in using the UT+, which can possibly be overcome using the M12

DISCLAIMER

Certain trade names and company products are mentioned in text of this paper. In no case does such mention imply recommendation or endorsement by the CSIR - National Metrology Laboratory, or the

CSIR, nor does it imply that the products are necessarily the best available for the purpose.

REFERENCES

[1] Standard Time and Frequency Bulletin, CSIR - National Metrology Laboratory, Pretoria, South Africa, ISSN 1024-1612.

[2] "Use of Time Scales in the Field of Standard-Frequency and Time Services," ITU-R Recommendation 485-2, 1990.

[3] "Standard Time and Frequency Service Bulletin," http://www.nml.csir.co.za/services/timepub/tfpubl.html

[4] BIPM Bulletin "T," ftp://62.161.69.5/pub/tai/publication/cirt.xxx

[5] USNO Series 4 bulletins, ftp://tycho.usno.navy.mil/ /pub/series/series4.xxxx

Questions and Answers

FRANCOIS MEYER (Observatoire de Besançon, France): My question is about your NTP instrument called tick. What kind of hardware is used?

LOUIS MARAIS: We are running a Pentium 133 using a PDS 2.16 with general modifications by John Hay.

MEYER: Okay. And the 1PPS of an atomic clock is used to give the synchronization?

MARAIS: That's right.

MEYER: And what about possible 1-second or multiple of 1-second jumps in the – ?

MARAIS: We use GPS-based time to determine the time to ...(?) of the masers.

MEYER: And this is integrated in the NTP software?

MARAIS: No, it's not. We use an off-laboratory source for that. So we use a server on the CSIR campus that's not in our laboratory.

WLODZIMIERZ LEWANDOWSKI (BIPM, France): Do you have the TSA antenna temperature-stabilized?

MARAIS: Yes, we do.

LEWANDOWSKI: And this is connected on your 3S Navigation receiver right now?

MARAIS: Yes.

JACQUES AZOUBIB (BIPM, France): I am wondering why you aren't sending the BIPM your clock data? You have two clocks –

MARAIS: Yes, the other clock is three times worse than the HP. So I don't think it will add any value.