TIME AND FREQUENCY ACTIVITIES AT ROA

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Abstract

The Real Instituto y Observatorio de la Armada (ROA) was founded in 1758 to increase the knowledge of the Spanish Navy's midshipmen in astronomy matters. Since then, the Observatory has been the astronomical center of the Spanish Navy and it is the oldest Spanish observatory. Jorge Juan, the Spanish Navy Officer, who founded the Observatory, participated in the expedition to Perú to measure the length of one degree of arc of a meridian circle organized by the Royal Académie des Sciences de Paris. Its activities have been historically related to astrometry, ephemerides, geophysics, and the time and frequency fields.

The Astronomy Department was charged with maintaining the astronomical and civil time scales. It was also responsible for synchronizing the master clocks of the Spanish warships before they left port. In 1972, an independent department was founded to maintain the time scales using physical standards. A few years later this Time Department (Sección de Hora) received its first atomic clocks. Sección de Hora has been contributing to BIPM for TAI since these former days.

In this paper we will discuss the activities of Sección de Hora in the time and frequency fields, and as depository of the Spanish time and frequency standards. These activities include time scale algorithm studies and time transfer using single-channel and multichannel GPS receivers, geodetic GPS receivers, and TWSTT.

ROA is an active and permanent participant in international cooperation in time and frequency activities. In this paper, an overview of the activities on time and frequency fields at ROA will be given, as well as some of the investigations in fields of our interest.

INTRODUCTION

This paper will describe the current and recent activities of the Time and Frequency Laboratory of the Real Instituto y Observatorio de la Armada (ROA).

We will detail the historical background of the Observatory, beginning with some details about the reasons of its foundation. We will give some example of the activities on astronomy related to the determination of longitude of certain geographical points, and will continue with the present and planned activities.

HISTORICAL BACKGROUND

When the Académie des Sciences de Paris asked Philipus V, the King of Spain, for permission to go to Perú to measure the length of one arc of the meridian, as a part of a campaign to investigate the shape of the Earth, one condition was enforced: that two Spaniard scientists be included in the expedition. Jorge Juan and Antonio de Ulloa, two midshipmen of the Naval Academy of Cádiz, were designated by the Navy Minister to join the expedition and immediately appointed to the rank of Lieutenant.

Once they come back to Spain, they published the results of the campaign in 1748. Jorge Juan was sent to London to study the British's warship construction and in 1749 he proposed that the King found an observatory as an annex to the Naval Academy to "prevent the situation we experienced joining a scientific campaign without having the adequate level of scientific knowledge of the rest of the people," probably influenced by a visit to Greenwich Observatory.

Four observatories were founded: Cádiz (1758), Cartagena (1776), Ferrol (1776), and Madrid (1796), but only the observatories of Cádiz and Madrid (now called the National Astronomical Observatory) continued operating continuously.

Cádiz Observatory was established in the Homenade Tower of the Castle of Cádiz, where the Naval Academy had settled [1]. The equipment was bought by the founder: a quarter-circle mural telescope, a reflector telescope, a meridian circle, and an Ellicot pendulum clock. In 1792 the first issue of the Nautical Almanac and Ephemeris was published by execution of a Royal Order. It has been continuously published since then.

In 1799 the Observatory moved from Cádiz to San Fernando, its current location. The staff of the Observatory was composed of scientists, naval officers, that complemented their activities as teachers in the Naval Academy.

ROA has organized a lot of expeditions to Central and South America and to the Philippine Islands to make hydrographical studies of the coast of the colonial possessions of Spain. Most of the existing charts of this epoch were referred either to Cádiz or San Fernando Observatory's longitude. An example of that was the expedition to Baja California in 1758, to observe the transit of Venus across the solar disk.

Additional information on former ROA activities can be found in [2].

TIME SECTION

The Time Section was formerly included as a service of the Astronomical Section. In 1972 ROA received new physical time standards and a new separate section was created.

ROA is a member of the "Comité Consultatif pour la Définition de la Second" and contributed in the former work to precisely define the duration of the second by astronomical observations.

ROA has made a lot of effort to continue in the vanguard of the laboratories of time and frequency.

By a decree, since 1976 ROA is the depository of the time and frequency standards of Spain and is also the institute that generates, maintains, and disseminates the legal time scale of the Kingdom of Spain.

INSTRUMENTS AND SERVICES

CLOCKS

The main components of the equipment are the time and frequency standards. ROA has an ensemble of five cesium clocks: two HP 5071A high performance option and three HP 5061 high performance option. Two HP 5071As have been recently purchased and will be delivered at the beginning of the year 2000.

The time UTC(ROA) is traceable to UTC by means of the Circular T from the Time Section of BIPM. Figure 1 shows the evolution of UTC(ROA) compared with other national scales. As a part of this work, the correlation of the clocks is being studied and a method to determine such correlation has been evaluated and is presented at this meeting [3].

Lt. Galindo is working on his Ph.D. thesis, on the study of an algorithm for the calculation of the local atomic time scale. This work is being directed by Dr. P. Tavella of IEN.

TIME TRANSFER

To follow the GPS tracking schedule issued by the Time Section of BIPM, ROA is equipped with three GPS receivers: one TTR-5 AOA (#063) and two TTR-6 AOA (#253 and #419). Receiver #063 will be used as travelling standard in a EUROMET project to intercompare the GPS receivers used by European laboratories contributing to TAI.

The location of the Observatory, in the southwestern part of Europe, makes its GPS link have special differences compared with other laboratories in Central Europe. Some tracks are near 20 degrees of elevation, as shown in Figure 2.

Four years ago, ROA acquired one of the first geodetic GPS receivers applied to time transfer from Allen Osborne Associates: TTR-4P. The receiver had some problems while tracking, showing a lot of losses of phase tracking (cycle slips). The receiver was sent to the factory; the unit was fitted with a bypass of an internal oscillator and, when it was received, ROA joined the BIPM/IGS Pilot Project. In June 1999, an application to IGS Central Bureau was sent to join the network. Unfortunately, on 21 August 1999 the receiver did not cross over the GPS week rollover.

ROA is equipped with a TWSTT apparatus consisting of a 1.8 m, model 1184, Prodelin antenna, a 4W SSE Technologies model KSTAR transceiver, and a SATRE modem. The station has been approved by the HISPASAT Agency and tested in June 1998. Funding from the Spanish Ministerio de Educación y Ciencia (ESP99-1074-C02-02) will allow upgrading the station and completion of it by acquiring a satellite simulator and ancillary equipment. The antenna will be replaced in the next months with a 1194 model from Prodelin, Intelsat-approved. This will allow us to join the ongoing TWSTT inside Europe and Europe-USA.

Studies to do time transfer using a Motorola Oncore multichannel GPS receiver were started during this year. We are trying to use the same receiver we are using for the NTP server to track the satellites following the "common view" scheme.

TIME DISSEMINATION

TIME SIGNAL

Time signals are broadcasted from 1000 UTC to 1025 UTC at 15.002 kHz and from 1030 UTC to 1055 UTC at 4.998 kHz. The signal is coded to contain DUT1 corrections following the recommendation of ITU-R. The transmitter is an RF-130 model from Harris, having 1 kW transmitting power, and its frequency reference comes from a cesium standard. The timing signal is advanced at the origin to be within 1 millisecond from UTC(ROA) at the antenna.

A project to automate the transmission of the signal, including change of frequencies, audio modulation, and inclusion of DUT1 code, is being carried out.

TELEPHONE CODE

ROA disseminates time signals using the so-called European Telephone Code standard [4]. The telephone number to access this service is (+34)956 599 429. Time access is limited to 2 minutes, hanging up after this period of time. There is no limit to access the service, so international calls are accepted.

NTP

ROA is the responsible for the maintenance of the synchronization of the Spanish R & D network, RedIRIS [5].

Three NTP servers are working at ROA: ntp.roa.es, ntp1.roa.es, and roasf.roa.es. The last one is used to test the new versions of the software and hardware. ntp.roa.es has been running more than one year continuously, receiving more than 200 interrogations per day.

ROA has proposed an EUROMET project to evaluate the performances of a remote computer time scale, synchronized to NTP servers maintained by NMIs.

TIME STAMPING

In collaboration with Universidad Politécnica de Madrid, ROA has put into operation a time-stamping server, that certifies documents, giving them a time stamping accurate to 1 second to UTC.

ACCREDITATION SERVICE

ROA cooperates with the Spanish Accreditation Enterprise (ENAC), supporting time and frequency calibration activities and piloting frequency intercomparisons.

During 1997, an intercomparison of frequency, LC-ENAC-034 TF, was carried out in Spain. Nine laboratories participated in the intercomparison; seven of them were accredited and two were invited.

Masts were installed in the roof of each laboratory, and their coordinates were accurately calculated, after a survey using a travelling GPS geodetic receiver, to within few millimeters error with respect to ROA's TTR-6 master receiver antenna.

An HP5071A cesium clock was used as travelling standard. The clock was compared to UTC(ROA) by mean of a TTR-6 GPS receiver using the common-view technique. The fractional frequency deviation of the travelling standard referenced to UTC(ROA) during the trip is shown in Figure 3.

The results of the intercomparison was highly satisfactory, all the accredited laboratories having a normalized coefficient smaller than unity, as shown in Figure 4.

REFERENCES

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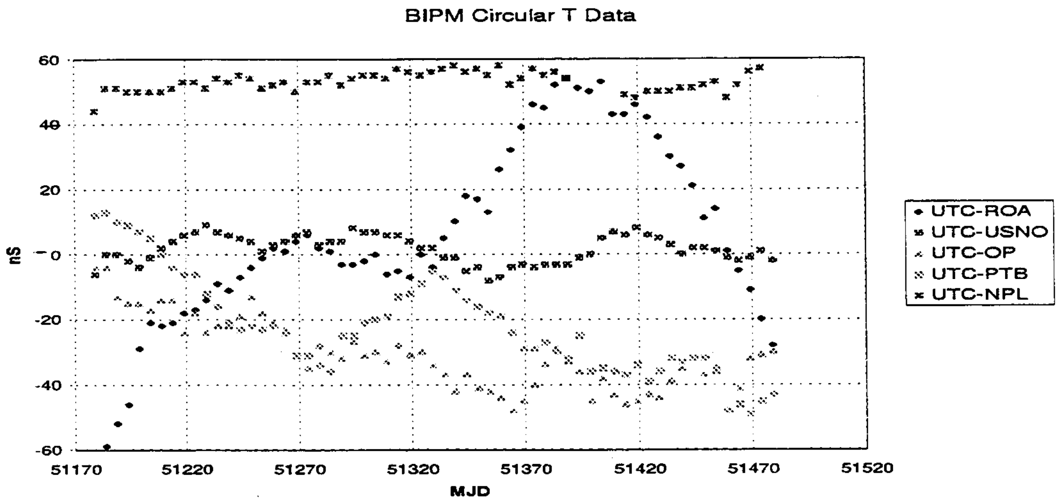

Figure 1: UTC(ROA) by means of Circular T

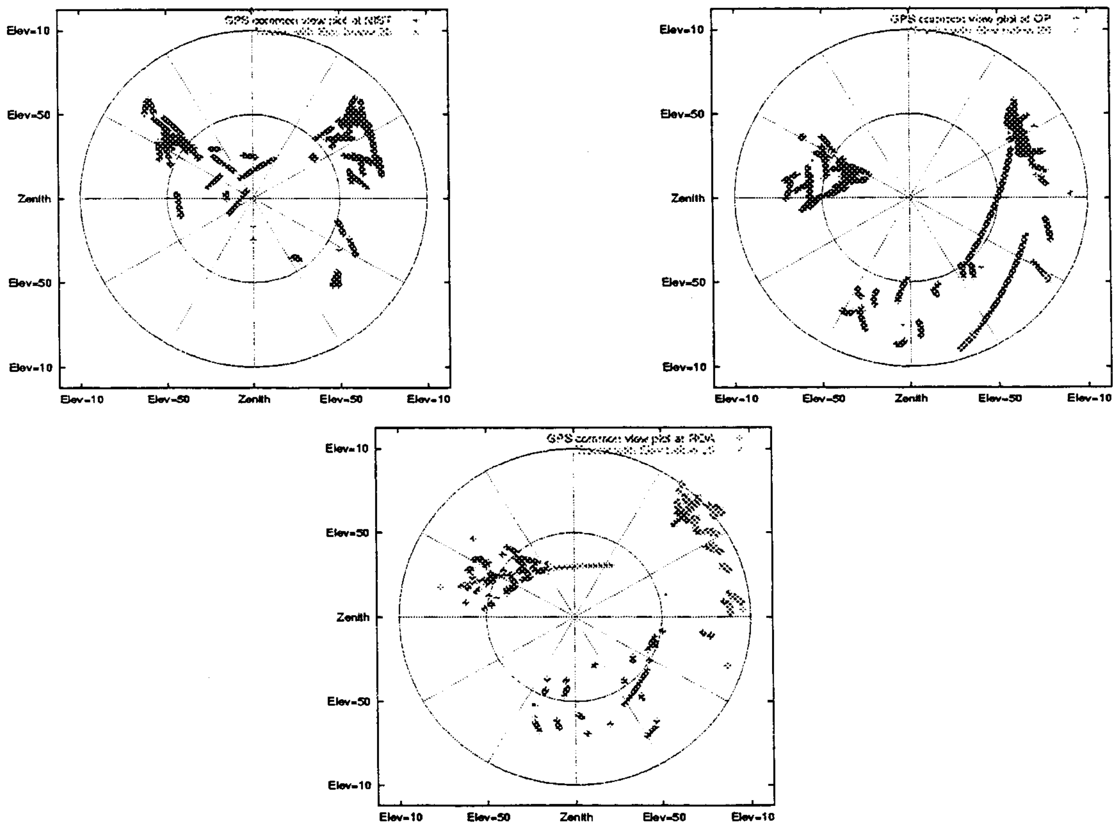

Figure 2: Polar plot of BIPM Schedule #30 at NIST, OP, and ROA

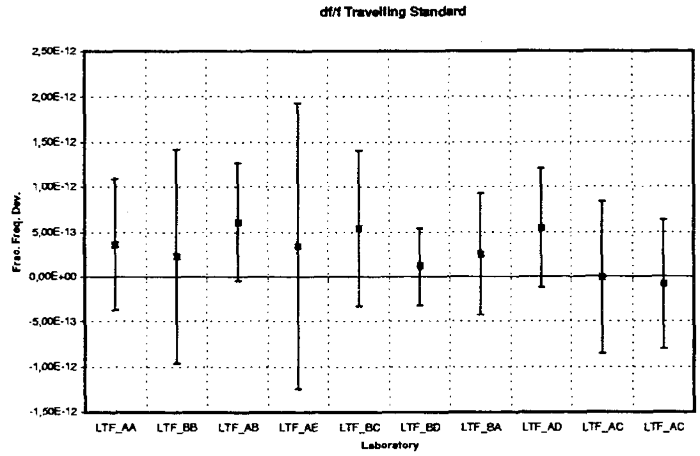

Figure 3: Fractional frequency deviation of the travelling clock by GPS CV

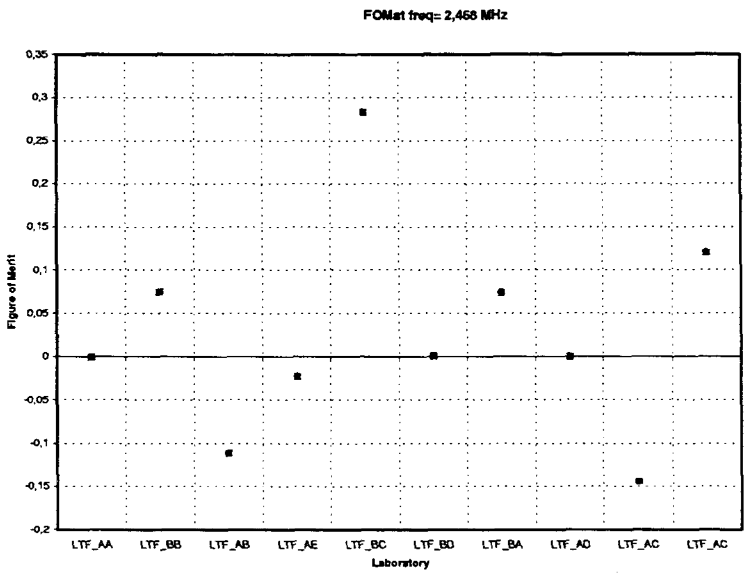

Figure 4: Figure of Merit of results of the intercomparison