PRECISE TIME FOR VERY LONG BASELINE INTERFEROMETRY AT SANTIAGO, CHILE AND RELATED PROBLEMS GERMANE TO THIS GEOGRAPHIC AREA

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ABSTRACT

A general description of the activities of the Time and Latitude Service of the National Astronomical Observatory at Cerro Calán, Santiago, is given.

Precise time is provided by Cerro Calán Time and Latitude Service for a radio-astronomy project, which using VLBI technique, has been carried out in collaboration with the University of Florida in order to determine accurate positions and sizes of Jupiter's radiosources. According to the frequency of the signal recorded at the observing sites, the required accuracy in time synchronization must be better than 10 microseconds.

Time synchronization is based on a cesium atomic clock of Cerro Calán Time Service, which is synchronized through a flying clock of NASA with UTC(USNO). It is shown in this paper that the synchronization can be kept at Santiago, better than the required accuracy, measuring the mean monthly frequency difference of the local standard with respect to USNO, by observing daily relative phase variations of VLF signal of station NBA. With the observed frequency differences, a daily estimated error in time is computed for Cerro Calán atomic clock. This computed error is in good agreement with the observed error obtained via flying clock after 15 months of operation.

The services for time dissemination through the country for scientific and public use, as well as the future plans of development including accurate clock synchronization by means of TV line 10 method are described.

I. INTRODUCTION

The National Astronomical Observatory of the University of Chile was founded in 1850. Its main activities concern the research in Astrophysics, Radioastronomy and specially in Fundamental Astronomy. At the present time the Observatory is located on Cerro Calán, a small hill in the eastern suburbs of Santiago, where a Time and Latitude Service for scientific purposes is in operation. The main scope of this service is the accurate determination of UTO and latitude, which are used in investigations of the earth rotation and the variations of the local geographic coordinates. Both determinations, UTO and latitude, are based on the observations made with a Danjon Astrolabe, which is working at Cerro Calán since 1965, under an agreement signed between the European Southern Observatory and the University of Chile for a joint research project whose main goal is the improvement of the Fundamental Reference System at the southern hemisphere (1, 2, 3).

Since 1971 the astrolabe of Santiago is one of the 17 astronomical instrumentsof 12 observatories determining time and/or latitude, whose results are used regularly by the BIH for the Rapid Service which provides accurate UT1 and polar coordinates to the JET PROPULSION LABORATORY (JPL). These data are used by the JPL in spacecraft navigation (4).

Until 1973 our time reference for the astronomical observations was based on a Rohde und Schwarz quartz clocks unit of type CAA with a frequency stability of 1×10^{-10}. The phase of the master clock was compared with that of the 24 kHz standard frequency of NBA by means of a Rohde und Schwarz VLF receiver type XKE. Synchronization with UTC was made through the reception of time signals (WWV) in HF, so the uncertainty in our epoch was of the order of 2ms.

In 1973 a time service with an accuracy of ±10 microseconds with respect to UTC, was required to provide precise time for a Very Long Baseline Interferometry (VLBI) project which is being undertaken by our Radio-Astronomy group at the Radio-Observatory of Maipú, through a joint program with the University of Florida. The purpose of this project is to obtain information on the sizes of the radio-sources of the powerful decametric bursts from the planet Jupiter. Simultaneous radio observations of Jupiter at 18MHz with a narrow banwith (2.4 kHz), are being made at Maipú, about 30 Km to the SW of Santiago, at Gainesville, Florida and at Bowling Green, Western Kentucky.

The baseline is about 7100 Km for Maipú-Gainesville and about 7900 Km for Maipú-Bowling Green (5, 6).

Since the time synchronization of the observing sites should be performed using UTC(USNO) as the transfer standard, I shall describe how we are achieving at Santiago a precise time comparison with USNO:

II. PTTI AVAILABILITIES AT SANTIAGO

In the plans for a precise time service we considered our timing requirements and the PTTI availabilities for these requirements at our geographic area, i.e. accurate synchronization and reliable phase control that could be obtained at Santiago.

Since Santiago is a rather faraway area from PTTI dissemination systems, it is interesting to show how we are trying to solve our problems.

1) Synchronization with UTC(USNO)

For the synchronization with UTC (USNO) with the required accuracy, we obtained the kind cooperation of NASA which offered to us the facilities of its flying clock that comes periodically to the Spaceflight Tracking and Data Network (STDN) station of Peldehue, about 40 Km north of Santiago.

Since NASA's flying clock comes to Santiago more or less once in the year, we realized that, in order to make a regular and profitable use of these facilities a strong improvement should be made in our time keepers. This improvement was implemented by means of a cesium beam frequency standard HP 5061 A, which was got by the National Observatory with funds provided by the Scientific Research Office of the University of Chile. The cesium standard was put in operation at the end of 1973 and the first synchronization through flying clock was made in February 11, 1974 and the second one in May 13, 1975.

Time synchronization, through LORAN-C was also considered. However, if we take into account the distance from Santiago to any LORAN-C station, we must conclude that the accuracy which could be obtained through this method should be below our requirements (7). To our knowledge this is confirm at the STDN station of Peldehue, where the skywave propagated signals of the LORAN-C stations of UPOLO and JOHNSTON ISLAND are regularly received. If we consider that Santiago is

located at a higher southern latitude than that of NASA's STDN station of Carnarvon, Australia, we might deduce, at least theoretically, that the precision in time synchronization which could be obtained at Santiago through LORAN-C, should be of the same order as that obtained at Carnarvon, that is ±75 microseconds (8).

2) Phase control

For phase control we have a Rohde und Schwarz VLF receiver mentioned in I, which is fix tuned for 24 kHz, that is the frequency of station NBA. We know that the reception of only one VLF station is unreliable for a continuous phase tracking, (9) however for the moment these are our only instrumental possibilities. At Santiago, although we have a clean reception of NBA during day propagation, there are frequently phase jumps during sunrise and sunset, which produce troublesome phase discontinuities. (Fig. 1) (10). So, if phase tracking, using NBA, is unreliable to estimate the rate of our atomic clock, it is best to compute from the phase comparisons the relative frequency difference between UTC(USNO) and our atomic standard. A numerical integration could give us the time difference USNO - National Observatory (11).

III. RESULTS

Let UTC(NAO) be the UTC of the National Astronomical Observatory and DF the relative frequency difference between USNO MC and the local atomic clock. DF is computed from the daily phase comparisons with the VLF of NBA. The time difference USNO-NAO is obtained for a certain epoch t, in days, by

$$1) \qquad (UTC(USNO-NAO))_t = (UTC(USNO-NAO))_0 + \int_{t_0}^{t} DF\,dt$$

where the integration constant $(UTC(USNO-NAO))_0$ is derived by means of flying clock comparison at epoch t_0.

In Table 1 we give the results obtained applying this method between two flying clock comparisons: February 11, 1974 and May 13, 1975.

TABLE I

TIME AND FREQUENCY COMPARISONS BETWEEN USNO AND THE NATIONAL ASTRONOMICAL OBSERVATORY (NAO) AT SANTIAGO

	USNO	NAO	
	FREQUENCY(1)	TIME	
	UNIT: 1×10^{-12}	1 microsecond	
	VIA : NBA	NBA(2)	Flying Clock
1974 FEB.	+1	00	0(3)
MAR.	-1	00	-
APR.	-1	-03	-
MAY.	-1	-05	-
JUN.	0	-06	-
JUL.	-2	-09	-
AUG.	-2	-14	-
SEP.	-4	-22	-
OCT.	-1	-29	-
NOV.	-1	-30	-
DEC.	-1	-33	-
1975 JAN.	-2	-36	-
FEB.	+3	-35	-
MAR.	-2	-33	-
APR.	-1	-37	-
MAY.	+1	-37	-33

(1) Monthly means.
(2) Computed using equation. 1) and referred to the 13 of each month.
(3) Synchronization with UTC(USNO) on February 11.

It can be seen from this data that the time at the National Observatory was kept within 5 microseconds with respect to USNO after a period of 15 months. It seems to us that the frequency data for Sep. 1974 and Feb. 1975 look ratner abnormal. Perhaps these values are due to propagation anomalies or seasonal disturbances affecting the phase comparisons or may be to an abnormal behaviour of the equipment produced by environmental causes. However, we think that it is necessary to have a longer period of observations in order to disclose the real causes of the observed anomalies.

IV. PRESENT SERVICES AND FUTURE DEVELOPMENTS.

Although the agency who has the legal responsability for time determination and dissemination in Chile is the Hydrographic Institute of the Chilean Navy, two special services for time dissemination through the country are operated by the National Observatory. One is transmitted in HF, four times a day, for the network of seismological stations of the Geophysical Department of the University of Chile. The other one, for public use, provides time signals every thirty minutes through telephone lines, to the commercial radiobroadcasting stations of Santiago.

The accuracy of the time services for seismology at the sites of reception is limited by the HF propagation mode. The time signals are similar to those of WWV and with a special code, some minutes and hours are identified.

At the present time there are five atomic clocks operating in Chile: two cesium of the Hydrographic Institute of the Navy at Valparaiso, one cesium and one rubidium at the STDN station of NASA at Peldehue and a cesium at the National Observatory. All these clocks are located in a small area of the country; the longest distance between them is more or less 100 Km.

We are implementing now a project in order to link the cesium atomic clocks of the National Observatory with those of the STDN station of NASA by means of the TV line 10 method. Strong signals of TV National Channel, emitted from the same station, are received at Cerro Calán and Peldehue. In this way we expect to make a strong improvement in our time keeping which will be of significant benefit for both institutions.

For a near future it is expected to get an agreement with the Chilean Navy to compare by means of TV, the atomic clocks of the Hydrographic Institute at Valparaiso with those of Cerro Calán and Peldehue near Santiago.

The transmissions of TV National Channel are received practically through all the country. So, time comparisons along the Chilean territory, using line 10 method could be easily made in the future if the corresponding delays are previously measured.

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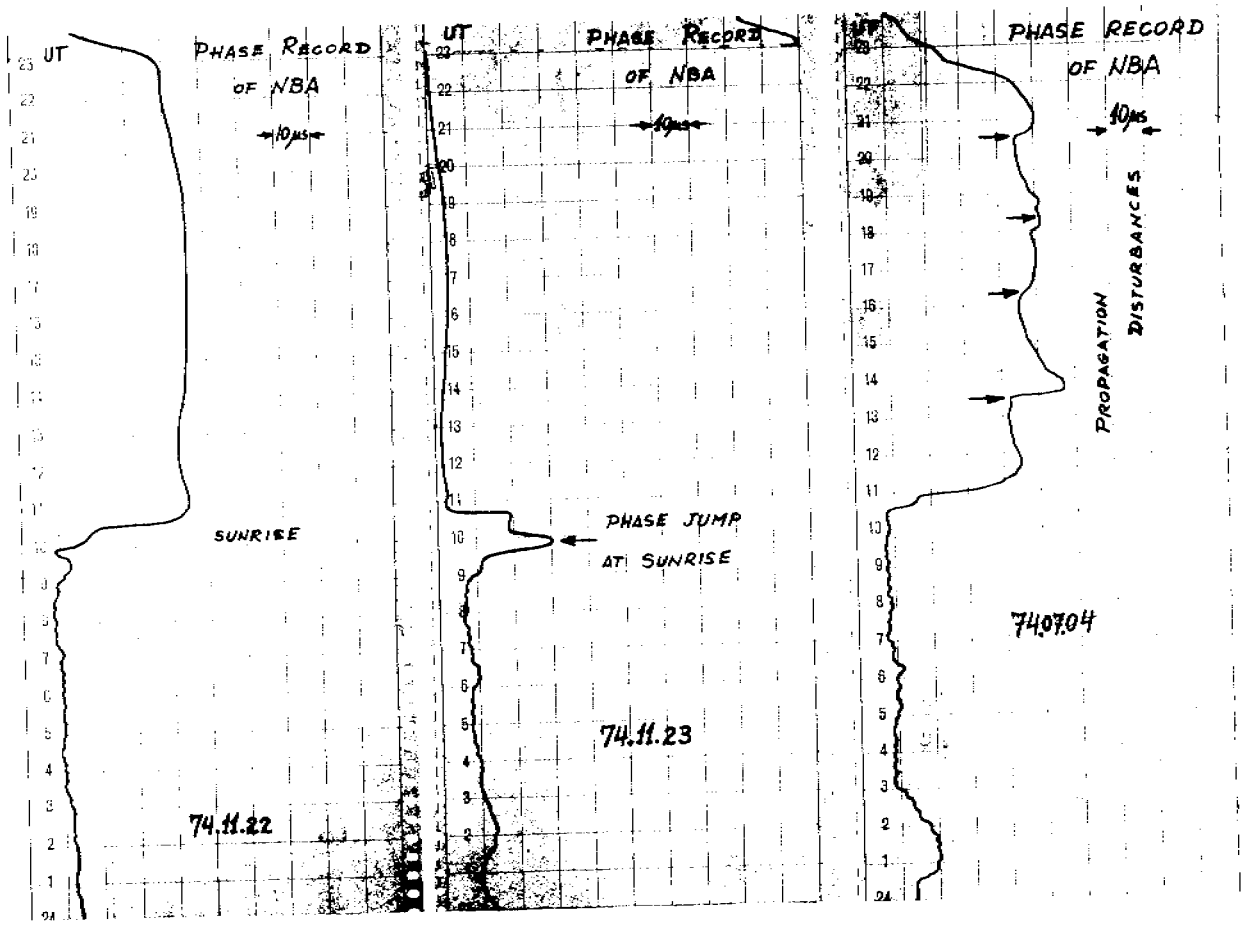

Fig. 1) Phase Records of NBA obtained at Santiago de Chile.
(a) Normal reception.
(b) Phase jump ocurred at sunrise.
(c) With strong disturbances during day propagation.

QUESTION AND ANSWER PERIOD

NO DISCUSSION