THE PRESENT DEVELOPMENT OF TIME SERVICE IN BRAZIL, WITH THE APPLICATION OF THE TV LINE-10 METHOD FOR COORDINATION AND SYNCHRONIZATION OF ATOMIC CLOCKS

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ABSTRACT

A short historical review will be followed by a description of the resources available at the Time Service of the National Observatory. Various methods presently used for the dissemination of time at several levels of precision will be described along with future projects in the field. Different aspects of time coordination will be reviewed and a list of future laboratories participating in a National Time Scale will be presented. A Brazilian Atomic Time Scale will be obtained from as many of these laboratories as possible. The problem of intercomparison between the Brazilian National Time Scale and the International one will be presented and probable solutions will be discussed. Needs related to the TV Line-10 method will be explained and comments will be made on the legal aspects of time dissemination throughout the country.

Following this there will be a description of measurements taken between two laboratories, ONRJ and INPE. A comparison will be made between these measurements and those obtained in 1969 and 1970 by the NAFS and USNO in the U.S.A. Finally, a comparison will be made between the Line-10 and the physical clock transportation methods. The comparisons show good promise for the effectiveness of the Line-10 method in Brazil.

I - SHORT HISTORICAL NOTE

The Time Service of the National Observatory of the Ministry of Education and Culture, active since 1847 is specifically dedicated to the countrywide dissemination and determination of Legal and Astronomical Time in Brazil.

In 1902 our Time Service obtained time by solar and certain star meridian passages and maintained time by pendulum and chronometers. Time transmission for public use was visible by the release of a balloon from a small tower on the terrace of the Observatory on a hill near the center of Rio de Janeiro.

The law nº 2784 of June 18, 1913 that established legal time in Brazil and adopted the time zones, which was regulated by the Decree nº 10.546 of November 5, 1913 is still valid. It determined that the National Observatory of Rio de Janeiro, as well as future stations that may be designated, are responsible for the determination of time and its transmission for geographical and navigational purposes by telegraphic or "Time Ball" means, in agreement with the accepted and valid international agreements.

On June 1, 1918 the first radio-telegraph station of time signals was inaugurated. They were transmitted twice daily, from 13 h 55 m 55 s to 14 h 00 m 00 s, and from 23 h 55 m 55 s to 00 h 00 m 00 s, GMT.

The operation of the Observatory was regulated by Decree nº 6361 of October 1, 1940 which established that:

> Chapter III, Art. 7 - The Division of Meridian Services and attached Services, will determine and transmit legal time by radio-telegraphy in accordance with decisions of the International Time Committee, with the adequate precision not only for the purposes of navigation, but for engineers and the public and also, in cooperation with the Bureau International de l'Heure, for Universal Time determination:

With these fundamental objectives operating since the time of the Empire (before 1889) several techniques and varied instruments have been used by generations to cooperate with the Time Service, beginning with pendulums and arriving at the present status where everything depends on atomic clocks.

II - ACTUAL SYSTEM

We are now in a transition state in which we are trying to solve our problems of time dissemination for both scientific and non-scientific users. We are only beginning to adapt to our conditions, some techniques previously used by other countries.

Of course this adaptation implies, in all cases, an investigation of the methods of all possible theoretical and practical considerations. It is possible that we must develop new techniques more useful to our particular conditions in South America.

For this purpose we have had pendulum clocks, clocks with crystal oscillators and more recently commercial Cesium and Rubidium frequency standards.

To establish a time scale based on as many standards as possible, we began in December 1972 making comparisons between all available standards using one of our Rubidium standards as a portable clock.

We know of course, that the Rubidium standard is not the best choice for a portable clock, and we intend as soon as possible to get a Cesium for this purpose.

In July of last year, 1973, we started the comparisons between standards located in Rio and two places in Sao Paulo using the Line-10 method. Initially we studied the observed flucuations in the propagation delay in the path. The two locations now used are approximately 300 and 450 km from Rio. More experiments are being made at Brasilia, Belém, Natal and Manaus, which are far from Rio at straight distances of 900; 2470; 2170 and 2820 km respectively.

At present, we have in Brazil a "Working Group on Time" that, with the coordination of "National Observatory" and sponsored by our "National Research Council," has regular meetings. All the Brazilian institutes that have atomic clocks participate in the Brazilian time scale.

For the dissemination of time and frequency we are now using broadcast transmissions in HF (Short waves) and VHF. We know the limitations involved by these bands. For precision comparisons of time or frequency we normally go with our Rubidium to the users that require such precision, or they come to us, or we have a connection by telephone line, depending on the frequency.

We are now installing in our capital of Brasilia, a new time service station. We intend in the next year to begin transmissions of time signals and standard frequencies using the advantage that Brasilia is more or less a central point in Brazil. We have started experimental transmissions, using the help of a government broadcasting station, that is putting high power transmitters of 250 kw and 300 kw into operation.

Using the facilities of our Brazilian Telecommunication Company, EMBRATEL, that has a microwave link along the entire coast, we will retransmit by new coastal stations, (16) time signals, that are useful for the ships communicating with those stations.

Normally in some transmissions of Time signals, for users of low precision we transmit voice announcements of time every 10 seconds. These announcements are generated from automatic equipment which is synchronized with our Cesium standard.

We have daily reception of Time signals from other countries in VLF, HF and VHF, (two years ago, during the experimental transmission of the ATS-3 satellite).

In the near future, we intend to have regular comparisons between the Brazilian time scales and the International time scales using portable clocks and/or reception of signals transmitted from satellites.

III - LINE-10 METHOD IN BRAZIL

As there are now or soon will be, various laboratories with atomic frequency standards (commercial types only) in Brazil, it was decided by the GTH ("Working Group on Time," created by the National Research Council) that the National Observatory would initiate experiments to obtain a national standard time scale from the individual scales of the several laboratories.

Table 1 presents a list of these laboratories and Figure 1 presents the map of Brazil with their locations. Because of the dimensions of Brazil (more or less 3200 km in the N-S direction and 4200 km in the E-W direction) line-10 will be the most useful method available for comparisons.

TABLE I

POSSIBLE AND ACTUAL PLACES USING THE LINE-10 METHOD

City-State	Institution	Standard (Commercial)
Rio de Janeiro-GB	EMBRATEL	Cs (1) HP
	UFRJ	Cs (1) Ebauche
	ON	Cs (2) HP. Rb (2) HP and Tracor
S. José dos Campos-SP	INPE	Cs (1) HP
S. Paulo-SP	IAG	Cs (1) Ebaushe; Rb (1) Sulzer
Atibaia-SP	CRAAM	Cs (1) HP, Rb (2) Tracor

EMBRATEL - Brazilian Telecommunication Corporation
UFRJ - Federal University of Rio de Janeiro
INPE - Space Research Institute
IAG - Astronomical and Geophysical Institute of S. Paulo University
CRAAM - Radio Astronomy and Astrophysical Center of Mackenzie

The experiments were started with measurements between INPE (Space Research Institute) and ONRJ (National Observatory of Rio de Janeiro) which are approximately 300 km apart.

ONRJ versus INPE

The measurements are made twice per week for six minutes each day. As there is transmission in both directions, measurements are made during three minutes in each direction. This system allows determination of propagation delay between the two laboratories.

Only 30 measurements are used for the reduction of the measurements made during the 3 minutes.

The reduction actually is made by means of a small table calculator, and when more laboratories start to participate we will use a PDP8/E from Digital Equipment Corp. (DEC).

Figure 2 presents the results for ONRJ-INPE in comparison with the result of NAFS-USNO comparison, in terms of the Allan variance.

We can observe that our result is more or less ten times worse that the other. We think that this is because we are comparing only two single standards, whereas the NAFS-USNO is a comparison between two scales resulting from several standards each. Another difference between the two results is in the number of data points; our situation covers only one 100 day interval.

Another result is also presented.

Parallel to the Line-10 measurements, we make physical transportation of clocks for precise measurements of propagation delay. Figure 3 presents this comparison.

Following are observations on this figure.

a - the line-10 values are not as dispersed in the JUL-OCT interval as in the Nov-Mar interval. This may be due to the rain precipitation that is more pronounced in the latter period.

b - in the end of November there was a sudden change in the relative frequency because of a failure in one of the two clocks.

c - the variation, -1.5×10^{-12} and $+1.0 \times 10^{-12}$ is in agreement with the specification of the two standards, which is $\pm 5 \times 10^{-12}$.

d - propagation delay in this experiment is of no importance because its variations, over one year, is of the order of $\pm 0.3\ \mu s$.

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Figure 1.

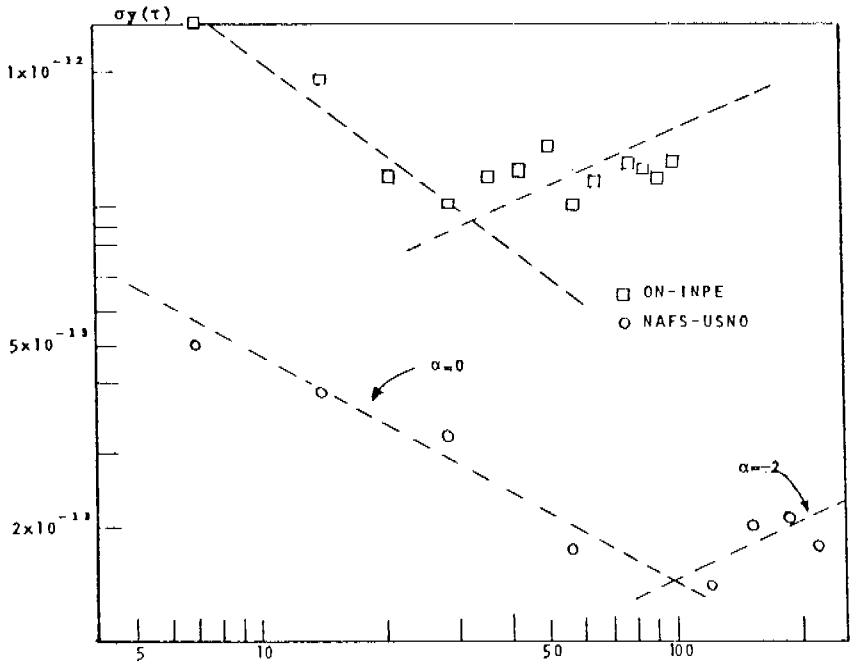

Figure 2. Sampling time (τ) in days

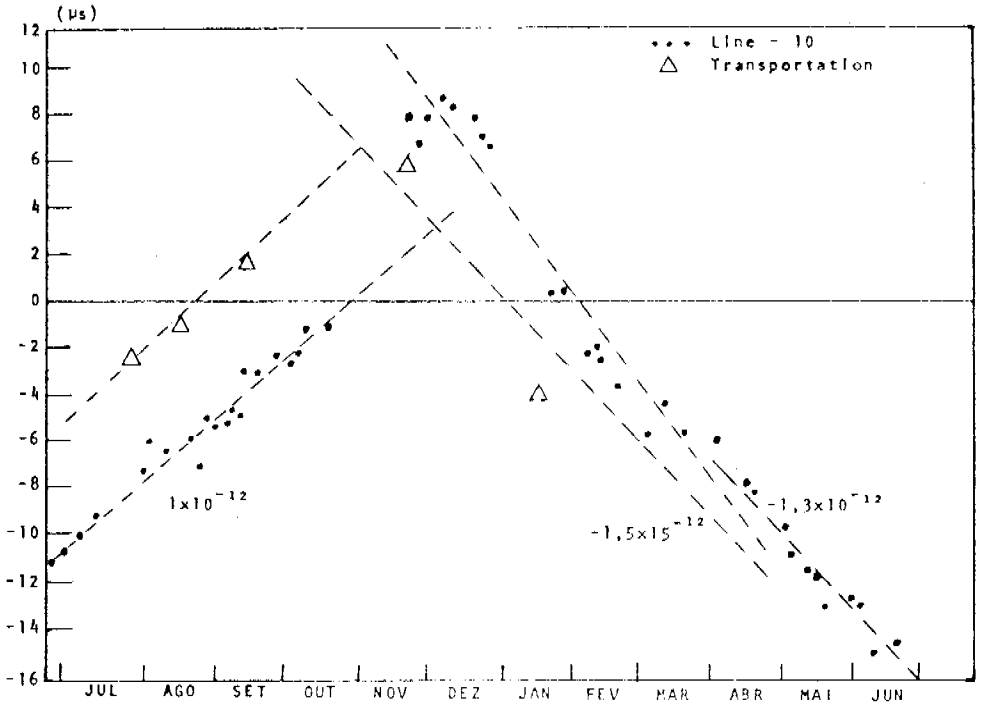

Figure 3. Comparison between the Line-10 and physical clock transportation

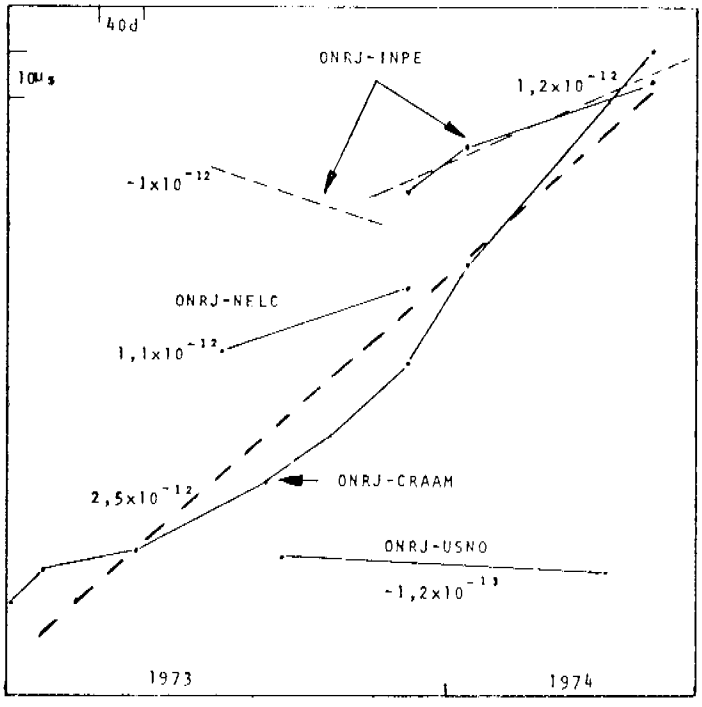

Figure 4. Global comparisons