A Comparison of the TA_1 and the NBS-A Atomic Time Scales

The Observatory of Neuchatel, Switzerland, publishes information[1] from which it is possible to determine the reception time in Neuchatel of the time signals emitted by the standard frequency and time-interval broadcast station WWV, located in Greenbelt, Md., and operated by the United States National Bureau of Standards. In this communication the reception times of the WWV time signals on the TA_1 atomic time scale are compared with the emission times assigned to the WWV signals according to the NBS-A atomic time scale. The TA_1 scale was established in 1957 and is maintained by the Laboratoire Suisse de Recherches Horlogeres in Neuchatel, while the NBS-A scale was also established in 1957 and is maintained by the National Bureau of Standards. Each of the scales has been established with the intention that the frequency of the cesium transition widely used as a frequency standard shall be 9192631770.00 . . . cycles per unit time interval. In the following discussion and figure this unit of time interval is called a second since it is believed[2] to differ from the second as presently defined by no more than a few parts in 10^9.

The origin of the NBS-A time scale has been set with the intention that this scale shall assign $0^h0^m0^s$ as the occurrence time to an event occurring at $0^h0^m0^s$ UT2 time on January 1, 1958. The National Bureau of Standards does not have facilities for determining the occurrence times of events on the UT2 scale so that reception times of WWV pulses on the A.1 scale, as listed in the U. S. Naval Observatory Time Service Notice 6, January 1, 1959, were used to set the origin. Recent measurements made by the National Bureau of Standards in cooperation with the U. S. Naval Observatory have indicated that 0.316 msec is the effective propagation time between the WWV transmitter and the U. S. Naval Observatory.[3] In setting the origin of NBS-A, the 0.316-msec figure has been used.

The TA_1 scale was intended originally to coincide as closely as possible with Ephemeris Time on January 1, 1958, 0^h UT. Since the accuracy with which ET is known is rather poor, the origin of TA_1 with respect to ET is to be considered uncertain.

The TA_1 scale and the NBS-A scale are constructed from independently obtained frequency measurements made with the aid of atomic frequency standards located in the laboratory constructing the time scale. Fig. 1 shows the comparison.

Over the course of years, various refinements in techniques and instrumentation for atomic timekeeping have evolved and have been incorporated into either the procedure or the equipment used to establish the time scales TA_1 and NBS-A. Two changes which

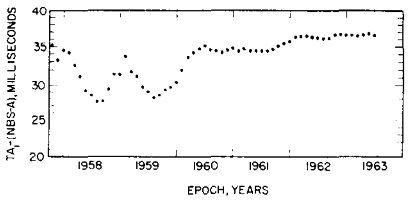

Fig. 1—Comparison of the time scales TA_1 and NBS-A.

occurred near June, 1960, and which resulted in a significant improvement of the time scale comparison are the switch by LSRH from the $N^{14}H_3$ maser to a Cs resonator for a frequency standard, and the adoption of NBS II as the United States Frequency Standard.[4]

The curve of Fig. 1, as expected, becomes smoother as time progresses and as more and more refinements are incorporated into the timekeeping procedure and apparatus. Since, as mentioned above, the origin of the TA_1-scale is not the same as that of NBS-A, the magnitude of the difference in Fig. 1 has little significance, although about 22.8 msec[5] is due to propagation delay. The quantity plotted in Fig. 1 is the reception at Neuchatel of the 0700 UT WWV pulse on the TA_1 scale minus the emission time of the 0700 UT WWV pulse on the NBS-A scale.

During the last several years, Fig. 1 shows that the NBS-A and TA_1 scales were diverging at a rate of $\sim 3 \times 10^{-11}$ sec/sec. If this divergence is entirely attributed to a difference in the NBS and LSRH atomic frequency standards, then it would appear that if the two groups were presented with the problem of determining the frequency of identical sources, the LSRH group would report a value ~ 3 parts in 10^{11} less than the NBS group would report. Both laboratories monitor the frequencies of the very low frequency stations, NBA and GBR. During the years 1961–62 the measurements on GBR indicate that the average frequency reported by LSRH is 1.7 parts in 10^{11} less than the frequency reported by NBS. During this same period the measurements on NBA indicate that the average frequency reported by LSRH is 3.4 parts in 10^{11} less than the frequency reported by NBS. This rather good agreement between Fig. 1 and records made by monitoring GBR and NBA is found not only in the averages for the two-year period 1961–62, but also during shorter periods such as the period from 1961.6 to 1962.1. There the average VLF reported by LSRH is about 8 parts in 10^{11} less than that reported by NBS. This is explained by temporary poor shielding of the C-Field region of the LSRH Cs Beam Tube and bas been reported by Karatschoff [4]. A new improved shield was installed in March 1962. From 1960.5 to 1961.6, and since 1962.2, the rate of divergence of NBS-A and TA_1 has been about 1 part in 10^{-11}, with the points plotted in Fig. 1 having a standard deviation of 0.2 msec. This rate of divergence is consistent with the estimated accuracies of both standards,[6,7] and illustrates the practicality of keeping time by using the techniques of quantum electronics.

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Manuscript received November 18, 1963.

[1] "Bulletin horaire de l'Observatoire de Neuchatel," Series A–D, published monthly by the Observatory of Neuchatel, Switzerland.

[2] W. Markowitz, R. G. Hall, L. Essen, and J. V. L. Parry, "Frequency of cesium in terms of ephemeris time," *Phys. Rev. Letters*, vol. 1, pp. 105–107; August, 1958.

[3] J. A. Barnes and R. L. Fey, "Synchronization of two remote atomic time scales," to be published.

[4] J. Newman, L. Fey, and W. R. Atkinson, "A comparison of two independent atomic time scales," PROC. IEEE, vol. 51, pp. 498–499; March, 1963.

[5] George W. Haydon, Radio Systems Division, National Bureau of Standards, Boulder, Col., private communication.

[6] P. Kartaschoff, "Operation and improvement of a cesium beam standard having 4-meter interaction length," IRE TRANS. ON INSTRUMENTATION, vol. I-11, pp. 224–230; December, 1962.

[7] R. E. Beehler, W. R. Atkinson, L. E. Heim, and C. S. Snider, "A comparison of direct and servo methods for utilizing cesium beam resonators as frequency standards," IRE TRANS. ON INSTRUMENTATION, vol. I-11, pp. 231–258; December, 1962.

Reprinted from the

PROCEEDINGS OF THE IEEE

VOL. 52, NO. 4, APRIL, 1964