LETTERS TO THE EDITORS

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Comparison of an Ammonia Maser with a Cæsium Atomic Frequency Standard

SEVERAL atomic frequency standards of different types are now in use for comparisons with astronomically determined time. As the adopted frequencies of these atomic standards have been derived from the smoothed universal time U.T.$_2$, which is itself variable in time[1], they disagree by several parts in 10^9. In order to obtain a uniform base for the atomic times determined by the different standards, their frequencies have to be compared directly. This has been done between cæsium resonators at the National Physical Laboratory in Teddington and the Naval Observatory in Washington using the *GBR* 19·6 kc./s. transmissions. Later the same comparison was repeated between similar cæsium resonators at the National Physical Laboratory[2].

The present communication reports on similar measurements between the cæsium resonator of the National Physical Laboratory and the ammonia maser in operation at Neuchâtel. Such a comparison is of particular interest to prove the consistency of atomic and molecular frequencies produced by completely different devices.

Two different methods of reception were used.

(1) The phase of the time signals superimposed on the *MSF* 10 or 5 Mc./s. standard frequency transmissions received in Neuchâtel was differentiated over six days centred on the days when the quartz clocks were calibrated in terms of the maser frequency standard. An accuracy of approximately ± 1 part in 10^9 is achieved.

(2) The frequency of the *MSF* 60 kc./s. standard frequency transmission is connected to the maser frequency obtained the same day. The accuracy given by this method seems better, a few parts in 10^{10}, though the reception on 60 kc./s. is often bad. The results obtained by using the corrections published by the National Physical Laboratory which have to be applied to *MSF* to obtain the frequency based on the cæsium resonator are summarized in Table 1. The correction to be applied to the adopted maser frequency (23 870 129 235 c./s.) to reduce it to the adopted cæsium resonator frequency (9 192 631 830 c./s.) is 9×10^{-9}. Within the limits of accuracy, both methods agree. It is not yet clear if the systematically lower values given by method 1 in autumn 1957 are due to relative drift of the atomic standards, statistical error or ionospheric disturbance.

Table 1. FREQUENCY DIFFERENCE CÆSIUM – MASER

Date	Time signals *MSF* 10 Mc./s.	Frequency *MSF* 60 kc./s.	Date	Time signals *MSF* 10 Mc./s.	Frequency *MSF* 60 kc./s.
	($\times 10^{-9}$)	($\times 10^{-9}$)		($\times 10^{-9}$)	($\times 10^{-9}$)
1957			1957		
July 16	10	—	Nov. 21	7	—
Aug. 19	8	—	Nov. 23	7	—
Aug. 31	8	—	Dec. 13	7	—
Sept. 14	8	—	Dec. 23	7	—
			1958		
Sept. 27	7	—	Jan. 4	7	—
Sept. 30	7	—	Jan. 20	8	—
Oct. 18	7	—	Mar. 28	8·4	9·3
Oct. 26	7	—	April 25	9·2	9·0
Nov. 2	8	—	May 13	10·4	9·0
Nov. 4	7	—	June 10*	10·5	9·5
Nov. 5	7	—	June 13*	8·0	9·3
Nov. 19	7	—	July 3*	8·4	9·5
Nov. 20	7	—	July 18*	10·3	8·4

* Correction *MSF* – cæsium taken as zero.

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Neuchâtel. Aug. 8.

[1] Essen, L., Parry, J. V. L., Markowitz, W., and Hall, G. R., *Nature*, **181**, 1054 (1958).

[2] Essen, L., Parry, J. V. L., and Pierce, J. A., *Nature*, **180**, 526 (1957).

Comparison of Astronomical Time Measurements with Atomic Frequency Standards

ATOMIC frequency standards have been in regular operation in several laboratories for the past few years. It has rapidly become clear that they can be used for comparisons with astronomical time determinations.

This problem has been studied in Neuchâtel, where the atomic frequency standards (ammonia masers) have been used to define an atomic time in conjunction with a set of quartz clocks. The same clocks are related to the time determined astronomically (U.T. defining the angle of rotation of the Earth) with a photographic zenith tube and a Danjon astrolabe. The precision of these different comparisons is given roughly in Table 1.

Table 1

Type of measurement	Frequency	Ref.	Clock correction	Ref.
Atomic	10^{-10}		$3T + 2\sqrt{T}$ m.sec. (T in years)	*a*
Astronomical: universal time (U.T.)	$1{\cdot}6 \times 10^{-9}$	*b*	3 m.sec.	*c*
Ephemeris time (E.T.)	(5×10^{-9})	2	(30 m.sec.)	2

(*a*) Obtained by integration of the frequency of a quartz clock calibrated every two weeks in terms of atomic frequency.

(*b*) Obtained from astronomical data over a period short enough (about 1 month) to allow differentiation (ref. 1).

(*c*) Average over 1–2 weeks, the accuracy being partly limited by the uncertainty of polar motion.

It appears that atomic and astronomical clock corrections can be compared with similar accuracies whereas astronomical frequencies are much less precise. This follows from the fact that integration of atomic frequency by a quartz clock can easily be achieved without loss of relative accuracy, while astronomical data do not lend themselves to precise differentiation.

On the other hand, it seems preferable, for studying the rotation of the Earth, to use the U.T.$_1$, in which polar motion has been removed and which is a direct result of observation and therefore identical for all observatories.

If one assumes that atomic time (A.T.) is uniform, U.T.$_1$ − A.T. is a direct measure of all effects changing the rotation of the Earth. This quantity, as determined by different observatories and atomic frequency standards, should be directly comparable except for a linear term originating from the adopted atomic frequency. Fig. 1 shows such a comparison. Even small and rapid changes in the rate of rotation of the Earth can be detected, whereas these disappear in Fig. 2, where the differentiated astronomical data are plotted against atomic frequency. Besides the