LETTERS TO THE EDITOR

ASTRONOMY

Atomic Standards of Frequency and the Second of Ephemeris Time

On the authorization of the twelfth General Conference, the International Committee of Weights and Measures assigned, in October 1964 (ref. 1), the frequency 9 192 631 770 hertz to the well-known transition of caesium-133 at zero field, for temporary use pending consideration of a new definition of the second; the second, as at present defined, is the second of ephemeris time. The number 9 192 631 770 with a quoted probable error of ±20 is that originally determined by Markowitz *et al.*[2] by the comparison, during the period 1954·0 to 1958·5, of an integrated measure of atomic time based on the frequency of the caesium transition with the measure of ephemeris time (E.T.) as determined by observations of the Moon with moon-cameras. Subsequent comparisons over longer periods have tended to confirm that this frequency lies within the uncertainty quoted.

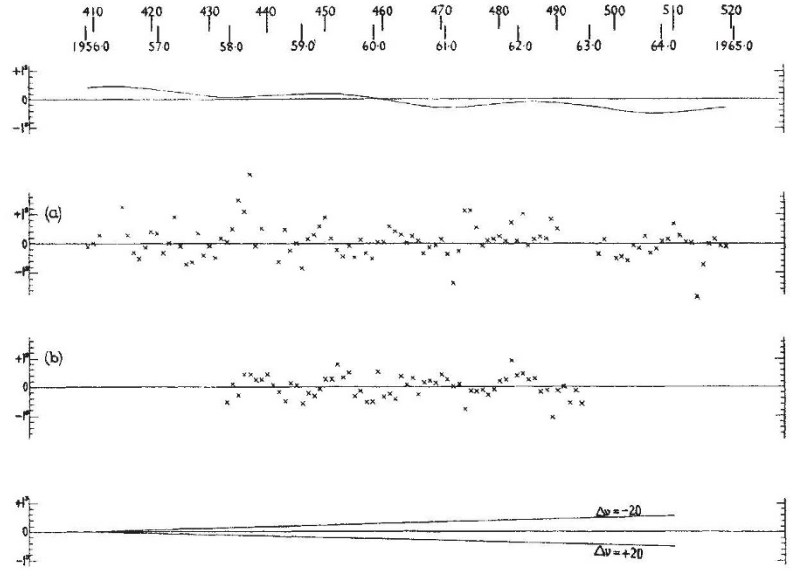

Fig. 1

However, the International Astronomical Union at its General Assembly in August 1964 recommended the use of a new IAU System of Astronomical Constants[3]; its adoption leads to modifications of a periodic nature in the lunar ephemeris which affect the determination of ephemeris time from observations of the Moon. Moreover, Eckert[4], in the course of a comprehensive recalculation of the main problem of the lunar theory, discovered a numerical error in the coefficient of one of the periodic terms of Brown's theory; the presence of this error in the lunar ephemeris has since been confirmed by analysis of both the meridian[5] and occultation (unpublished) observations.

The application of these two periodic corrections to the lunar ephemeris affects the determination of the deduced frequency in terms of the (ephemeris) second by amounts that could, over short intervals, reach as much as 40 (or even 50) hertz. The correction to the deduced frequency depends on the precise method of discussion and, for this reason, no estimates are given in respect of previous determinations. However, two new determinations, incorporating these corrections, have recently been made; the purpose of this communication is to report that they confirm that the frequency of the caesium transition is close (within its previously quoted probable error) to the adopted value of 9 192 631 770 hertz. It is emphasized that, as in all other current determinations, the measure of the (ephemeris) second is deduced from observations of the motion of the Moon around the Earth, although it is defined in terms of the motion of the Earth around the Sun.

The new determinations are based on the provisional discussion of two homogeneous series of lunation mean values of ΔT = E.T. − U.T.2 deduced from: (*a*) the Washington meridian observations[6] of the Moon from 1956·0 to 1965·0; (*b*) the observations of occultations of stars by the Moon as collected and reduced at Herstmonceux (to be published), from 1958·0 to 1963·0.

In both series the observations have been corrected for the irregularities of the limb of the Moon. The values of ΔT, amended for the effect of the corrections above, are compared with the corresponding lunation mean values of ΔA = A.T. − U.T.2, where A.T. is an atomic time scale based on the adopted frequency of 9 192 631 770 hertz, thus eliminating U.T.2. In this preliminary discussion straight lines are fitted to the differences $\Delta T - \Delta A$; the slope of the lines indicates directly the correction to the frequency (+0^{s}·01/lunation = − 36 hertz). The formal results are:

(*a*) Meridian, 1956·0–1965·0: −14 ± 5 (standard error).

(*b*) Occultations, 1958·0–1963·0: +2 ± 11 (standard error).

The residuals, in seconds of time, from these fitted straight lines are plotted in Fig. 1 in which the abscissa is the lunation number. For comparison there are also given: in the upper diagram, as a continuous line, the effect on ΔT of the corrections to the lunar ephemeris; in the lower diagram, the slopes corresponding to frequency corrections of ±20 hertz.

There is some evidence, especially in the occultation values (*b*), of the presence of periodic terms; these are probably due to the effects of selection, which is inevitable in both forms of observation, on the difference between the centre of mass and the centre of figure of the Moon. The consequence is to enhance the importance of the observations at the ends of the series; for example, the omission of the last six lunations from the occultation data changes the deduced correction from +2 to −19. Pending a more elaborate discussion, all that can be said with reasonable certainty is that the frequency of the caesium transition is unlikely to lie outside the range 9 192 631 750–775 hertz. Formal estimates of error have little significance.

W. Nicholson
D. H. Sadler

Royal Greenwich Observatory,
Herstmonceux Castle,
Sussex.

[1] Résolution 5, *Comptes rendus des Séances de la Douzième Conférence Général des Poids et Mesures*, 93 (1964).
[2] Markowitz, W., Hall, R. G., Essen, L., and Parry, J. V. L., *Phys. Rev. Lett.*, **1**, 105 (1958).
[3] *Trans. IAU*, **12** B, 594 (1966).
[4] Eckert, W. J., *Trans. IAU*, **12**, B (in the press).
[5] Klock, B. L., and Scott, D. K., *Astro. J.*, **70**, 335 (1965).
[6] *U.S. Naval Observ. Circ.* Nos. 103 (1964), 105 (1964) and 108 (1965).