A RE-INTERPRETATION OF THE DEFINITION OF UT1

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SUMMARY. Universal time is a commonplace quantity, and yet it has no generally accepted definition. The expression for sidereal time is often quoted as a definition, but this does not convey much meaning to the average person. Also sidereal time is measured from the equinox of date, and so involves the precession formulae of the stellar reference frame, and hence may not be ideal for other modern techniques of observation. Guinot (1979) has proposed a broad definition of UT1:
"UT1 is an angle which is proportional to the sidereal rotation of the Earth, the coefficient of proportionality being chosen so that UT1, in the long term, remains in phase with the alternation of day and night. In some applications, UT1 can be considered as a non-uniform time scale".
Xu et al (1986) add their support to this definition, and point out that it is a conceptual definition. We agree with this approach to defining UT1, and suggest that the crucial points are that a constant numerical value of the rotation rate is chosen, and that UT1 is a non-uniform timescale. It would be better to refer to an inertial rather than sidereal rotation rate, to make the definition more general. A re-worded definition could be:
"UT1 is a non-uniform timescale relative to which the Earth has a numerically constant rotation rate of ω_o degrees/day with respect to an inertial frame. The value of ω_o is close to the value determined by Newcomb for the mean over many years of the angle through which the Earth rotates relative to an inertial frame between successive crossings of a meridian by the Sun."
This conceptual definition makes it clear how the UT1 scale keeps closely in phase with the alternation of day and night, and it is easy to see how the definition could be used in principle to determine intervals of UT1. If by some observing technique it is possible to determine the orientation of the Earth relative to some realisation of an inertial frame (eg. the FK5 star catalogue or the distant radio sources) then the change of orientation between two observations gives the elapsed interval of UT1, by dividing by ω_o.

In order to derive a useable mathematical expression (e.g. the expression for sidereal time) from this definition it is necessary to define what is meant by the concept of an inertial rotation rate. This is done using Euler's kinematical equations, and brings in the

A. K. Babcock and G. A. Wilkins (eds.), The Earth's Rotation and Reference Frames for Geodesy and Geodynamics, 39–40.

expressions for the motion of the equator relative to an inertial frame due to precession. In addition a particular axis in the Earth and the equinox of date have to be defined. Hence the sidereal time expression is the mathematical implementation of a number of conceptual definitions, one of them being that of UT1.

The value of ω_o implicit in Newcomb's work is

$$\omega_o = 1 \text{ rev/day} + 8639877.301 \text{ s/cy},$$

where 1 cy is 36525 days. Until recently the FK4 star catalogue has been the realisation of an inertial frame. It is now recognised that the FK4 reference system is not in fact inertial, but has a rotation in right ascension of about 0.016119 s/cy, due to the systematic errors of the FK4 proper motions in right ascension. The rotation is not known to this accuracy, but this is the precise value used in the conversion from FK4 to FK5. Hence the realisation of the UT1 scale during the usage of the FK4 catalogue has actually been "a non-uniform time scale relative to which the Earth has an inertial rotation rate of 1 rev/day + (8639877.301+0.016119) s/cy". It can be shown that the expression for sidereal time adopted for the FK5 system (Aoki et al., 1982) does in effect adopt this realisation of the UT1 scale as the new definition. Hence the value of ω_o in the conceptual definition of UT1 has been changed to the value

$$\omega_o(\text{FK5}) = 1 \text{ rev/day} + 8639877.317119 \text{ s/cy}.$$

The FK5 expression for sidereal time can be derived simply from

$$\text{GMST(FK5)} = \text{constant} + \omega_o(\text{FK5}).t(\text{UT}) + M(\text{FK5})$$

where t(UT) is an interval of UT1, and M(FK5) is the FK5 expression for accumulated precession in right ascension. The constant is chosen to allow for the difference of the FK4 and FK5 equinox positions at the change-over date, so that there is no discontinuity in the position of the Earth relative to an inertial frame.

Guinot also suggests that a non-rotating origin should be used instead of the equinox of date for the sidereal time expression. This is a separate issue from the definition of UT1, and is part of a recommendation by Guinot for a complete reconsideration of the representation of the motions of the equator and ecliptic relative to an inertial frame. He recommends the non-rotating origin as an intermediate origin instead of the equinox of date, but it could be argued that the node of the equator on the inertial reference plane would be more convenient.

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