JULY - AUGUST 1955 no. 4 (SERIES 4)

BULLETIN HORAIRE

OF THE

BUREAU INTERNATIONAL DE L'HEURE (B.I.H.)

On the Determination of Universal Time by the Time Services according to the Decisions of the General Assembly of the I.A.U. in Dublin (1955)

At the General Assembly of the International Astronomical Union in Dublin there was a series of resolutions concerning the International Commission of Time (Comm. 31), the most important concerning the new definition of Universal Time and its calculation. These resolutions are as follows :

“ 6. The I.A.U. instructs the B.I.H. to compute for the various observatories cooperating in the international time service the longitude corrections due to the motion of the pole, using for this purpose the values of the polar motion supplied by the Central Bureau of the International Latitude Service : extrapolated corrections for several month in advance shall be provided for current use. The x and y components of the polar motion used for the computation of these corrections should also be published in the *Bulletin Horaire*.

7. The B.I.H. shall adopt and shall publish in advance, each year, corrections for the annual fluctuation in the speed of rotation of the Earth. These corrections shall be used by all observatories in the determination of Universal Time. Studies of the annual fluctuations of the rotation of the Earth shall be

Address all communications to the Director of the Bureau International de l'Heure, *Avenue de l'Observatoire*, no 61, Paris (XIVe).

continued, especially with the aid of atomic standards of frequency.

8. The I.A.U. recommends that the bulletins published by observatories cooperating in the international time service should contain the quantities to be added to the times of reception of radio time signals tabulated in UT to allow for the effects of polar motion and the annual fluctuation in the rotation of the Earth.

9. The I.A.U. recommends that, to facilitate intercomparisons between time-keeping establishments, data tabulated at intervals of 5 days, 10 days, and so on should be given for days on which the number of Julian days elapsed at Greenwich noon is divisible by the tabular interval.

According to these decisions which must take effect from 1 January 1956, changes must take place in the calculation of Universal Time. The B.I.H. is responsible for giving the necessary corrections to the calculation of this new Universal Time starting from the old Universal Time ".

Astronomical observations of time in a given location allow us to determine the local sidereal time. Using the sidereal time at midnight and the conversion tables from sidereal time to mean time produces the local civil time.

Universal Time, generally used until recently, was deduced from the local civil time by adding the conventional longitude of the place of observation relative to Greenwich.

Regardless of the errors in the astronomical determination of time, Universal Time (UT0) thus defined is not uniform for two reasons :

1) The polar motion ;
2) The irregular rotation of the Earth .

1) The polar motion changes the position of the meridian of the place, and, therefore, changes longitude. Ordinarily longitudes are determined from the Greenwich meridian. As the meridian passing through Greenwich moves under the influence of the polar motion, there will be a further variation of the differences of longitudes. To remove this

additional variation of longitudes, refer to the instantaneous meridian passing through the point on the equator that meets the mean meridian (mean pole) of Greenwich, because at the equator influence the movement of the pole on the longitude place is zero.

If the coordinates of the instantaneous pole are x and y (the axis x is tangent to the international meridian and directed toward Greenwich, the axis y is directed toward the longitude of $+6^h$), the instantaneous and mean longitudes and latitudes of the place of observation are λ_i, λ_m, φ_i, φ_m, the correction of the longitude of the location relative to the mean pole (pole at the origin) is :

(1) $\Delta\lambda = \lambda_i - \lambda_m = 1/15\ (x \sin \lambda_m - y \cos \lambda_m) \tan \varphi_m$

Thus, to get the Universal Time corrected for the influence of polar motion (UT1), just add $\Delta\lambda$ to the Universal Time from astronomical observations (UT0).

(2) $UT1 = UT0 + \Delta\lambda$

The Universal Time (UT1), thus determined at different places on Earth, will be the same if the errors of astronomical observation and conventional longitudes are small.

In many astronomical and geodetic applications (determination of geographic positions), the Universal Time UT1 corrected for polar motion is sufficient.

The Director of the Central Bureau of the International Latitude Service, according to the recommendations of the International Commission of Latitudes (Comm. 19), will send regularly to the Director of B.I.H. the x and y coordinates of the instantaneous pole.

The B.I.H., using these results, will calculate according to resolution no. 6, the corrections $\Delta\lambda$ of longitude for observatories participating in the International Time Service. In addition, the B.I.H. will extrapolate the x and y coordinates of the instantaneous pole several months in advance and calculate the corresponding corrections of longitude ($\Delta\lambda$). The B.I.H. will communicate these results to the participating observatories for them to use for the current service of the broadcast time signals.

2) Universal Time (UT1) thus calculated will be the same all over the Earth. But it will not be uniform because of the irregularity of the rotation of the Earth. Thus, for the study of precision clocks and frequency standards, where the precision attains 1.10^{-9}, the use of Universal Time 1 (TU1) is not sufficient.

Table **A**

Corrections ΔT_S to be applied to the classic Universal Time to correct it to Universal Time free from changes of short period of the rotation of the Earth.

DATE	**J.D.**	**Corr.**	**DATE**	**J.D.**	**Corr.**	**DATE**	**J.D.**	**Corr.**	**DATE**	**J.D.**	**Corr.**
1955	**2435**	ΔT_S	**1955**	**2435**	ΔT_S	**1956**	**2435**	ΔT_S	**1956**	**2435**	ΔT_S
Nov.			**Feb.**			**June**			**Sept.**		
3	415	-0^{s},024 0	**16**	520	-0^{s},003 4	**3**	630	$+0^{s}$,034 2	**23**	740	-0^{s},027 1
8	420	-0^{s},022 8	**21**	525	-0^{s},002 0	**8**	635	$+0^{s}$,033 1	**28**	745	-0^{s},027 6
13	425	-0^{s},021 5	**26**	530	-0^{s},000 3	**13**	640	$+0^{s}$,031 5	**Oct.**		
18	430	-0^{s},020 1	**Mar.**			**18**	645	$+0^{s}$,029 4	**3**	750	-0^{s},028 1
23	435	-0^{s},018 8	**2**	535	$+0^{s}$,001 5	**23**	650	$+0^{s}$,027 7	**8**	755	-0^{s},028 1
28	440	-0^{s},017 5	**7**	540		**28**	655	$+0^{s}$,024 2	**13**	760	-0^{s},027 7
Dec.			**12**	545		**July**			**18**	765	-0^{s},027 3
3	445	-0^{s},016 3	**17**	550		**5**	660	$+0^{s}$,021 1	**23**	770	-0^{s},026 4
8	450	-0^{s},015 2	**22**	555	$+0^{s}$,010 5	**10**	665	$+0^{s}$,017 7	**28**	775	-0^{s},025 4
13	455	-0^{s},014 1	**27**	560	$+0^{s}$,013 1	**15**	670	$+0^{s}$,014 1	**Nov.**		
18	460	-0^{s},013 2	**April**			**20**	675	$+0^{s}$,010 4	**2**	780	-0^{s},024 2
23	465	-0^{s},012 3	**1**	565	$+0^{s}$,015 7	**25**	680	$+0^{s}$,006 5	**7**	785	-0^{s},023 0
28	470	-0^{s},011 6	**6**	570	$+0^{s}$,018 4	**30**	685	$+0^{s}$,002 6	**12**	790	-0^{s},021 7
1956			**11**	575	$+0^{s}$,021 0	**Aug.**			**17**	795	-0^{s},020 4
Jan.			**16**	580	$+0^{s}$,023 6	**4**	690	-0^{s},001 3	**22**	800	-0^{s},019 0
2	475	-0^{s},010 9	**21**	585	$+0^{s}$,026 0	**9**	695	-0^{s},005 0	**27**	805	-0^{s},017 8
7	480	-0^{s},010 2	**26**	590	$+0^{s}$,028 2	**14**	700	-0^{s},008 6	**Dec.**		
12	485	-0^{s},009 6	**May**			**19**	705	-0^{s},012 0	**2**	810	-0^{s},016 6
17	490	-0^{s},008 9	**1**	595	$+0^{s}$,030 2	**24**	710	-0^{s},015 2	**7**	815	-0^{s},015 4
22	495	-0^{s},008 2	**6**	600	$+0^{s}$,032 0	**29**	715	-0^{s},018 0	**12**	820	-0^{s},014 3
27	500	-0^{s},007 5	**11**	605	$+0^{s}$,033 4	**Sept.**			**17**	825	-0^{s},013 4
Feb.			**16**	610	$+0^{s}$,034 4	**3**	720	-0^{s},020 6	**22**	830	-0^{s},012 5
1	505	-0^{s},006 7	**21**	615	$+0^{s}$,035 0	**8**	725	-0^{s},022 8	**27**	835	-0^{s},011 7
6	510	-0^{s},005 8	**26**	620	$+0^{s}$,035 2	**13**	730	-0^{s},024 6	**1957**		
11	515	-0^{s},004 7	**31**	625	$+0^{s}$,034 9	**18**	735	-0^{s},026 0	**Jan.**		
									1	840	-0^{s},011 0

As the fluctuations in the deceleration of the rotation of the Earth change the scale of time, partly in a random manner, it can not be computed in advance. Moreover, for many efforts extending over less than a year, these fluctuations of deceleration do not alter the uniformity of the time scale during the interval studied, but they change this scale.

Instead, the seasonal fluctuations in the rotation of the Earth have a major influence on the uniformity of the time scale in the work of short-term precision. Thanks to precision clocks the seasonal irregularity in the rotation of the Earth can be determined.

Although the annual fluctuations are not exactly the same from one year to the next, their variations are small: they are of the order of a few units of 10-9 per day. Thus, by correcting the time (UT1) of the variations of the rotation of the Earth determined in previous years, an improvement in the uniformity of the time scale will be obtained. The time thus corrected will be designated by UT2.

Taking into account the studies done in Greenwich, Paris and Washington, the following formula for extrapolating the seasonal variation in Earth's rotation can be adopted for 1956:

(3) $\Delta T_S = +0^s,022 \sin 2\pi t - 0^s,017 \cos 2\pi t - 0^s,007 \sin 4\pi t + 0^s,006 \cos 4\pi t$

where $t = 0$ at the beginning of the year.

Thus, we have the following formula for the provisional uniform Universal Time (UT2) :

(4) $UT2 = UT0 + \Delta\lambda + \Delta T_S = UT1 + \Delta T_S$

From 1 January 1956 the time services shall use the time UT2 for the transmission of time signals using $\Delta\lambda$ (Table C) calculated from the coordinates of the instantaneous pole extrapolated by the B.I.H. and ΔT_S given every 5 days in Table A.

The times of the broadcast time signals entered by the time services shall be calculated using formula (4) by replacing $\Delta\lambda$, extrapolated by interpolated values

(Table B) communicated by the B.I.H. Given the existence of irregularities in the propagation of radio waves and to facilitate their study, the results of the *individual* time services of the wave propagation time between the transmitting station and the observatory *should not be corrected*.

According to Resolution no. 8, the bulletins issued by observatories must contain, in addition to the hours of the time

Table **C** (Circular no. 1)

Instantaneous pole coordinates extrapolated by B.I.H. based on data from the Rapid Service of the International Latitude Service and corresponding corrections of longitude.

(Use only for the transmission of signals)

DATE	**J.D.**	**Extr.**		$\Delta\lambda$									
1955	**2435**	**x**	**y**	**BA**	**Bl**	**G**	**H**	**Ir**	**Kh**	**L**	**M**	**MS**	**Mz**
Dec. 8	450	- 0'',15	+ 0'',30	+ 0^s,013	-15	-25	-24	+19	-12	-21	-15	-16	+18
18	460	- 12	+ 31	+ 12	-17	-26	-26	+17	-14	-24	-17	-16	+17
28	470	- 09	+ 32	+ 11	-18	-27	-25	+15	-16	-26	-19	-15	+17
1956													
Jan. 7	480	- 06	+ 32	+ 10	-18	-27	-27	+12	-18	-28	-21	-14	+16
17	490	- 03	+ 32	+ 09	-19	-27	-28	+09	-19	-30	-23	-14	+14
27	500	+ 01	+ 31	+ 07	-20	-26	-28	+06	-20	-31	-25	-13	+13
Feb. 6	510	+ 04	+ 30	+ 06	-20	-25	-27	+03	-21	-32	-26	-11	+11
16	520	+ 08	+ 29	+ 04	-20	-24	-27	00	-22	-33	-27	-10	+10
26	530	+ 11	+ 27	+ 02	-19	-22	-26	-03	-22	-33	-28	-08	+08
Mar. 7	540	+ 14	+ 25	00	-19	-21	-24	-07	-22	-33	-28	-07	+06

DATE	$\Delta\lambda$														
1955	**N**	**Nk**	**O**	**Pa**	**Pr**	**Pt**	**Pz**	**Rc**	**Rg**	**RJ**	**Ta**	**To**	**U**	**W**	**Z**
Dec. 8	-20	-12	-15	-22	-20	-22	-21	-6	-22	+9	+02	+15	-24	-11	+11
18	-21	-14	-13	-23	-22	-24	-23	-6	-24	+9	00	+15	-25	-10	+11
28	-22	-15	-12	-24	-23	-25	-24	-5	-26	+8	-01	+14	-25	-09	+10
1956															
Jan. 7	-22	-17	-09	-24	-24	-26	-25	-4	-27	+8	-03	+14	-26	-07	+09
17	-22	-18	-07	-24	-24	-26	-26	-3	-29	+7	-05	+12	-26	-05	+08
27	-22	-19	-05	-24	-24	-26	-26	-2	-30	+6	-07	+11	-25	-03	+06
Feb. 6	-22	-19	-02	-23	-24	-26	-26	0	-30	+5	-08	+10	-24	-01	+05
16	-21	-20	00	-22	-24	-26	-26	+1	-30	+4	-10	+08	-23	00	+04
26	-20	-20	+03	-21	-23	-25	-25	+2	-30	+3	-12	+06	-21	+02	+02
Mar. 7	-19	-20	+05	-19	-22	-24	-24	+3	-29	+2	-13	+05	-19	+04	00

signals in UT2, the corrective terms of the formula (4) $\Delta\lambda$ and ΔT_S, as well as their sum which gives UT2 - UT0. We have for l'Observatoire de Paris the following table :

1956	$\Delta\lambda$	ΔT_S	UT2 - UT0
January 1	$-0^s,024$	$-0^s,011$	$-0^s,035$
2	$-0^s,024$	$-0^s,011$	$-0^s,035$
3	$-0^s,024$	$-0^s,010$	$-0^s,034$
4	$-0^s,024$	$-0^s,010$	$-0^s,034$

The corrections $\Delta\lambda$, ΔT_S and UT2 - UT0 can be given every 5 days for the dates on which the Julian Day numbers are divisible by 5.

Mr. A. Danjon, President of the International Astronomical Union and Director of the B.I.H., Sir Harold Spencer Jones, Chairman of the International Commission of Time (Comm. 31) at the General Assembly of the I.A.U. at Dublin and Mr. Wm. Markowitz, current President of the Commission 31, were kind enough to read and critique the article above; I accepted their suggestions and I thank them for this support.

N. STOYKO.

Head of Services of the B.I.H.