BUREAU INTERNATIONAL DES POIDS ET MESURES

Annual Report of the BIPM Time Section
Rapport annuel de la Section du temps du BIPM

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THE NEW ORGANIZATION OF INTERNATIONAL SERVICES FOR TIME (TAI, UTC), EARTH ROTATION AND RELATED REFERENCE SYSTEMS

On the 1st of January 1988, the data and services provided by the Bureau International de l'Heure (BIH) from 1920 to the end of 1987 were reorganized as follows.

INTERNATIONAL ATOMIC TIME, TAI
COORDINATED UNIVERSAL TIME, UTC

The establishment of TAI and UTC (with the exception of the determination and the announcement of leap seconds of UTC) is placed under the responsibility of the Bureau International des Poids et Mesures (BIPM) and of the Comité International des Poids et Mesures (CIPM).

The periodic publications of the Time Section of BIPM are :

- Circular T, monthly, continuing pages 1 and 2 of the previous BIH Circular D (first issue T-1 covering January 1988, mailed on the 1st of March 1988) ;

- Annual Report, similar to the parts devoted to TIME of the previous BIH Annual Report (the present volume is the first of this new series).

Some of the data of the BIPM Time Section, as well as other information, are available by telephone line, either through the General Electric Mark 3 system, or through the BIPM data service. Information concerning access to these services can be obtained on request from the BIPM.

Practical information

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EARTH ROTATION AND RELATED REFERENCE SYSTEMS

The International Earth Rotation Service (IERS), which started operation on the 1st of January 1988, is responsible for Earth rotation determinations and the maintainance of the related celestial and terrestrial reference systems. Information on IERS can be obtained from

Central Bureau of IERS (IERS/CB)
(Head : Dr. M. Feissel)
Observatoire de Paris
61, avenue de l'Observatoire
F-75014 Paris, France

Telephone : + 33 1 40 51 22 26
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One of the tasks of IERS is the determination and the announcement of dates of occurrence of leap seconds of the UTC.

NOUVELLE ORGANISATION DES SERVICES INTERNATIONAUX POUR LE TEMPS (TAI, UTC) ET LA ROTATION DE LA TERRE AINSI QUE LES SYSTEMES DE REFERENCE ASSOCIES

Le 1er janvier 1988, les données et les services sur le temps et la rotation de la Terre que le Bureau international de l'heure (BIH) avait fournis de 1920 à la fin 1987 ont été réorganisés comme suit

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TEMPS ATOMIQUE INTERNATIONAL, TAI
TEMPS UNIVERSEL COORDONNE, UTC

L'établissement de TAI et de UTC (à l'exception de l'annonce des secondes intercalaires de l'UTC) est placé sous la responsabilité du Bureau international des poids et mesures (BIPM) et du Comité international des poids et mesures (CIPM).

Les publications périodiques de la Section du temps du BIPM sont :

- Circulaire T, mensuelle, prenant la suite des pages 1 et 2 de la Circulaire D du BIH (la première circulaire, T-1, couvrant janvier 1988, a été publiée le 1er mars 1988) ;

- Rapport annuel de la Section du Temps, similaire aux parties consacrées au temps du Rapport annuel du BIH (le présent volume est le premier de cette nouvelle série).

Certains résultats des travaux de la Section du temps du BIPM, ainsi que d'autres informations, sont aussi disponibles par ligne téléphonique, soit par le système informatique General Electric Mark 3, soit par un service de données propre au BIPM. L'accès à ces services sera expliquée sur demande faite au BIPM.

Renseignements pratiques

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ROTATION DE LA TERRE
SYSTEMES DE REFERENCE ASSOCIES

Le Service international de la rotation terrestre (IERS), entré en fonction le 1er janvier 1988, est responsable de la détermination de la rotation terrestre et de la conservation des systèmes de référence terrestre et céleste associés. Les renseignements sur l'IERS et ses publications peuvent être obtenus à l'adresse suivante :

Bureau Central de l'IERS (IERS/CB)
(Directeur : Mme M. Feissel)
Observatoire de Paris
61, avenue de l'Observatoire
F-75014 Paris, France

téléphone : + 33 1 40 51 22 26
Télex : OBS 270776 F

L'une des missions de l'IERS est le choix des dates et l'annonce des secondes intercalaires de l'UTC.

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PARTIE A

INFORMATIONS GENERALES

EXPLICATION DES TABLEAUX

1 - ATOMIC TIME SCALES

ESTABLISHMENT OF INTERNATIONAL ATOMIC TIME AND COORDINATED UNIVERSAL TIME IN 1988

International Atomic Time (TAI) and Coordinated Universal Time (UTC) are obtained from a combination of atomic clocks and frequency standards data, as explained in part D of this report.

We recall that, to this end, a stability algorithm ALGOS produces first a free atomic time scale, denoted EAL (Echelle atomique libre). EAL is optimized for the stability for two-month sample time. No attempt is made to ensure the conformity of the EAL unitary scale interval with the second of the International System of Units: this interval may diverge progressively from the second.

The duration of the unitary scale interval of EAL is evaluated from the data of primary cesium standards. Then TAI is derived from EAL by adding a linear function of time with a convenient slope to ensure the accuracy of the TAI unitary scale interval. The frequency offset between TAI and EAL is changed as necessary to maintain accuracy, the magnitude of the changes being of the same order as the frequency fluctuations resulting from the instability of EAL. This operation is often called "steering" of TAI.

TAI and UTC are made available in the form of time differences with respect to time scales kept by national laboratories "k": UTC(k), approximation to UTC, and TA(k), independent local atomic time.

These differences UTC - UTC(k), TAI - TA(k), are computed at 10-day intervals for Modified Julian Dates (MJD) ending by 9, at 0 h UTC, thereafter designated as "standard dates".

The computation of TAI has a basic periodicity of two months. However a provisional computation is made every other month (January, March, etc.) with the data which are available. The following month, TAI is re-computed for the whole span of two months. The deviations between the provisional one month and complete two month solutions are usually smaller than 10 ns. This organization allows the monthly publication of results in the BIPM Circular T.

When preparing the Annual Report, the results of Circular T are revised taking into account some improvements in the data made known after the publication of Circular T. The computations are then made strictly by six two-month batches.

In the following, and everywhere in this Report, the laboratories are designated by the acronyms explained in Table 1 of Part B.

Time links used by the BIPM in 1988

Figure 1 at the end of Section B shows the network of links used in 1988.

(a) LORAN-C links

The laboratories where only LORAN-C is received are linked to "pivot" laboratories where both LORAN-C and GPS are received. Simultaneous receptions of the LORAN-C signals have been organized.

The time differences of the UTC(k)'s of the laboratories are computed daily, then the values at the standard dates are evaluated by linear fit over 10 days (5 before and 5 after the standard date), except when time or frequency steps of the UTC(k)'s are reported or found.

The following LORAN-C time comparisons are evaluated by BIPM and used in the TAI computations (end 1988) :

FTZ - PTB
BEV - OP
PKNM - OP
SU - OP, until 1988 July 27
CAO - IEN
YUZM - IEN
CSAO - TAO
JATC - TAO
NAOM - TAO
NRLM - TAO
NIM - TAO
SO - TAO

(b) GPS links

The time comparisons are made by simultaneous tracking of satellites ("common views") according to schedules established by BIPM.

In the TAI computations, the following GPS links are used (end 1988) :

IEN - OP
IFAG - OP
INPL - OP
NPL - OP
NPLI - OP
ORB - OP
PTB - OP
ROA - OP computed by BIPM
STA - OP
TUG - OP
USNO - OP
VSL - OP
KSRI - TAO
TL - TAO
USNO - TAO

NRC - NIST USNO - NIST	computed by NIST
APL - USNO	computed by APL
AUS - USNO	computed by ORR
CRL - USNO	computed by CRL
CH - PTB	computed by CH

The link USNO-OP was reinforced by adding observations in common view to the normal schedule, the number of daily common views reaching 23 instead of 9. For this link, measured values of the ionospheric delay in the Paris area, have been used since November 1988 [Imae, M., Lewandowski, W., Thomas, C., Miki, C., A dual frequency GPS receiver measuring ionospheric effects without code demodulation and its application to time comparisons, Proc. 20th PTTI meeting (1988)].

For the European links involving IEN, NPL, OP, ORB, PTB, TUG, VSL, corrections to the adopted coordinates of the antennas have been applied. These corrections were derived from the time comparisons themselves [Guinot, B., Lewandowski, W., Nanosecond time comparisons in Europe using GPS, Proc. Europ. Freq. and Time Forum, 1988, pp. 187-194].

Several measurements of relative instrumental delays of GPS receivers have been organized by NIST, OP and BIPM. They are mentioned in Table 6. Their results have been taken into account.

(c) Other links

The simultaneous reception of public television signals provides the links

PTB - ASMW
ASMW - ZIPE
ZIPE - AOS
PTB - TP
TP - OMH.

On the other hand, as the LORAN-C link SU-OP became exceedingly noisy in August 1988, UTC-UTC(SU) was derived from August to December 1988 from UTC(SU)-UTC(k), measured by SU clock transportations to various european laboratories.

<u>Accuracy of the TAI scale interval</u>

Table A gives the frequency offsets between EAL and TAI. The relationship TAI-EAL has not been changed, in principle, since 1984 February 29.

However, when revising the computations of TAI for 1987, it was found that the value of TAI for 1987 December 30 differed by 27 ns from the value already published in BIH Circular D, owing to an error in May 1987. In order to align the results for 1988 with the revised results for 1987, while avoiding a step of 27 ns, the TAI-EAL relationship between 1987 April 24 and 1987 December 30 (MJD 46909 to 47159) was slightly modified by a rate change of 0.108 ns/d, corresponding to 1.25×10^{-15} in relative frequency.

Table A - Differences between the normalized frequencies of EAL and TAI (until February 1989)

Date	MJD	f(EAL) - f(TAI) in 10^{-13}
until 1977 JAN 1	until 43144	0
1977 JAN 1 - 1977 APR 26	43144 - 43259	10.0
1977 APR 26 - 1977 JUN 25	43259 - 43319	9.8
1977 JUN 25 - 1977 AUG 24	43319 - 43379	9.6
1977 AUG 24 - 1977 OCT 23	43379 - 43439	9.4
1977 OCT 23 - 1978 OCT 28	43439 - 43809	9.2
1978 OCT 28 - 1979 JUN 25	43809 - 44049	9.0
1979 JUN 25 - 1979 AUG 24	44049 - 44109	8.8
1979 AUG 24 - 1979 OCT 23	44109 - 44169	8.6
1979 OCT 23 - 1982 APR 30	44169 - 45089	8.4
1982 APR 30 - 1982 JUN 29	45089 - 45149	8.2
1982 JUN 29 - 1982 AUG 28	45149 - 45209	8.0
1982 AUG 28 - 1984 FEB 29	45209 - 45759	7.8
1984 FEB 29 - 1987 APR 24	45759 - 46909	8.0
1987 APR 24 - 1987 DEC 30	46909 - 47159	8.0125
1987 DEC 30 -	47159 -	8.0

As the time scales UTC and TAI differ by an integral number of seconds (see Tables 2 and 3), UTC is therefore submitted to the same intentional frequency adjustement as TAI.

TIME SCALES ESTABLISHED IN RETROSPECT

For the most demanding applications, such as millisecond pulsar timing, BIPM issues atomic time scales in retrospect designated as TT(BIPMxx) where 1900 + xx is the year of the computation. The successive versions of TT(BIPMxx) are not only updates, but also revisions: they may differ for common dates.

The principles of establishment of TT(BIPMxx) are described by Guinot, B. in "Atomic time scales for pulsar studies and other demanding applications, Astron. and Astrophys., 192, 1988, pp. 370-373".

These time scales are available on request from BIPM.

EXPLANATIONS OF THE TABLES

TABLE 1

ATOMIC TIME, COLLABORATING LABORATORIES

The table lists the laboratories contributing data on atomic time, with the abbreviations used in this Report.

TABLE 2

FREQUENCY OFFSETS AND STEP ADJUSTMENTS OF UTC

From 1961 January 1 to 1989 June 30.

TABLE 3

RELATIONSHIP BETWEEN TAI AND UTC

From 1961 January 1 to 1989 June 30.

TABLE 4

LABORATORIES KEEPING AN INDEPENDENT LOCAL ATOMIC TIME

The Table gives, for 1988, the equipment of the laboratories which compute an independent local atomic time TA(k) and the relationship between TA(k) and UTC(k) (or the references for finding the values of TA(k)-UTC(k)).

TABLE 5

EQUIPMENT AND TIME LINKS OF THE COLLABORATING LABORATORIES

The Table shows the equipment (number and type of clocks) and the time links available in the collaborating laboratories in 1988. See also figure 1, end of section B.

TABLE 6

ABSOLUTE TIME COMPARISONS BETWEEN LABORATORIES

A. Clock transportation

Unless otherwise stated, the transportation was carried out by the first-mentioned laboratory.

B. GPS time comparisons with differential calibration of receiver delays.

Some measurements of differential delays are performed by transportation of a GPS time receiver used as a transfer standard. Assuming that the laboratories are linked by tracking simultaneously 10 GPS satellites per day (common views) the total uncertainty of the clock comparison which is reported in Table 6B is conservatively estimated by the quadratic combination of the following elements:

(i) uncertainty of the calibration (usually of the order of 1 ns);
(ii) uncertainty due to the ephemerides and the differential refraction, given in nanoseconds as a function of the linear distance D between the laboratories, in km, by D/500;
(iii) a local systematic error, due to geodetic coordinates and other causes, of 5 ns;
(iv) a local random uncertainty of 5 ns due to the noise of the measurements and of the time scales.

TABLE 7

INDEPENDENT LOCAL ATOMIC TIME SCALES

The Table gives the values of TAI-TA(k) for laboratories k where independent atomic times TA(k) are established. The data are rounded to 10 ns for laboratories using LORAN-C and television links.

TABLE 8

PRIMARY FREQUENCY STANDARDS USED AS CLOCKS

Five primary frequency standards were used as clocks in 1988: Cs V, Cs VI-A, Cs VI-C of NRC, CS1 and CS2 of PTB. Table 8 gives TAI-standard.

TABLE 9

COORDINATED UNIVERSAL TIME

The Table gives the value of UTC-UTC(k), where UTC(k) designates the approximation to UTC kept by the laboratory k. The values are based on permanent links: GPS, LORAN-C, television (for Very Low Frequency links, see Table 9A). The data are rounded off to 10 ns for the laboratories using LORAN-C and television links.

TABLE 9A

COORDINATED UNIVERSAL TIME (VLF)

The origin of the published UTC-UTC(k) is adjusted by the last available clock transportation to laboratory k.

TABLE 9B

TAI-GPS TIME AND UTC-GPS TIME

The GPS satellites which appear in this section disseminate, to within about ± 20 ns (1 σ), a common time scale designated here as "GPS time". The relation between GPS time and TAI is

$$\text{TAI} - \text{GPS time} = 19\ \text{s} + \text{Co},$$

where the time difference of 19 seconds is kept constant and Co is a quantity of the order of a few microseconds, varying with time. The relation between GPS time and UTC involves a variable number of seconds as a consequence of the leap seconds of the UTC system . In January 1989,

$$\text{UTC} - \text{GPS time} = -\ 5\ \text{s} + \text{Co}.$$

This relation will be valid until the introduction of the next leap second.

Table 4 provides Co at 0 h UTC every day. In most applications TAI and UTC can be derived from the tracking of any of the listed satellites, at any time, by interpolating Co.

The synchronisation offset between satellites, DC, as measured at the Paris Observatory, is also given at T, the time of the day (corresponding to tracking schedule at the Paris Observatory). The time T is given at the top of the table for the first tabular date; it must be decremented by 4 minutes per day (8 minutes when moving from 0 h ... to 23 h ...). When the synchronisation offset is large, it might be possible to improve the access to TAI and UTC by replacing Co by Co + DC. The values of DC are computed using the best available coordinates in WGS 84, and, since November 1988 with measured ionospheric delays.

GPS(i) being the time disseminated by GPS satellite i, at the time T(i) of its observation at Paris Observatory, one has strictly

$$\text{UTC(OP)} - \text{GPS(i)} = -\ 5\ \text{s} + \text{Co} + \text{DC} - \left[\text{UTC} - \text{UTC(OP)}\right],$$

Co and UTC-UTC(OP) being interpolated linearly.

TABLE 10

COMPARISON BETWEEN ABSOLUTE TIME COMPARISONS AND THE BIPM RESULTS

For the time comparisons listed in Table 6, Table 10 gives the residuals "measurement minus BIPM data". The BIPM data are deduced from Table 9.

TABLE 11

INTERNATIONAL ATOMIC TIME, BI-MONTHLY RATES OF TAI-CLOCK FOR 1988

The mean rates for intervals of two months are given for all the clocks which participated in the TAI computation in 1988. Similar tables are published in the BIH Annual Report, starting with 1972 January.

When an intentional frequency adjustement has been applied to a clock, the data prior to this adjustment are corrected, so that Table 11 gives homogeneous rates for the whole of the year 1988. However for studies including the rates of previous years, corrections must be brought to the data of BIH Annual Report of 1987 and before. These corrections are given by Table B.

When the operation of a clock is resumed after an interruption, marked*** in Tables 11 and 12, it is considered as a new clock.

TABLE 12

INTERNATIONAL ATOMIC TIME, WEIGHTS OF THE CLOCKS FOR 1988

It should be remembered that the weights have an assigned upper limit. In 1988, after the change of weighting procedure explained in Part D, the maximum weight was 100.

A clock appears to BIPM through the intercomparison method and therefore the Table reflects the combined instability of the clock and of the time intercomparison. On the other hand, the weights of Table 12 correspond to the long term stability of the clocks (2 months sample time) which is, in particular, dependent on the conditions of operation. For these two reasons, the weights should not be used as a general factor of quality of these clocks.

TABLE B - Corrections for an homogeneous use of the bi-monthly rates and weights published in the current and previous Annual Reports. Each line refers to the same clock working without interruption.

Lab.	1988 clock n°	1987 clock n°	1987 corr. (ns/d)	1986 clock n°	1986 corr. (ns/d)	1985 clock n°	1985 corr. (ns/d)
APL	14 773	14 773	+20.00	14 773	+20.00	14 773(1)	+20.00
CRL	14 932	14 932	+13.00	14 932	+13.00	14 932(2)	+13.00
	14 2456	14 2456		14 2456	+41.00	14 2456	+41.00
CSAO	12 1646	12 1646	+41.60	12 1646	+41.60		
	12 1647	12 1647		12 1647	+20.60		
	12 1648	12 1648		12 1648	+98.60	12 1648	+98.60
FTZ	14 1674	14 1674		14 1674		14 1674(3)	
NAOM	14 614	14 614		14 614		14 614	-17.28
NIM	12 1615	12 1615		12 1615	-940.67	12 1615(4)	-940.67
NIST	12 352	12 352		12 352	+17.00		
	14 323	14 323	-6.84	14 323	-6.84		
	14 324	14 324	+17.11	14 324	+24.81	14 324(5)	+24.81
ROA	14 1569	14 1569	-13.00	14 1569	-13.00		
	16 177	16 177	+46.00	16 177	+46.00	16 177(6)	+46.00
USNO	14 2314	14 2314	+31.00				
VSL	14 503	14 503		14 503		14 503(7)	+43.20

(1) A correction of +20.00 ns/d has to be applied in 1983 and 1984.

(2) A correction of +13.00 ns/d has to be applied for the last three two-month intervals of 1984.

(3) A correction of -19.50 ns/d has to be applied for the last four two-month intervals of 1982.

(4) A correction of -940.67 ns/d has to be applied for the last two two-month intervals of 1984.

(5) A correction of +24.81 ns/d has to be applied in 1984.

(6) A correction of +46.00 ns/d has to be applied for the last two month interval of 1984.

(7) A correction of +43.20 ns/d has to be applied in 1982, 1983, 1984 and for the last three two-month intervals of 1981.

Table C - Statistical data on the weights attributed to the clocks in 1988.

Interval 1988	Total Number of clocks	Number of clocks with a given weight							
		weights 0*	0**	weight 1-19	weight 20-39	weight 40-59	weight 60-79	weight 80-99	weight 100
JAN-FEB	166	25	18	57	17	14	7	4	24
MAR-APR	168	26	12	63	17	12	7	5	26
MAY-JUN	169	31	7	63	21	13	5	6	23
JUL-AUG	178	36	14	57	26	11	5	4	25
SEP-OCT	167	30	10	54	26	8	8	6	25
NOV-DEC	174	28	17	63	19	15	4	4	24

* A priori null weights (test interval of new clocks).
** Null weights resulting from the statistics.
Clocks with missing data during a two-month interval of computation are excluded.

Table C, contains some statistical data on the clocks which participated in the TAI computation in 1988.

TABLE 13

MEASUREMENTS OF THE EAL AND TAI FREQUENCY

Table 13 gives the differences which were measured in 1984-1988 between the normalized frequencies of EAL and TAI and of the laboratory cesium standards CRL-Csl, NIST-6, NRC-CsV, NRC-CsVI-A, C, PTB-CS1, PTB-CS2, SU-MCsR 101, SU-MCsR 102.

The standard NIST-6 (previously NBS-6) is operated in discontinuous mode. The calibration data, referred to UTC(NIST) are transferred to EAL and TAI by a linear adjustment of EAL-UTC(NIST) over 80 days.

The standard NRC-CsV has been working as a clock since May 1975. The EAL and TAI calibrations result from a linear adjustment of EAL-standard over 60-day intervals.

The standards NRC-CsVI-A, C are used as clocks since the end of 1979 and the calibration data are transferred to EAL as for NRC-CsV.

The standard PTB-CS1 was used as a frequency reference operating discontinuously until July 1978. Since then it has been running as a clock, and the calibrations are obtained as for NRC-CsV.

The standard PTB-CS2 runs as a clock. The data starting from August 1986 were received at BIH and used in the same way as those of PTB-CS1.

The standard CRL-Cs1 (previously RRL-Cs1) performs discontinuous calibrations of UTC(CRL) which are transferred to EAL by linear adjustment of EAL-UTC(CRL) over 60 days.

The standards SU-MCsR 101 and SU-MCsR 102 provide the frequency of TA(SU) and UTC(SU). The transfer to EAL is made by averaging the frequency difference of TA(SU) and EAL over several months.

TABLE 14

MEAN DURATION OF THE TAI SCALE INTERVAL IN SI SECOND AT SEA LEVEL

The estimate is made by the BIPM with the filter described in "Azoubib J., Granveaud M., Guinot B., Metrologia 13, 1977, pp. 87-93". It is based on the calibrations of Table 13. Special care has been taken so that the seasonal frequency variation which is observed between EAL and the primary standards is not smoothed out.

2 - TIME SIGNALS

Part C of the Report (yellow pages) contains information on the time signal emissions in the UTC system.

a - Until 1971 December 31, 23 h 59 m 60.1077580 s, UTC (old), the relationship between UTC and TAI included an internationally agreed frequency offset. Tables 2 and 3 of Part B give the relationship.

b - At the above-mentioned date, a time-step of - 0.1077580 s was applied to UTC and this date became 1972 January 1, 0 h UTC (new) exactly. The new UTC is such as TAI-UTC be equal to an integral number of seconds, in accordance with Recommendation 460-4 (1986) of the International Radio Consultative Committee (CCIR).

The information on the time signals is based on the answers to a questionnaire of February 1989. More detailed information may be obtained from the addresses listed on pages C-2 - C-4.

3 - BIPM TIME SECTION

The following persons participated in the activities of the BIPM time section, in 1988:

Prof.	B. Guinot,	Head
Dr.	C. Thomas,	Physicist
Dr.	W. Lewandowski,	"
Mr.	J. Azoubib,	"
Miss	H. Konaté,	Technician
Mr.	M. Imae*,	Visitor (until 31 October 1988)

* Mr. M. Imae, Engineer of the Communications Research Laboratory, Tokyo, Japan, worked at BIPM from 1 October 1987 to 31 October 1988.

1 - ECHELLES DE TEMPS ATOMIQUE

ETABLISSEMENT DU TEMPS ATOMIQUE INTERNATIONAL ET DU TEMPS UNIVERSEL COORDONNE EN 1988

Le Temps atomique international (TAI) et le Temps Universel coordonné (UTC) sont obtenus par une combinaison de données d'horloges atomiques et d'étalons primaires de fréquence, comme cela est expliqué, partie D de ce rapport.

Nous rappelons que, pour cela, un algorithme de stabilité ALGOS produit d'abord une "échelle atomique libre" (EAL) qui est optimisée pour la stabilité sur 2 mois. Il n'est pas tenté d'assurer la conformité de l'intervalle unitaire de l'EAL avec la seconde du Système international d'unités, elle peut en diverger lentement, mais indéfiniment.

La durée de cet intervalle unitaire de l'EAL est évaluée à partir des données d'étalons de fréquence à césium primaires. Ensuite le TAI se déduit de l'EAL par l'addition d'une fonction linéaire du temps dont la pente est convenablement choisie pour assurer l'exactitude de l'intervalle unitaire du TAI. Le décalage de fréquence entre le TAI et l'EAL est changé quand c'est nécessaire pour maintenir l'exactitude, les changements ayant le même ordre de grandeur que les fluctuations de fréquence qui résultent de l'instabilité de l'EAL. Cette opération est souvent désignée par l'expression "pilotage du TAI".

Le TAI et l'UTC sont disponibles sous forme de différences de temps avec les échelles de temps conservées par des laboratoires horaires nationaux "k" : UTC(k), approximation de UTC, et TA(k), temps atomique local indépendant.

Les différences UTC - UTC(k), TAI - TA(k), sont calculées de 10 jours en 10 jours pour les dates juliennes modifiées (MJD) se terminant par 9, à 0 h UTC, "dates normales".

Le calcul du TAI doit être fait, en principe, tous les deux mois. Mais un calcul provisoire est fait un mois sur deux (pour janvier, mars, ...) avec les données disponibles. Le mois suivant, le calcul du TAI est repris pour une durée de deux mois. L'écart entre les résultats des calculs provisoires et complets est ordinairement inférieur à 10 ns. Cette organisation permet la publication mensuelle des résultats dans la Circulaire T du BIPM.

Quand le Rapport annuel est préparé, les résultats de la circulaire T sont révisés, compte-tenu d'améliorations des données, connues après la publication de la Circulaire T. Les calculs sont alors strictement faits par période de deux mois.

Dans la suite et dans tout ce rapport, les laboratoires sont désignés par les sigles expliqués dans la table 1 de la partie B.

Liaisons horaires utilisées par le BIPM en 1988

Ces liaisons montrées par la figure 1 de la section B procurent les différences entre les UTC(k) des laboratoires participants, pour les dates normales. Elles sont établies
- par le LORAN-C,
- par le Global Positioning System, GPS,
- par la réception d'impulsions de la télévision publique.

Dans toutes ces méthodes on fait appel à la réception simultanée des signaux et l'on recherche la meilleure estimation des différences des UTC(k) aux dates normales. On a aussi utilisé pour calculer UTC - UTC(SU), à partir d'août 1988, des transports d'horloges, organisés par SU, entre SU et d'autres laboratoires européens.

L'ensemble des liaisons utilisées est donné dans le texte anglais qui précède. Il est sans redondance.

Pour le réseau de liaisons horaires par GPS, on a privilégié le lien OP-USNO en introduisant des poursuites en supplément au programme international normal. Pour cette liaison, on dispose de mesures du retard ionosphérique dans la région parisienne, à partir de novembre 1988, grâce à un récepteur à double fréquence construit par Mr Imae, du CRL, et en service au BIPM.

Les liaisons par GPS entre laboratoires européens ont été améliorées par l'usage de coordonnées géodésiques relatives déterminées au BIPM à partir des comparaisons horaires elles-mêmes.

Plusieurs mesures de retards instrumentaux relatifs de récepteurs du GPS ont été organisées par le NIST, l'OP et le BIPM. Elles sont mentionnées dans la table 6. Leurs résultats ont été pris en compte.

Exactitude de l'intervalle unitaire du TAI

Le tableau A (texte anglais) donne le décalage de fréquence entre le TAI et l'EAL. La relation entre TAI et l'EAL est, en principe, restée inchangée depuis 1984 février 29. Cependant, lorsque les calculs du TAI ont été révisés en 1987, on a obtenu pour 1987 décembre 30 une valeur du du TAI qui différait de 27 ns de la valeur déjà publiée dans la Circulaire D-255 du BIH, à cause d'une erreur faite en mai 1987. Pour aligner les résultats pour 1988 avec les résultats révisés de 1987, tout en évitant un saut de 27 ns, on a modifié la relation TAI-EAL entre 1987 avril 24 et 1987 décembre 30, le décalage de fréquence étant devenu $8{,}0125 \times 10^{-13}$, au lieu de $8{,}0000 \times 10^{-13}$.

ECHELLES DE TEMPS ETABLIES RETROSPECTIVEMENT

Pour les applications les plus exigeantes, comme le chronométrage des pulsars à la milliseconde, le BIPM produit des échelles de temps rétrospectivement, désignées par TT(BIPMxx), 1900 + xx étant l'année du calcul. Les versions successives de TT(BIPMxx) ne sont pas seulement des mises à jour, mais aussi des révisions, de sorte qu'elles peuvent différer pour les dates communes.

Les principes de l'établissement du TT(BIPMxx) ont été décrits par Guinot, B. dans "Atomic time scales for pulsar studies and other demanding applications, Astron. and Astrophys., 192, 1988, pp. 370-373".

Ces échelles de temps sont disponibles sur demande faite au BIPM.

EXPLICATION DES TABLEAUX

TABLEAU 1

TEMPS ATOMIQUE, LABORATOIRES COOPERANTS

Abréviations utilisées dans ce rapport.

TABLEAU 2

DECALAGES DE FREQUENCE ET AJUSTEMENT PAR SAUT DE L'UTC

De 1961 janvier 1 à 1989 juin 30.

TABLEAU 3

RELATION ENTRE LE TAI ET L'UTC

De 1961 janvier 1 à 1989 juin 30.

TABLEAU 4

LABORATOIRES CONSERVANT UN TEMPS ATOMIQUE LOCAL INDEPENDANT

Le tableau indique, pour 1988, l'équipement des laboratoires qui calculent une échelle de temps atomique local indépendant TA(k) et la relation entre TA(k) and UTC(k) (ou la référence des documents où se trouve cette relation).

TABLEAU 5

EQUIPEMENT ET LIAISONS HORAIRES DES LABORATOIRES COOPERANTS

Le tableau indique l'équipement (nombre et type des horloges) et les liaisons horaires dont disposaient les laboratoires coopérants en 1988.

TABLEAU 6

COMPARAISONS DE TEMPS ABSOLUES ENTRE LABORATOIRES

A. Transports d'horloges

Sauf mention contraire, le transport a été effectué par le laboratoire mentionné en premier.

B. Comparaisons horaires par le GPS avec étalonnage des retards relatifs des récepteurs.

Des mesures de retards relatifs ont été accomplies par transfert d'un récepteur horaire du GPS pris comme étalon de transfert. Dans l'hypothèse où les laboratoires sont liés par une dizaine de poursuites simultanées par jour (vues communes), l'incertitude totale qui figure dans le tableau 6B est estimée d'une manière prudente par la combinaison quadratique des éléments suivants :

1. incertitude de l'étalonnage (habituellement de l'ordre d'une nanoseconde) ;
2. incertitude due aux éphémérides et à la réfraction différentielle, donnée en nanosecondes en fonction de la distance linéaire D, en kilomètres, entre les laboratoires par D/500 ;
3. une erreur systématique locale, due aux coordonnées géodésiques ou à d'autres causes, de 5 ns ;
4. une incertitude aléatoire de 5 ns due au bruit de mesure et aux échelles de temps.

TABLEAU 7

TEMPS ATOMIQUES LOCAUX INDEPENDANTS

Le tableau donne les valeurs de TAI-TA(k) pour les laboratoires k où des temps atomiques locaux indépendants TA(k) sont établis. Les valeurs sont arrondies à 10 ns pour les laboratoires utilisant le LORAN-C ou des liaisons par télévision.

TABLEAU 8

ETALONS PRIMAIRES DE FREQUENCE UTILISES COMME HORLOGES

Cinq étalons primaires de fréquence ont été utilisés comme horloges en 1988 : CsV, Cs VI-A, Cs VI-C du NRC, CS1 et CS2 de la PTB. Le tableau 8 donne TAI-étalon.

Les échelles de temps délivrées pour les étalons du NRC n'ont subi aucune correction pour le décalage gravitationnel de fréquence. Pour exprimer leur marche au niveau de la mer, il faut ajouter une correction de - 0,000 97 µs/jour.

Au contraire les échelles de temps délivrées par les étalons de la PTB sont converties en temps-coordonnée suivant la même définition que le TAI. La correction de marche qui leur a été appliquée est - 0,000 66 µs/jour.

TABLEAU 9

TEMPS UNIVERSEL COORDONNE

Le tableau donne les valeurs de UTC-UTC(k), où UTC(k) désigne l'approximation du UTC qui est conservée par le laboratoire k. Ces valeurs reposent sur des liaisons horaires permanentes, par GPS, LORAN-C, et télévision (pour les liaisons VLF, voir le tableau Table 9A). Les valeurs sont arrondies à 10 ns pour le LORAN-C et la télévision.

TABLEAU 9A

TEMPS UNIVERSEL COORDONNE (VLF)

L'origine des UTC-UTC(k)publiés est fixée par le dernier transport d'horloge effectué dans le laboratoire k.

TABLEAU 9B

UTC-TEMPS DU GPS ET TAI-TEMPS DU GPS

Les satellites du Global Positioning System (GPS) qui figurent dans cette rubrique diffusent à une ou deux dizaines de nanosecondes près une échelle de temps commune appelée ici "temps du GPS". La relation de cette échelle avec TAI est

$$\text{TAI - temps du GPS} = 19 \text{ s} + \text{Co},$$

où l'intervalle de 19 secondes est constant et où Co est une quantité de l'ordre de quelques microsecondes, variable avec le temps. On a aussi, en janvier 1989 et jusqu'à l'introduction d'une nouvelle seconde intercalaire dans le système du UTC :

$$\text{UTC - temps du GPS} = -5 \text{ s} + \text{Co}.$$

Le tableau 9B donne Co pour chaque jour à 0 h UTC. Pour la plupart des applications il suffit de déduire le TAI et l'UTC de l'observation de n'importe quel satellite du tableau, à n'importe quel instant, par interpolation de Co.

L'écart de synchronisation entre satellites, DC, tel qu'il est mesuré à l'Observatoire de Paris est aussi fourni pour chaque jour à une heure T particulière à chaque satellite (qui correspond aux observations programmées à l'Observatoire de Paris) L'heure T est donnée en haut du tableau pour la première date tabulée ; elle doit être diminuée de 4 minutes par jour (8 minutes quand on passe de 0 h ... à 23 h ...). Dans les cas où l'écart de synchronisation est important, on peut espérer améliorer l'accès au TAI et à l'UTC en remplacant Co par Co + DC. Pour calculer DC, on a tenu compte des meilleures coordonnées connues dans le WGS 84 pour l'antenne du récepteur et de valeurs mesurées de la réfraction ionosphérique à partir de novembre 1988.

GPS(i) étant le temps diffusé par le satellite i du GPS, à l'instant T(i) de son observation à l'Observatoire de Paris, on a strictement

$$\text{UTC(OP)} - \text{GPS}(i) = -5 \text{ s} + \text{Co} + \text{DC} - \left[\text{UTC} - \text{UTC(OP)}\right],$$

Co et UTC-UTC(OP) étant interpolés linéairement.

TABLEAU 10

COMPARAISON ENTRE LES COMPARAISONS DE TEMPS ABSOLUES ET LES RESULTATS DU BIPM

Pour les comparaisons de temps figurant au tableau 6, le tableau 10 donne les résidus "mesure moins données du BIPM". Les données du BIPM sont obtenues par interpolation du tableau 9.

TABLEAU 11

TEMPS ATOMIQUE INTERNATIONAL, MARCHES BIMESTRIELLES DE TAI-HORLOGE POUR 1988

Les marches moyennes sur des intervalles de deux mois sont données pour toutes les horloges qui ont participé à l'établissement du TAI en 1988. On trouvera des tables similaires, depuis janvier 1972, dans les Rapports annuels du Bureau international de l'heure.

Quand la fréquence d'une horloge a été intentionnellement changée, les données qui précédent ce changement ont été corrigées, de sorte que le tableau 11 fournit des marches homogènes pour toute l'année 1988. Cependant, dans des études qui incluent les années antérieures, des corrections doivent être apportées aux tableaux correspondants des Rapports annuels du BIH pour 1987 et auparavant. Ces corrections sont données dans le tableau B (texte anglais).

Quand le fonctionnement d'une horloge reprend après une interruption, marquée par *** dans les tableaux 11 et 12, elle est considérée comme une horloge nouvelle.

TABLEAU 12

TEMPS ATOMIQUE INTERNATIONAL, POIDS DES HORLOGES POUR 1988

On rappelle que l'on a assigné aux poids statistiques des horloges une limite supérieure. En 1988, après le changement de pondération expliqué dans la partie D de ce rapport, le poids maximal est 100.

Une horloge apparaît au BIPM à travers les méthodes de comparaison de temps. Par suite, le tableau 12 reflète l'instabilité combinée de l'horloge et de ces comparaisons de temps. D'autre part, les poids du tableau 12 correspondent à la stabilité de fréquence à long terme, sur des échantillons de deux mois, qui dépend, en particulier, des conditions dans lesquelles l'horloge fonctionne. Pour ces deux raisons, les poids ne doivent pas être utilisés comme un témoin général de la qualité des horloges.

Le tableau C (texte anglais), semblable aux tableaux donnés depuis 1973 dans les Rapports annuels du BIH, contient quelques données statistiques sur les horloges qui ont participé à l'établissement du TAI en 1988.

TABLEAU 13

MESURES DE LA FREQUENCE DE L'EAL ET DU TAI

Le tableau 13 donne les différences entre les fréquences mesurées d'EAL et du TAI et celles des étalons à césium primaires des laboratoires : CRL-Cs1, NIST-6, NRC-CsV, NRC-CsVI-A, C, PTB-CS1, PTB-CS2, SU-MCsR 101, SU-MCsR 102.

L'étalon NIST-6 (antérieurement NBS-6) fonctionne en mode discontinu. Les résultats d'étalonnage, rapportés à UTC(NIST) sont transférés à l'EAL et au TAI par ajustement linéaire de EAL-UTC(NIST) sur 80 jours.

L'étalon NRC-CsV fonctionne comme horloge depuis mai 1975. Les résultats d'étalonnage de l'EAL et du TAI proviennent d'ajustements linéaires de EAL-étalon sur des intervalles de 60 jours.

Les étalons NRC-CsVI-A, C fonctionnent comme horloges depuis fin 1979. Les étalonnages sont obtenus comme ceux de NRC-CsV.

L'étalon PTB-CS1 a fonctionné d'une manière discontinue jusqu'en juillet 1978. Depuis, il fonctionne en horloge et les étalonnages de l'EAL et du TAI sont obtenus comme ceux de NRC-CsV.

L'étalon PTB-CS2 fonctionne comme horloge. Ses données ont été reçues par le BIH puis le BIPM depuis août 1986. Elles sont utilisées comme celles de PTB-CS1.

L'étalon CRL-Cs1 (antérieurement RRL-Cs1) donne d'une manière discontinue, la fréquence de UTC(CRL). Ces étalonnages sont transférés à l'EAL et au TAI par ajustement linéaire de EAL-UTC(CRL) sur 60 jours.

Les étalons SU-MCsR 101 et SU-MCsR 102 donnent la fréquence de TA(SU) et UTC(SU). Le transfert à l'EAL et au TAI repose sur un calcul de la différence de fréquence moyenne de EAL et TA(SU) sur plusieurs mois.

TABLEAU 14

DUREE MOYENNE DE L'INTERVALLE UNITAIRE DU TAI EN SECONDES DU SI AU NIVEAU DE LA MER

L'estimation utilise le filtre décrit dans "Azoubib J., Granveaud M., Guinot B., Metrologia 13, 1977, pp. 87-93", en utilisant les étalonnages du tableau 13. Un soin particulier a été apporté pour que les variations saisonnières qui ont été observées entre l'EAL et les étalons primaires ne soient pas réduits par lissage.

2 - SIGNAUX HORAIRES

La partie C du rapport (pages jaunes) donne les principales caractéristiques des émissions de signaux horaires dans le système du UTC.

a - Jusqu'en 1971 décembre 31, 23 h 59 m 60,1077580 s, UTC (ancien), la relation entre l'UTC et le TAI comprenait un décalage de fréquence convenu. Les tableaux 2 et 3 de la partie B donnent cette relation.

b - A la date mentionnée ci-dessus, un saut de temps de - 0,1077580 s a été appliqué à l'UTC, de sorte que cette date est devenue 1972 janvier 1, 0 h UTC (nouveau) exactement. Le nouveau UTC est tel que TAI-UTC soit égal à un nombre entier de secondes, en accord avec la Recommandation 460-4 (1986) du Comité consultatif international des radiocommunications (CCIR).

Les renseignements sur les signaux horaires proviennent de réponses à notre enquête de février 1989. Des renseignements plus détaillés peuvent être obtenus aux adresses données par les pages C-2 à C-4.

3 - SECTION DU TEMPS DU BIPM

Les personnes suivantes ont participé aux travaux de la section du temps, en 1988

Mr	B. Guinot,	Responsable
Mrs	C. Thomas,	Physicien
Mr	W. Lewandowski,	"
Mr	J. Azoubib,	"
Mlle	H. Konaté,	Technicien
Mr	M. Imae*	Stagiaire (jusqu'au 31 octobre 1988)

* Mr. M. Imae, Ingénieur au Communications Research Laboratory, Tokyo, Japon, a effectué un stage au BIPM, du 1 octobre 1987 au 31 octobre 1988.

PART B

TABLES AND FIGURES

PARTIE B

TABLES ET FIGURES

TABLE 1 - ATOMIC TIME, COLLABORATING LABORATORIES

AOS	Astronomical Latitude Observatory, Borowiec, Polska
APL	Applied Physics Laboratory, Laurel, USA
ASMW	Amt für Standardisierung, Messwesen und Warenprüfung, Berlin, Deutsche Demokratische Republik
ATC	Australian Telecommunications Commission, Melbourne, Australia
AUS	Consortium of laboratories in Australia
BEV	Bundesamt für Eich - und Vermessungswesen, Wien, Oesterreich
BAO	Beijing Observatory, Beijing, P.R. China
CAO	Astronomical Observatory of Cagliari University, Cagliari, Italy
CH	Consortium of laboratories in Switzerland (see Table 4)
CRL	Communications Research Laboratory, Tokyo, Japan (formerly RRL)
CSAO	Shaanxi Astronomical Observatory, Lintong, P.R. China
DDR	Consortium of laboratories in Deutsche Demokratische Republik
DPT	Division of Production Technology, CSIR, Pretoria, South Africa (formerly NPRL)
F	Commission Nationale de l'Heure, Paris, France (see Table 4)
FTZ	Fernmeldetechnisches Zentralamt, Darmstadt, Bundesrepublik Deutschland
IEN	Istituto Elettrotecnico Nazionale Galileo Ferraris, Torino, Italia
IFAG	Institut für Angewandte Geodäsie, Frankfurt am Main, Bundesrepublik Deutschland
IGMA	Instituto Geografico Militar, Buenos-Aires, Argentina
INPL	National Physical Laboratory, Jerusalem, Israel
INTI	Instituto Nacional de Tecnologia Industrial, Buenos-Aires, Argentina
JATC	Joint Atomic Time Commission, Lintong, Shaanxi, P. R. China
KSRI	Korea Standards Research Institute, Taejon, Ch'ungnam, Rep. of Korea
NAOM	National Astronomical Observatory, Misuzawa, Japan (formerly ILOM)
NIM	National Institute of Metrology, Beijing, P.R. China
NIST	National Institute of Standards and Technology, Boulder, USA (formerly NBS)
NML	National Measurement Laboratory, CSIRO, Sydney, Australia
NPL	National Physical Laboratory, Teddington, U.K.
NPLI	National Physical Laboratory, New-Delhi, India
NRC	National Research Council of Canada, Ottawa, Canada
NRLM	National Research Laboratory of Metrology, Ibaraki, Japan
OMH	Orszagos Mérésügyi Hivatal, Budapest, Hungary
ONBA	Observatorio Naval, Buenos-Aires, Argentina
ONRJ	Observatorio National, Rio de Janeiro, Brazil
OP	Observatoire de Paris, Paris, France
ORB	Observatoire Royal de Belgique, Bruxelles, Belgique
ORR	Orroral Observatory, Australia (formerly DNM)
PKNM	Polski Komitet Normalizacji Miar I Jakosci, Warszawa, Polska
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig, Bundesrepublik Deutschland
RAO	Radio Astronomical Observatory, Johannesburg, South Africa
RGO	Royal Greenwich Observatory, Herstmonceux, U.K.
ROA	Real Instituto y Observatorio de la Armada, San Fernando, España (formerly OMSF)
RSA	Consortium of laboratories in South Africa

TABLE 1 - ATOMIC TIME, COLLABORATING LABORATORIES (CONT.)

SAAO	South African Astronomical Observatory, Cape Town, South Africa
SO	Shanghai Observatory, Shanghai, China
STA	Swedish Telecommunications Administration, Stockholm, Sweden
SU	Laboratoire d'état de l'étalon de temps et de fréquences, URSS
TAO	Tokyo Astronomical Observatory, Tokyo, Japan
TID	Tidbinbilla Deep Space Communications Center, Australia
TL	Telecommunication Laboratories, Taiwan, China
TP(1)	Ústav Radiotechniky a Elektroniky ČSAV, Praha, Československo Astronomický ústav ČSAV, Praha, Československo
TUG	Technische Universität Graz, Oesterreich
USNO	U.S. Naval Observatory, Washington D.C., USA
VSL	Van Swinden Laboratorium, Delft, Nederland
YUZM	Bureau Fédéral des Mesures et Métaux Précieux, Belgrade, République Socialiste Fédérative de Yougoslavie
ZIPE	Zentralinstitut Physik der Erde, Potsdam, Deutsche Demokratische Republik

(1) Both laboratories cooperate in the derivation of UTC(TP).

TABLE 2 - FREQUENCY OFFSETS AND STEP ADJUSTEMENTS OF UTC, UNTIL 1989 JUNE 30

Date (at 0 h UTC)			Offsets	Steps
1961	Jan.	1	-150×10^{-10}	
	Aug.	1	"	+0.050 s

1962	Jan.	1	-130×10^{-10}	
1963	Nov.	1	"	-0.100 s

1964	Jan.	1	-150×10^{-10}	
	Apr.	1	"	-0.100 s
	Sep.	1	"	-0.100 s
1965	Jan.	1	"	-0.100 s
	Mar.	1	"	-0.100 s
	Jul.	1	"	-0.100 s
	Sep.	1	"	-0.100 s

1966	Jan.	1	-300×10^{-10}	
1968	Feb.	1	"	+0.100 s

Date (at 0 h UTC)			Offsets	Steps
1972	Jan.	1	0	-0.107 7580 s
	Jul.	1	"	-1 s
1973	Jan.	1	"	-1 s
1974	Jan.	1	"	-1 s
1975	Jan.	1	"	-1 s
1976	Jan.	1	"	-1 s
1977	Jan.	1	"	-1 s
1978	Jan.	1	"	-1 s
1979	Jan.	1	"	-1 s
1980	Jan.	1	"	-1 s
1981	Jul.	1	"	-1 s
1982	Jul.	1	"	-1 s
1983	Jul.	1	"	-1 s
1985	Jul.	1	"	-1 s
1988	Jan.	1	"	-1 s

TABLE 3 - RELATIONSHIP BETWEEN TAI AND UTC, UNTIL 1989 JUNE 30

Limits of validity (at 0 h UTC)	TAI - UTC (in seconds)
1961 Jan. 1 - 1961 Aug. 1	1.422 8180 + (MJD - 37300) x 0.001 296
Aug. 1 - 1962 Jan. 1	1.372 8180 + " "
1962 Jan. 1 - 1963 Nov. 1	1.845 8580 + (MJD - 37665) x 0.001 1232
1963 Nov. 1 - 1964 Jan. 1	1.945 8580 + " "
1964 Jan. 1 Apr. 1	3.240 1300 + (MJD - 38761) x 0.001 296
Apr. 1 Sep. 1	3.340 1300 + " "
Sep. 1 - 1965 Jan. 1	3.440 1300 + " "
1965 Jan. 1 Mar. 1	3.540 1300 + " "
Mar. 1 Jul. 1	3.640 1300 + " "
Jul. 1 Sep. 1	3.740 1300 + " "
Sep. 1 - 1966 Jan. 1	3.840 1300 + " "
1966 Jan. 1 - 1968 Feb. 1	4.313 1700 + (MJD - 39126) x 0.002 592
1968 Feb. 1 - 1972 Jan. 1	4.213 1700 + " "
1972 Jan. 1 - Jul. 1	10 (integral number of seconds)
Jul. 1 - 1973 Jan. 1	11
1973 Jan. 1 - 1974 Jan. 1	12
1974 Jan. 1 - 1975 Jan. 1	13
1975 Jan. 1 - 1976 Jan. 1	14
1976 Jan. 1 - 1977 Jan. 1	15
1977 Jan. 1 - 1978 Jan. 1	16
1978 Jan. 1 - 1979 Jan. 1	17
1979 Jan. 1 - 1980 Jan. 1	18
1980 Jan. 1 - 1981 Jul. 1	19
1981 Jul. 1 - 1982 Jul. 1	20
1982 Jul. 1 - 1983 Jul. 1	21
1983 Jul. 1 - 1985 Jul. 1	22
1985 Jul. 1 - 1988 Jan. 1	23
1988 Jan. 1	24

TABLE 4 - LABORATORIES KEEPING AN INDEPENDENT LOCAL ATOMIC TIME

Laboratory (k)	Equipment in atomic standards (1)	Interval of validity (in MJD at 0 h UTC)	Information on TA(k) - UTC(k): TA(k) - UTC(k) in s
AOS	1 Ind. Cs	47161-47229	23.000 075 260 $+225\times10^{-9}\times$(MJD-47161)
		47229-47256	23.000 090 560 $+140\times10^{-9}\times$(MJD-47229)
		47256-	23.000 094 340 $+210\times10^{-9}\times$(MJD-47256)
APL	1 Ind. Cs 4 H Masers	47169-47369 47379-	24.000 000 000 24.000 000 180
CH	13 Ind. Cs (2)	46823-47161 47161-	TA(CH)-UTC(CH) is sent to BIPM
CRL	1 Lab. Cs 11 Ind. Cs 3 H Masers	year 1988	published in CRL Standard Frequency and Time Bulletin
CSAO	5 Ind. Cs 3 H Masers	year 1988	TA(CSAO)-UTC(CSAO) is published by the CSAO Time and Frequency Services Bulletin
DDR	2 Ind. Cs (3)	year 1988	TA(DDR)-UTC(ASMW) is sent to BIPM
F	20 Ind. Cs (4)	year 1988	TA(F)-UTC(OP) is published in bulletin H by OP (LPTF)
JATC	1 Lab. Cs 14 Ind. Cs 6 H Masers (5)	year 1988	TA(JATC)-UTC(JATC) is sent to BIPM
NIM	3 Ind. Cs	year 1988	TA(NIM)-UTC(NIM) is sent to BIPM
NIST	1 Lab. Cs 19 Ind. Cs 1 H Maser (6)	year 1988	TA(NIST)-UTC(NIST) is published in the NIST T and F Bulletin

TABLE 4 - (CONT.)

Laboratory (k)	Equipment in atomic standards (1)	Information on TA(k) - UTC(k) Interval of validity (in MJD at 0 h UTC)	TA(k) - UTC(k) in s
NRC	1 2.1 m Lab. Cs 2 1 m Lab. Cs 1 Ind. Cs (7)	year 1988	23.999 968 931
PTB	2 Lab. Cs 8 Ind. Cs (8)	year 1988	23.000 363 400
SO	1 Lab. Cs 4 Ind. Cs 3 H Masers	year 1988	TA(SO)-UTC(SO) is published by the SO Atomic Time Bulletin
SU	2 Lab. Cs 8 H Clocks	year 1988	20.172 750 000
USNO	40 Ind. Cs 4 H Masers (4 VLG 11 B serial # 18,19, 22,23) 3 Prototype Mercury Ion freq. Std serial # 1,2,3 (9)	year 1988	A.1(MEAN)-UTC(USNO,MC) values are available upon request. (10)

NOTES OF TABLE 4

(1) Ind. Cs designates an industry made Cs standard; Lab. Cs a laboratory Cs standard and H Maser an Hydrogen Maser.

(2) The standards are located as follows (at the end of 1988).

Office Fédéral de Métrologie (Berne)	(OFM)	7 Cs
Observatoire de Neuchâtel (Neuchâtel)	(ON)	4 Cs
Direction Générale des PTT (Berne)	(PTT)	2 Cs

They are intercompared by LORAN-C (OFM-ON) and TV method (OFM-PTT) and linked to the foreign laboratories through the Swiss Federal Office of Metrology.

(3) The standards are located as follows : ASMW, 1Cs ; ZIPE, 1 Cs.

NOTES OF TABLE 4 (CONT.)

(4) The standards are located as follows (at the end of 1988).

Centre Electronique de l'Armement (Rennes)	2 Cs
Centre National d'Etudes Spatiales	2 Cs
Centre National d'Etudes des Télécommunications	3 Cs
Observatoire de la Côte d'Azur (OCA, formerly CERGA)	3 Cs
Electronique Serge Dassault (Trappes)	1 Cs
Hewlett-Packard (Orsay)	1 Cs
Observatoire de Paris : Laboratoire Primaire du Temps et des Fréquences (LPTF)	4 Cs
Observatoire de Besançon (OB)	2 Cs
Laboratoire de Physique et de Métrologie des Oscillateurs (Besançon) (LPMO)	1 Cs
Ecole Nationale Supérieure de Mécanique et des Microtechniques (Besançon) (ENSMM)	1 Cs

Links by GPS : OP-OB (since Feb. 1988), OP-OCA (since May 1988)
Cable links : OB-LPMO, OB-ENSMM.
Other national links by the TV method
Link to foreign laboratories through OP(LPTF) by GPS (see Table 5).

(5) JATC. The standards are located in the following laboratories
Shaanxi Astronomical Observatory (CSAO)
Shanghai Astronomical Observatory (SO)
Beijing Astronomical Observatory
Wuhan Time Observatory
Beijing Institute of Radio Metrology and Measurement

(6) The laboratory primary standards control TA(NIST) via an accuracy algorithm. Six of the commercial standards provide the reference for WWV and WWVB and two for GOES Satellite time but do not contribute directly to TA(NIST); they are available for NIST time scales back-up and are compared to TA(NIST) to within 0.01 us. The hydrogen maser is passively operated.
An other independent local time is evaluated by a different algorithm. It is designated as AT1, but appears in BIPM publications as TA(NISA).

(7) The 2.1 meter primary cesium clock, CsV, operated continuously during 1988 producing the scale of proper time PT(NRC CsV) except for the period from the 5th of July to the 2nd of September, during which period it was reloaded with cesium.

During the period 1 January 1988 to 5 July 1988 and 2 September to 31 December the time scales UTC(NRC) and TA(NRC) were derived from PT(NRC CsV) according to the following expression given in microsecond :

UTC(NRC) = PT(NRC CsV) - (MJD - 43144) x 0.000 97 + 52.041

TA(NRC) = PT(NRC CsV) - (MJD - 43144) x 0.000 97 + 20.972

with integral seconds disregarded.

NOTES OF TABLE 4 (CONT.)

During the period 5 July to 2 September the time scale UTC(NRC) and TA(NRC) were derived from PT(NRC CsVIC) with an appropriate frequency offset which made the rate of UTC(NRC) and TA(NRC) equal to that derived from CsV before interruption.

(8) The two Lab. Cs are functionning continuously (primary clocks). TA(PTB) and UTC(PTB) are derived directly from a local oscillator monitored by the primary clock CS1.
MEZ(D) = UTC(PTB) + 1 h or MESZ(D) = UTC(PTB) + 2 h (summer time) is the legal time of the Federal Republic of Germany, which is disseminated by DCF77.
Two Ind. Cs are localed at the transmitter station Mainflingen and provide the DCF77 steering signal.

(9) The time scales UTC(USNO) and TA(USNO) depend on nominally 20 Cs selected clocks (selected on the basis of observed 5-day stability).

(10) TA(USNO) is designated by A.1 (MEAN) by USNO.

TABLE 5 - EQUIPMENT AND LINKS OF THE COLLABORATING LABORATORIES IN 1988

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
AOS	1 Ind. Cs	1 Cs		TP, ZIPE	
APL	see Table 4	1 H Maser			*
ASMW	1 Ind. Cs	1 Cs + microstepper	7970-W	ZIPE, TP, PTB	
ATC	7 Ind. Cs	1 Cs + microstepper		other lab. in Australia	*
BEV	1 Ind. Cs	1 Cs	7970-W 7990-M 7990-X 7990-Y	OMH, TUG, lab. in Czechoslovakia	
CAO	2 Ind. Cs	1 Cs	7990-M 7990-X 7990-Z	IEN, other lab. in Italy	
CH	see Table 4	all the Cs	7970-W 7990-Z	PTT	*
CRL	see Table 4	6 Cs	9970-M	NRLM, TAO	*
CSAO	see Table 4	all the Cs	9970-Y	lab. in China	
DPT	2 Ind. Cs	1 Cs			*
FTZ	7 Ind. Cs	1 Cs	7970-W		
IEN	5 Ind. Cs	1 Cs + microstepper	7990-Z	CAO, other lab. in Italy	*
IFAG	4 Ind. Cs 2 H Masers	1 Cs + microstepper	7970-W		*
IGMA	4 Ind. Cs	1 Cs + microstepper		ONBA, other lab. in Argentina	*
INPL	3 Ind. Cs	1 Cs			*
JATC	see Table 4	1 Cs + microstepper	9970-Y		

TABLE 5 - (CONT.)

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
KSRI	4 Ind. Cs	1 Cs	9970-Y		* (since July 1988)
NAOM	4 Ind. Cs	1 Cs	9970-M 9970-X		
NIM	see Table 4	1 Cs + microstepper	9970-Y	lab. in China	
NIST	see Table 4	11 Cs 1 Lab. Cs 1 H Maser	9940-M 9960-Z		*
NML	2 Ind. Cs 2 H masers	all the Cs		other lab. in Sydney region	*
NPL	7 Ind. Cs	1 Cs + microstepper	7970-W	transmitting station at Rugby	*
NPLI	5 Ind. Cs	1 Cs			*
NRC	see Table 4	47169 to 47329 CsV 47339 to 47405 CsVIC 47406 - CsV	9960-M		*
NRLM	5 Ind. Cs 2 Lab. Cs	1 Cs	9970-M 9970-X	CRL, TAO	
OMH	1 Ind. Cs	1 Cs		BEV, SU, TP	
ONBA	2 Ind. Cs	2 Cs		IGMA other lab. in Argentina	
ONRJ	5 Ind. Cs	5 Cs		other lab. in Brasil	* (since Dec. 1988)
OP	4 Ind. Cs	1 Cs	7970-W 7990-Z 8940-M	18 lab. in France.	*
ORB	2 Ind. Cs	1 Cs	7970-W		*

TABLE 5 - (CONT.)

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
ORR	4 Ind. Cs	all the Cs		other lab. in Australia	*
PKNM	4 Ind. Cs	corrected mean of 4 Cs	7970-W (3)		
PTB	see Table 4	Ind. Cs + microstepper steered by PTB primary st.	7970-W	ASMW, TP, ZIPE and other lab.	*
RAO	1 Maser				*
ROA	6 Ind. Cs	all the Cs	7990-Z		*
SAAO	1 Ind. Cs	1 Cs			*
SO	see Table 4	1 Cs + microstepper	9970-Y	lab. in China	
STA	3 Ind. Cs	1 Cs	7970-W	other lab. in Sweden	*
SU	see Table 4	2 Lab. Cs 8 H Clocks	7970-W 7990-X 7990-Y 9970-X	TP, OMH	
TAO	8 Ind. Cs	1 Cs + microstepper	9970-M 9970-Y	CRL, NAOM NRLM	*
TL	5 Ind. Cs	1 Cs + microstepper	9970-Y		* (since Oct. 1988)
TP	2 Ind. Cs	1 Cs + microstepper	7970-W	PTB, AOS, SU, ZIPE, ASMW, OMH	
TUG	3 Ind. Cs	1 Cs	7970-W 7990-M	BEV	*
USNO(4)	see Table 4	Master clock is H Maser + freq. synthesizer steered to UTC(USNO) (see table 4)	(5)		* (6)

TABLE 5 - (CONT.)

Laboratory (k)	Equipment (1)	Source of UTC(k)	LORAN-C reception (2)	Television link with	GPS reception
VSL	4 Ind. Cs	1 Cs + microstepper	7970-M 7970-W 9980-X	11 Lab. in Netherlands	*
YUZM	1 Ind. Cs	Cs	7990-M		
ZIPE	1 Ind. Cs	1 Cs + microstepper	7970-W	AOS, ASMW, TP, PTB	

NOTES OF TABLE 5

(1) Ind. Cs designates an industry made Cs standard;
Lab. Cs a laboratory Cs standard, H. Maser an Hydrogen Maser, and Rb designates a Rubidium standard.

(2) LORAN-C stations :

7970-M	Norwegian Sea chain,	Ejde
7970-W	" "	Sylt
7990-M	Mediterranean chain,	Simeri Crichi
7990-X	" "	Lampedusa
7990-Y	" "	Kargabarun
7990-Z	" "	Estartit
8940-M	French chain,	Lessay
9940-M	West Coast chain,	Fallon
9960-M	Northeast Coast chain,	Seneca
9960-X	" "	Nantucket
9960-Z	" "	Dana
9970-M	Northwest Pacific chain,	Iwo Jima
9970-X	" "	Hokkaido
9970-Y	" "	Gesashi
9980-M	North Atlantic chain,	Angissog
9980-X	" "	Ejde

NOTES OF TABLE 5 (CONT.)

(3) Reception of the Soviet Union LORAN chain 8000.

(4) USNO Time Service Publication, Series 16, entitled Precise Time Transfer Report, lists UTC(USNO MC) - UTC(Reference Clock). Difference from Satellite Communication terminals and international timing centers using the Global Positioning System are reported. USNO Time Service Publication, Series 17, entitled Transit Satellite Reports, lists UTC(USNO MC) - UTC(Satellite Clock) and also the frequency offset of each satellite. Series 17 is available via the Automated Data Service and the General Electric Mark 3 international computer network (RC28 catalog).

(5) The daily phase values (published weekly, Series 4 of USNO) gives the values of UTC(USNO MC) - transmitting station for :

the LORAN-C chains,
the Washington D.C. TV Station WTTG,
the GPS satellite system.

These data are also available via the Automated Data Service (ADS) and the General Electric Mark 3 international computer network (RC28 catalog).
The ADS may be accessed on :

BELL 103/212 (300 or 1200 Baud)	202-653-1079,
CCITT V.21 (300 Baud)	202-653-1095,
CCITT V.22/V.22 bis (1200 or 2400 Baud)	202-653-1783.

(6) Two-way satellite time transfer also operates between USNO and NIST.

* Laboratories with GPS receiver equipment.

TABLE 6 - ABSOLUTE TIME COMPARISONS BETWEEN LABORATORIES IN 1988

A - CLOCK TRANSPORTATION

Unless otherwise stated, the transportation was carried out by the first mentioned laboratory.

DATE 1988		MJD	TIME COMPARISONS (Unit : 1 microsecond)	UNCERT.	SOURCE	
JAN	6	47166.06	UTC(CRL) - UTC(TAO) = -1.059	0.005	RRL	message
JAN	27	47187.05	UTC(TAO) - UTC(CRL) = 0.803	0.005	TAO	message
MAR	4	47224.23	UTC(CRL) - UTC(TAO) = -0.261	0.005	CRL	letter
MAR	28	47248.22	UTC(TAO) - UTC(CRL) = 0.159	0.005	TAO	message
APR	28	47279.05	UTC(CRL) - UTC(TAO) = -0.139	0.005	CRL	message
MAY	18	47299.01	UTC(TAO) - UTC(NRLM) = -22.212	0.008	TAO	message
MAY	19	47300.94	UTC(SU) - UTC(ASMW) = -20.46	0.05	SU	letter
MAY	24	47305.02	UTC(TAO) - UTC(NAOM) = -33.747	0.010	TAO	message
MAY	26	47307.05	UTC(TAO) - UTC(CRL) = 0.143	0.005	TAO	message
JUN	30	47342.06	UTC(CRL) - UTC(TAO) = -0.216	0.005	CRL	message
JUL	19	47361.05	UTC(TAO) - UTC(CRL) = 0.303	0.005	TAO	message
AUG	10	47383.56	UTC(ASMW) - UTC(PTB) = 3.690	0.020	ASMW	telex
SEP	7	47411.54	UTC(PKNM) - UTC(ASMW) = -3.603		PKNM	telex
AUG	31	47404.00	UTC(OMH) - UTC(SU) = -23.85	0.30	SU	letter
OCT	20	47454.50	UTC(SU) - UTC(BEV) = -17.60	0.05	SU	letter
OCT	20	47454.50	UTC(SU) - UTC(TUG) = -13.96	0.05	SU	letter
NOV	9	47474.08	UTC(TAO) - UTC(NRLM) = -27.901	0.008	TAO	message
NOV	14	47479.05	UTC(TAO) - UTC(CRL) = 0.677	0.005	TAO	message
NOV	18	47483.38	UTC(SU) - UTC(OP) = -19.26	0.05	SU	letter
NOV	24	47489.38	UTC(SU) - UTC(TP) = -18.36	0.05	SU	letter

B - GPS TIME COMPARISONS WITH DIFFERENTIAL CALIBRATION OF RECEIVER DELAYS

Unless otherwise stated, under the heading SOURCE is designated the laboratory which has organized the measurement of delays.

DATE 1988		MJD	TIME COMPARISONS (Unit : 1 microsecond)	UNCERT.	SOURCE
MAY	8	47289.00	UTC(OP) - UTC(TUG) = 0.178	0.004	NIST
MAY	25	47306.38	UTC(OP) - UTC(ORB) = -9.036	0.004	BIPM
MAY	27	47308.74	UTC(OP) - UTC(VSL) = 4.567	0.004	BIPM
JUN	1	47313.36	UTC(OP) - UTC(PTB) = 5.087	0.004	BIPM
JUN	3	47315.03	UTC(NIST) - UTC(TAO) = -1.222	0.015	NIST
JUN	5	47317.03	UTC(NIST) - UTC(CRL) = -1.066	0.015	NIST

TABLE 7 - INDEPENDENT LOCAL ATOMIC TIME SCALES

TA(k) DENOTES THE ATOMIC TIME OF THE LABORATORY k

Unit is one microsecond

DATE 1988		MJD	TAI - TA(k)			
			AOS (1)	APL	CH	CRL (2)
JAN	9	47169	-76.57	0.023	-46.824	-2.820
JAN	19	47179	-78.63	0.011	-47.008	-2.903
JAN	29	47189	-80.55	0.028	-47.161	-2.991
FEB	8	47199	-82.66	0.031	-47.357	-3.129
FEB	18	47209	-84.50	0.035	-47.558	-3.305
FEB	28	47219	-86.47	0.029	-47.765	-3.451
MAR	9	47229	-88.41	0.025	-47.961	-3.536
MAR	19	47239	-90.32	0.035	-48.164	-3.568
MAR	29	47249	-92.46	0.025	-48.374	-3.616
APR	8	47259	-94.45	0.023	-48.582	-3.627
APR	18	47269	-96.55	0.013	-48.803	-3.633
APR	28	47279	-98.70	0.008	-49.021	-3.669
MAY	8	47289	-101.00	0.020	-49.255	-3.673
MAY	18	47299	-102.88	0.012	-49.465	-3.710
MAY	28	47309	-104.90	0.020	-49.689	-3.729
JUN	7	47319	-106.97	-0.013	-49.918	-3.757
JUN	17	47329	-109.09	-0.032	-50.126	-3.721
JUN	27	47339	-111.49	-0.062	-50.342	-3.721
JUL	7	47349	-113.78	-0.087	-50.538	-3.709
JUL	17	47359	-115.74	-0.118	-50.759	-3.699
JUL	27	47369	-117.94	-0.186	-50.920	-3.671
AUG	6	47379	-119.99	-0.197	-51.147	-3.666
AUG	16	47389	-122.34	-0.215	-51.331	-3.638
AUG	26	47399	-124.20	-0.250	-51.559	-3.622
SEP	5	47409	-126.02	-0.287	-51.793	-3.604
SEP	15	47419	-128.03	-0.329	-52.018	-3.599
SEP	25	47429	-130.00	-0.360	-52.255	-3.579
OCT	5	47439	-132.05	-0.399	-52.474	-3.571
OCT	15	47449	-133.76	-0.413	-52.692	-3.539
OCT	25	47459	-135.60	-0.426	-52.887	-3.500
NOV	4	47469	-137.49	-0.440	-53.083	-3.503
NOV	14	47479	-139.21	-0.447	-53.278	-3.463
NOV	24	47489	-141.29	-0.467	-53.464	-3.434
DEC	4	47499	-	-0.484	-53.646	-3.415
DEC	14	47509	-	-0.511	-53.839	-3.383
DEC	24	47519	-	-0.541	-54.010	-3.321

TABLE 7 - (CONT.)

Unit is one microsecond

DATE 1988		MJD	TAI - TA(k) CSAO (3)	DDR (4)	F	JATC (3)
JAN	9	47169	39.87	-24.35	49.859	-0.31
JAN	19	47179	39.73	-24.68	50.234	-0.32
JAN	29	47189	39.76	-24.95	50.640	-0.28
FEB	8	47199	39.66	-25.28	51.014	-0.63
FEB	18	47209	39.68	-25.67	51.384	-0.57
FEB	28	47219	39.63	-25.90	51.750	-0.47
MAR	9	47229	39.60	-26.08	52.124	-0.27
MAR	19	47239	39.57	-26.31	52.538	-0.06
MAR	29	47249	39.54	-26.56	52.930	-0.22
APR	8	47259	39.58	-26.82	53.318	-0.19
APR	18	47269	39.58	-27.09	53.733	-0.14
APR	28	47279	39.67	-27.42	54.153	-0.07
MAY	8	47289	39.59	-27.77	54.536	-0.06
MAY	18	47299	39.60	-28.11	54.985	0.01
MAY	28	47309	39.63	-28.51	55.431	0.09
JUN	7	47319	39.67	-28.84	55.885	0.18
JUN	17	47329	39.79	-29.16	56.317	0.32
JUN	27	47339	39.84	-29.56	56.781	0.42
JUL	7	47349	39.74	-29.95	57.292	0.43
JUL	17	47359	39.84	-30.35	57.751	0.56
JUL	27	47369	39.97	-30.71	58.229	0.68
AUG	6	47379	40.00	-31.12	58.675	0.79
AUG	16	47389	40.14	-31.29	59.139	0.94
AUG	26	47399	40.20	-30.56	59.591	0.96
SEP	5	47409	40.24	-30.66	60.046	1.06
SEP	15	47419	40.38	-30.72	60.466	1.18
SEP	25	47429	40.46	-30.77	60.900	1.31
OCT	5	47439	40.55	-30.76	61.299	1.46
OCT	15	47449	40.59	-30.70	61.711	1.52
OCT	25	47459	40.52	-30.74	62.120	1.55
NOV	4	47469	40.49	-30.63	62.513	1.69
NOV	14	47479	40.58	-30.46	62.878	1.85
NOV	24	47489	40.55	-30.36	63.240	1.71
DEC	4	47499	40.47	-30.18	63.609	1.63
DEC	14	47509	40.47	-29.95	63.988	1.53
DEC	24	47519	40.39	-29.73	64.360	1.46

TABLE 7 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	TAI - TA(k) NIM (3)	NISA (5)	NIST	NRC
JAN 9	47169	-7.39	-45045.280	-45105.738	20.794
JAN 19	47179	-7.56	-45045.531	-45106.144	20.939
JAN 29	47189	-7.58	-45045.754	-45106.512	21.121
FEB 8	47199	-7.61	-45046.005	-45106.892	21.242
FEB 18	47209	-7.54	-45046.249	-45107.275	21.404
FEB 28	47219	-7.52	-45046.500	-45107.659	21.504
MAR 9	47229	-7.61	-45046.745	-45108.029	21.574
MAR 19	47239	-7.67	-45046.983	-45108.397	21.630
MAR 29	47249	-7.76	-45047.239	-45108.789	21.649
APR 8	47259	-7.87	-45047.497	-45109.187	21.692
APR 18	47269	-8.06	-45047.744	-45109.573	21.753
APR 28	47279	-8.20	-45047.992	-45109.973	21.818
MAY 8	47289	-8.34	-45048.212	-45110.371	21.846
MAY 18	47299	-8.46	-45048.442	-45110.767	21.874
MAY 28	47309	-8.48	-45048.661	-45111.163	21.882
JUN 7	47319	-8.22	-45048.905	-45111.547	21.888
JUN 17	47329	-8.16	-45049.123	-45111.938	21.895
JUN 27	47339	-8.20	-45049.358	-45112.323	21.898
JUL 7	47349	-8.38	-45049.594	-45112.708	21.826
JUL 17	47359	-8.41	-45049.790	-45113.063	21.758
JUL 27	47369	-8.50	-45049.970	-45113.421	21.706
AUG 6	47379	-8.50	-45050.172	-45113.804	21.682
AUG 16	47389	-8.50	-45050.357	-45114.172	21.665
AUG 26	47399	-8.66	-45050.544	-45114.538	21.549
SEP 5	47409	-8.77	-45050.734	-45114.914	21.367
SEP 15	47419	-8.79	-45050.920	-45115.290	21.063
SEP 25	47429	-8.92	-45051.102	-45115.681	20.775
OCT 5	47439	-9.27	-45051.290	-45116.064	20.461
OCT 15	47449	-9.30	-45051.485	-45116.446	20.152
OCT 25	47459	-9.55	-45051.669	-45116.809	19.860
NOV 4	47469	-9.76	-45051.854	-45117.170	19.559
NOV 14	47479	-9.80	-45052.049	-45117.536	19.261
NOV 24	47489	-10.04	-45052.253	-45117.909	18.945
DEC 4	47499	-10.09	-45052.472	-45118.305	18.602
DEC 14	47509	-9.95	-45052.701	-45118.708	18.420
DEC 24	47519	-9.70	-45052.920	-45119.106	18.250

TABLE 7 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	TAI - TA(k) PTB	SO (3)	SU	USNO
JAN 9	47169	-359.091	-44.96	2827271.46	-34551.671
JAN 19	47179	-359.130	-45.14	2827271.24	-34552.276
JAN 29	47189	-359.137	-45.39	2827271.51	-34552.844
FEB 8	47199	-359.165	-45.67	2827271.28	-34553.409
FEB 18	47209	-359.161	-45.72	2827271.13	-34553.999
FEB 28	47219	-359.156	-45.79	2827271.04	-34554.542
MAR 9	47229	-359.136	-45.70	2827270.75	-34555.125
MAR 19	47239	-359.116	-45.66	2827270.55	-34555.681
MAR 29	47249	-359.102	-45.66	2827270.37	-34556.252
APR 8	47259	-359.097	-45.73	2827270.16	-34556.835
APR 18	47269	-359.061	-45.70	2827270.08	-34557.388
APR 28	47279	-359.072	-45.66	2827269.62	-34557.954
MAY 8	47289	-359.093	-45.75	2827269.62	-34558.549
MAY 18	47299	-359.067	-45.68	2827269.52	-34559.131
MAY 28	47309	-359.053	-45.70	2827269.18	-34559.705
JUN 7	47319	-359.054	-45.69	2827269.32	-34560.280
JUN 17	47329	-359.028	-45.63	2827269.42	-34560.810
JUN 27	47339	-359.051	-45.63	2827269.44	-34561.350
JUL 7	47349	-359.061	-45.74	2827269.34	-34561.898
JUL 17	47359	-359.102	-45.69	2827269.13	-34562.447
JUL 27	47369	-359.097	-45.80	2827268.79	-34562.924
AUG 6	47379	-359.197	-45.88	2827268.99	-34563.414
AUG 16	47389	-359.167	-45.95	2827268.84	-34563.912
AUG 26	47399	-359.149	-46.06	2827268.70	-34564.422
SEP 5	47409	-359.141	-46.06	2827268.55	-34564.918
SEP 15	47419	-359.158	-46.04	2827268.41	-34565.449
SEP 25	47429	-359.168	-45.99	2827268.27	-34565.914
OCT 5	47439	-359.189	-46.00	2827268.12	-34566.405
OCT 15	47449	-359.204	-45.93	2827267.98	-34566.937
OCT 25	47459	-359.221	-45.95	2827267.84	-34567.429
NOV 4	47469	-359.254	-45.83	2827267.71	-34567.974
NOV 14	47479	-359.224	-45.57	2827267.58	-34568.527
NOV 24	47489	-359.212	-45.48	2827267.36	-34569.032
DEC 4	47499	-359.271	-45.34	2827267.25	-34569.587
DEC 14	47509	-359.294	-45.05	2827267.03	-34570.149
DEC 24	47519	-359.287	-44.89	2827266.75	-34570.729

TABLE 7 - (CONT.)

NOTES

(1) AOS . UTC(AOS) being linked to UTC(ZIPE) by TV, the published values of TAI-TA(AOS) have a time step of 610 ns between MJD=47389 and MJD=47399, due to the change of delay correction of the link PTB-ZIPE.

(2) CRL . As a result of NIST campaign of GPS receivers comparison from 2 June to 11 June 1988, the delay of the receiver at CRL has been modified. The results TAI-TA(CRL) for the whole year 1988 have been computed with the new delay. A step of -90 ns appears between MJD=47159 and MJD=46169 (beginning of year 1988).

(3) CSAO, JATC, NIM, SO . On MJD=47239 interpolated values for LORAN-C time link.

(4) DDR . Recalibration of the TV links ASMW-PTB and ZIPE-PTB and change of the delay corrections on MJD=47399. In order to keep the continuity of the published values of UTC-UTC(ASMW) and UTC-UTC(ZIPE), the UTC(ASMW) and UTC(ZIPE) have been shifted at MJD=47399 according to :
UTC(ASMW)new - UTC(ASMW)old = 770 ns
UTC(ZIPE)new - UTC(ZIPE)old = 610 ns
The consequent apparent time step on TAI-TA(DDR) between MJD=47389 and MJD=47399 is 770 ns.

(5) NIST. TA(NISA) designates the scale AT1 of NIST.

TABLE 8 - PRIMARY FREQUENCY STANDARDS USED AS CLOCKS

unit is one microsecond

TAI-LAB.STD.

DATE 1988	MJD	PTB (1)		NRC (2)			
		CS1	CS2	CsV (3)	CsVI A	CsVI B	CsVI C
JAN 9	47169	4.287	2.864	37.861	29.539	43.329	30.914
JAN 19	47179	4.254	2.835	37.997	29.732	50.161	30.828
JAN 29	47189	4.259	2.831	38.169	29.996	-	30.742
FEV 8	47199	4.248	2.808	38.281	30.217	-	30.966
FEV 18	47209	4.255	2.800	38.433	30.449	-	31.015
FEV 28	47219	4.254	2.785	38.523	30.632	-	30.991
MAR 9	47229	4.266	2.764	38.583	30.695	-	30.994
MAR 19	47239	4.300	2.748	38.630	30.748	-	30.920
MAR 29	47249	4.288	2.723	38.639	30.765	-	30.866
APR 8	47259	4.321	2.695	38.671	30.622	-	30.800
APR 18	47269	4.335	2.702	38.722	30.589	-	30.770
APR 28	47279	4.329	2.677	38.778	30.476	-	30.674
MAY 8	47289	4.308	2.653	38.797	30.411	-	30.607
MAY 18	47299	4.335	2.640	38.815	30.463	-	30.544
MAY 28	47309	4.352	2.615	38.814	30.364	-	30.555
JUN 7	47319	4.359	2.593	38.810	30.250	-	30.481
JUN 17	47329	4.370	2.574	38.808	30.133	-	30.440
JUN 27	47339	4.355	2.535	38.801	29.953	-	30.375
JUL 7	47349	4.318	2.496	-	29.782	-	30.286
JUL 17	47359	4.301	2.465	38.750	29.644	-	30.208
JUL 27	47369	4.271	2.445	38.907	29.495	-	30.146
AUG 6	47379	4.239	2.396	39.010	29.303	-	30.113
AUG 16	47389	4.258	2.380	39.232	29.058	-	30.086
AUG 26	47399	4.253	2.343	39.237	28.827	-	29.960
SEP 5	47409	4.239	2.300	38.898	28.592	-	29.814
SEP 15	47419	4.242	2.264	38.584	28.393	-	29.688
SEP 25	47429	4.223	2.228	38.288	28.189	-	29.661
OCT 5	47439	4.210	2.192	37.964	27.854	-	29.657
OCT 15	47449	4.176	2.163	37.645	27.498	-	29.583
OCT 25	47459	4.162	2.154	37.344	27.155	-	29.401
NOV 4	47469	4.175	2.143	37.033	26.813	-	29.214
NOV 14	47479	4.195	2.110	36.725	26.455	-	28.938
NOV 24	47489	4.161	2.081	36.400	26.105	-	28.658
DEC 4	47499	4.143	2.069	36.047	25.758	-	28.363
DEC 14	47509	4.118	2.053	35.855	25.420	-	28.056
DEC 24	47519	4.108	2.035	35.675	25.099	-	27.667

TABLE 8 - (CONT.)

NOTES

(1) The time scales under the headline PTB are coordinate time scales at sea level derived from the scales of proper time produced by standards CS1 and CS2 of PTB. The gravitational correction is -0.00066us/d .

(2) The time scales under the headlines NRC Cs V, Cs VI A, Cs VI B, Cs VI C are the scales of proper time PT(NRC Cs V), PT(NRC Cs VI A), PT(NRC Cs VI B), PT(NRC Cs VI C) produced directly by primary frequency standards Cs V, Cs VI A, Cs VI B, Cs VI C of NRC used as clocks. The gravitational frequency corretion to these time scales of proper time to obtain coordinate times at sea level is -0.00097us/d .

(3) NRC-CsV. In late June 1988, CsV was opened for repair of detector wiring, and the opportunity was taken to install higher efficiency detectors, replace the ion pump elements, and replenish the cesium ovens. After re-evaluation, CsV became operational again as of 2 September 1988.

TABLE 9 - COORDINATED UNIVERSAL TIME

UTC(k) DENOTES THE APPROXIMATION TO UTC KEPT BY THE LABORATORY k

Unit is one microsecond

DATE 1988		MJD	UTC - UTC(k)					
			AOS (1)	APL (2)	ASMW (3)	AUS	BEV (4)	CAO
JAN	9	47169	0.49	0.023	0.22	-11.887	-2.12	0.08
JAN	19	47179	0.68	0.011	0.10	-12.018	-2.51	0.12
JAN	29	47189	1.01	0.028	0.09	-12.148	-3.04	0.22
FEB	8	47199	1.15	0.031	0.01	-12.305	-3.00	0.42
FEB	18	47209	1.56	0.035	-0.09	-12.459	-3.76	0.61
FEB	28	47219	1.84	0.029	0.04	-12.595	-4.52	0.90
MAR	9	47229	2.15	0.025	0.07	-12.793	-4.93	1.07
MAR	19	47239	1.64	0.035	0.06	-12.939	-5.45	1.31
MAR	29	47249	0.90	0.025	0.03	-13.074	-6.09	1.53
APR	8	47259	0.52	0.023	-0.01	-13.216	-6.82	1.86
APR	18	47269	0.52	0.013	-0.08	-13.368	-7.46	2.21
APR	28	47279	0.47	0.008	-0.22	-13.479	-8.13	2.54
MAY	8	47289	0.27	0.020	-0.36	-13.656	-8.73	2.87
MAY	18	47299	0.49	0.012	-0.34	-13.793	-9.31	3.11
MAY	28	47309	0.57	0.020	-0.39	-13.994	-9.96	3.50
JUN	7	47319	0.60	-0.013	-0.38	-14.192	-10.66	3.71
JUN	17	47329	0.58	-0.032	-0.38	-14.303	-11.39	3.84
JUN	27	47339	0.28	-0.062	-0.36	-14.508	-12.18	3.92
JUL	7	47349	0.09	-0.087	-0.33	-14.629	-12.85	4.08
JUL	17	47359	0.23	-0.118	-0.35	-14.819	6.46	4.19
JUL	27	47369	0.13	-0.186	-0.30	-14.990	5.77	4.26
AUG	6	47379	0.18	-0.017	-0.29	-15.172	5.05	4.39
AUG	16	47389	-0.07	-0.035	-0.05	-15.375	4.37	4.44
AUG	26	47399	0.17	-0.070	0.06	-15.623	3.68	4.46
SEP	5	47409	0.45	-0.108	0.08	-15.817	3.05	4.50
SEP	15	47419	0.54	-0.150	0.14	-16.038	2.34	4.50
SEP	25	47429	0.67	-0.180	0.22	-16.344	1.67	4.56
OCT	5	47439	0.72	-0.219	0.37	-16.496	0.90	4.64
OCT	15	47449	1.11	-0.233	0.45	-16.657	0.05	4.62
OCT	25	47459	1.37	-0.246	0.34	-16.829	-0.74	4.72
NOV	4	47469	1.58	-0.260	0.30	-17.032	-1.67	4.75
NOV	14	47479	1.96	-0.267	0.35	-17.266	-2.33	4.63
NOV	24	47489	1.98	-0.287	0.31	-17.453	-2.85	4.59
DEC	4	47499	-	-0.304	0.34	-17.577	-3.24	4.58
DEC	14	47509	-	-0.331	0.44	-17.688	-3.66	4.57
DEC	24	47519	-	-0.361	0.43	-17.831	-3.81	4.59

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	UTC - UTC(k) CH	CRL (5)(6)	CSAO (7)	DPT (8)	FTZ	IEN (9)
JAN 9	47169	1.529	-0.830	0.89		14.73	-1.254
JAN 19	47179	1.526	-0.953	0.74		14.94	-1.246
JAN 29	47189	1.554	-1.081	0.78		15.21	-1.238
FEB 8	47199	1.540	-1.259	0.68		15.46	-1.264
FEB 18	47209	1.520	-1.485	0.70		15.68	-1.310
FEB 28	47219	1.494	-1.651	0.65		15.92	-1.350
MAR 9	47229	1.480	-1.786	0.62		16.12	-1.357
MAR 19	47239	1.459	-1.838	0.59		16.27	-1.292
MAR 29	47249	1.430	-1.876	0.56		16.46	-1.080
APR 8	47259	1.404	-1.897	0.60		16.58	-0.813
APR 18	47269	1.364	-1.903	0.60		16.73	-0.543
APR 28	47279	1.328	-1.939	0.69		16.86	-0.301
MAY 8	47289	1.276	-1.943	0.61		17.02	-0.075
MAY 18	47299	1.247	-1.990	0.62		17.19	0.155
MAY 28	47309	1.206	-2.009	0.65		17.33	0.299
JUN 7	47319	1.158	-2.037	0.69		17.39	0.438
JUN 17	47329	1.131	-2.011	0.81		17.52	0.621
JUN 27	47339	1.097	-2.011	0.85		17.70	0.717
JUL 7	47349	1.083	-2.009	0.76		17.74	0.735
JUL 17	47359	1.043	-1.999	0.85		17.78	0.602
JUL 27	47369	1.064	-1.971	0.99		17.88	0.451
AUG 6	47379	1.019	-1.976	1.02		17.89	0.431
AUG 16	47389	1.017	-1.948	1.16		17.89	0.536
AUG 26	47399	0.970	-1.932	1.22		17.88	0.648
SEP 5	47409	0.917	-1.915	1.26		17.88	0.750
SEP 15	47419	0.874	-1.920	1.40		17.84	0.863
SEP 25	47429	0.820	-1.899	1.48		17.88	1.150
OCT 5	47439	0.784	-1.901	1.57		17.89	1.579
OCT 15	47449	0.747	-1.869	1.60		17.86	1.704
OCT 25	47459	0.735	-1.850	1.53		17.83	1.657
NOV 4	47469	0.720	-1.853	1.51		17.82	1.769
NOV 14	47479	0.708	-1.833	1.60		17.78	1.679
NOV 24	47489	0.704	-1.814	1.57		17.78	1.553
DEC 4	47499	0.705	-1.805	1.49		17.74	1.284
DEC 14	47509	0.694	-1.783	1.49		17.71	0.951
DEC 24	47519	0.706	-1.731	1.41		17.65	0.564

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	UTC - UTC(k) IFAG (10)	IGMA (11)	INPL	INTI (12)	JATC (7)	KSRI (7)(13)
JAN 9	47169	-4.304	-0.013	50.110	16.75	1.74	-3.08
JAN 19	47179	-4.071	-0.236	51.224	16.12	1.54	-3.56
JAN 29	47189	-3.725	-0.355	52.395	15.89	1.45	-4.04
FEB 8	47199	-3.543	-0.460	53.575	15.37	1.32	-4.45
FEB 18	47209	-3.061	-0.686	54.703	14.49	1.27	-4.90
FEB 28	47219	-2.444	-0.903	55.749	14.86	1.24	-5.32
MAR 9	47229	-1.22	-0.911	56.729	14.18	1.10	-5.48
MAR 19	47239	-0.52	-0.970	57.822	14.36	0.96	-5.64
MAR 29	47249	-0.06	-1.077	58.973	14.23	0.81	-5.80
APR 8	47259	0.77	-1.169	60.202	14.20	0.76	-6.15
APR 18	47269	-3.197	-1.146	61.375	14.07	0.58	-6.53
APR 28	47279	-2.887	-1.272	62.501	14.04	0.53	-6.80
MAY 8	47289	-3.739	-1.426	63.655	14.57	0.39	-7.09
MAY 18	47299	-3.882	-1.594	64.900	14.49	0.28	-7.65
MAY 28	47309	-3.580	-1.588	66.069	13.80	0.20	-7.98
JUN 7	47319	-3.341	-1.535	67.264	13.73	0.26	-8.32
JUN 17	47329	-3.117	-1.539	68.449	13.67	0.62	-8.49
JUN 27	47339	-2.879	-1.547	69.651	13.67	0.79	-8.95
JUL 7	47349	-2.638	-1.513	70.845	13.71	0.85	-9.986
JUL 17	47359	-2.443	-1.381	72.071	13.60	1.21	-10.356
JUL 27	47369	-2.309	-1.236	73.298	13.47	1.48	-10.774
AUG 6	47379	-2.106	-1.082	74.571	13.60	1.66	-11.204
AUG 16	47389	-1.627	-0.904	75.937	13.93	2.05	-11.592
AUG 26	47399	-1.398	-0.647	77.277	14.05	2.29	-11.995
SEP 5	47409	-1.249	-0.303	78.570	14.53	2.49	-12.416
SEP 15	47419	-1.10	0.203	79.893	-	2.73	-12.983
SEP 25	47429	-0.66	0.667	81.230	15.48	2.96	-13.552
OCT 5	47439	-2.29	1.029	82.607	15.70	3.27	-14.158
OCT 15	47449	-1.89	1.490	83.808	16.11	3.47	-14.773
OCT 25	47459	-1.58	2.037	84.970	16.63	3.67	-15.365
NOV 4	47469	-1.129	2.521	86.244	17.04	3.76	-15.967
NOV 14	47479	-0.813	2.929	87.635	17.11	3.84	-16.602
NOV 24	47489	-0.650	3.398	89.026	17.32	3.65	-17.229
DEC 4	47499	-0.431	3.997	90.443	17.49	3.48	-17.921
DEC 14	47509	-0.263	4.523	91.870	17.80	3.32	-18.609
DEC 24	47519	-0.072	5.048	93.315	17.88	3.21	-19.065

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	UTC - UTC(k)					
		NAOM (14)	NIM (7)	NIST (15)	NPL	NPLI (16)	NRC
JAN 9	47169	-35.16	10.39	-0.184	3.956	-7.521	-10.275
JAN 19	47179	-35.28	10.16	-0.272	3.967	-7.945	-10.130
JAN 29	47189	-35.36	10.11	-0.333	4.008	-8.271	-9.948
FEB 8	47199	-35.51	10.07	-0.414	4.059	-8.593	-9.827
FEB 18	47209	-35.61	10.08	-0.486	4.104	-8.930	-9.665
FEB 28	47219	-35.73	10.04	-0.564	4.112	-9.319	-9.565
MAR 9	47229	-35.74	9.92	-0.627	4.142	-9.902	-9.495
MAR 19	47239	-35.75	9.79	-0.680	4.166	-10.386	-9.438
MAR 29	47249	-35.78	9.70	-0.751	4.198	-10.910	-9.419
APR 8	47259	-35.71	9.60	-0.813	4.222	-11.492	-9.377
APR 18	47269	-35.57	9.42	-0.860	4.259	-12.030	-9.316
APR 28	47279	-35.59	9.06	-0.908	4.285	-12.168	-9.251
MAY 8	47289	-35.62	8.89	-0.922	4.318	-12.081	-9.223
MAY 18	47299	-35.63	8.81	-0.937	4.287	-12.153	-9.195
MAY 28	47309	-35.62	8.77	-0.949	4.296	-12.219	-9.187
JUN 7	47319	-35.57	8.81	-0.959	4.303	-12.123	-9.181
JUN 17	47329	-35.47	8.85	-0.948	4.270	-12.092	-9.174
JUN 27	47339	-35.45	8.76	-0.951	4.203	-12.056	-9.171
JUL 7	47349	-35.38	8.66	-0.945	4.150	-12.123	-9.243
JUL 17	47359	-35.35	8.68	-0.895	4.111	-12.134	-9.311
JUL 27	47369	-35.30	8.60	-0.829	4.074	-12.070	-9.363
AUG 6	47379	-35.17	8.61	-0.783	4.030	-12.081	-9.387
AUG 16	47389	-35.09	8.68	-0.718	4.024	-12.088	-9.404
AUG 26	47399	-34.93	8.55	-0.655	4.011	-12.085	-9.520
SEP 5	47409	-34.73	8.54	-0.592	4.002	-12.049	-9.703
SEP 15	47419	-34.56	8.59	-0.518	3.970	-11.979	-10.007
SEP 25	47429	-34.56	8.64	-0.439	3.928	-11.955	-10.294
OCT 5	47439	-34.45	8.55	-0.371	3.909	-11.141	-10.608
OCT 15	47449	-34.40	8.43	-0.316	3.939	-11.269	-10.917
OCT 25	47459	-34.43	8.22	-0.250	3.867	-11.396	-11.209
NOV 4	47469	-34.40	8.07	-0.189	3.708	-11.489	-11.510
NOV 14	47479	-34.50	8.08	-0.146	3.529	-11.532	-11.808
NOV 24	47489	-34.57	8.00	-0.113	3.328	-11.539	-12.123
DEC 4	47499	-34.64	7.88	-0.099	3.121	-11.498	-12.467
DEC 14	47509	-34.69	7.84	-0.106	2.925	-11.502	-12.649
DEC 24	47519	-34.76	7.87	-0.102	2.675	-11.505	-12.819

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	UTC - UTC(k) NRLM	OMH	ONBA (17)	OP	ORB (18)
JAN 9	47169	-21.98	-	-	0.188	-46.030
JAN 19	47179	-22.19	-	-	0.043	-46.526
JAN 29	47189	-22.36	-	-	-0.098	-47.012
FEB 8	47199	-22.55	-	-	-0.274	-47.517
FEB 18	47209	-22.72	-	-102.08	-0.348	-47.971
FEB 28	47219	-22.91	-	-103.28	-0.435	-48.417
MAR 9	47229	-23.06	-	-	-0.529	-48.923
MAR 19	47239	-23.21	-	-5.15	-0.572	-9.169
MAR 29	47249	-23.39	-	-5.05	-0.591	-9.236
APR 8	47259	-23.59	-	-	-0.552	-9.300
APR 18	47269	-23.81	-	-	-0.530	-9.406
APR 28	47279	-23.97	-	-	-0.578	-9.508
MAY 8	47289	-24.15	-	-2.10	-0.633	-9.590
MAY 18	47299	-24.32	-	-3.32	-0.681	-9.707
MAY 28	47309	-24.56	-	-4.60	-0.754	-9.822
JUN 7	47319	-24.74	-	-5.96	-0.763	-9.930
JUN 17	47329	-25.05	-	-7.22	-0.828	-10.034
JUN 27	47339	-25.45	-	-8.43	-0.922	-10.135
JUL 7	47349	-25.76	-	-9.75	-1.006	-10.200
JUL 17	47359	-26.11	-	-10.89	-1.110	-10.295
JUL 27	47369	-26.42	-	-	-1.197	-10.361
AUG 6	47379	-26.71	-	-12.60	-1.303	-10.418
AUG 16	47389	-27.07	-5.18	-14.07	-1.378	-10.443
AUG 26	47399	-27.40	-6.09	-15.22	-1.475	-10.502
SEP 5	47409	-27.78	-6.14	-16.69	-1.520	-10.634
SEP 15	47419	-28.21	-6.24	-18.08	-1.617	-10.712
SEP 25	47429	-28.59	-	-19.37	-1.679	-10.879
OCT 5	47439	-28.93	-7.61	-20.53	-1.735	-11.001
OCT 15	47449	-29.29	-8.17	-21.80	-1.722	-11.119
OCT 25	47459	-29.72	-8.49	-23.05	-1.705	-11.170
NOV 4	47469	-30.11	-8.76	-24.12	-1.704	-11.316
NOV 14	47479	-30.54	-8.84	-23.36	-1.733	-11.501
NOV 24	47489	-30.91	-9.12	-21.14	-1.772	-11.815
DEC 4	47499	-31.27	-9.28	-20.20	-1.809	-12.115
DEC 14	47509	-31.72	-9.21	-20.89	-1.857	-12.350
DEC 24	47519	-32.16	-9.00	-21.19	-1.897	-12.554

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	UTC - UTC(k) PKNM	PTB	ROA (19)	SO (7)	STA (20)
JAN 9	47169	-2.54	4.309	3.437	2.71	0.016
JAN 19	47179	-2.09	4.270	3.466	2.51	0.165
JAN 29	47189	-1.86	4.262	3.560	2.24	0.260
FEB 8	47199	-1.78	4.235	3.604	1.98	0.307
FEB 18	47209	-1.60	4.239	3.611	1.92	0.382
FEB 28	47219	-1.41	4.244	3.601	1.93	0.455
MAR 9	47229	-1.15	4.264	3.588	1.99	0.476
MAR 19	47239	-0.78	4.284	3.705	2.04	0.469
MAR 29	47249	-0.62	4.297	3.810	2.09	0.434
APR 8	47259	-0.26	4.303	3.729	2.03	0.388
APR 18	47269	0.16	4.339	3.736	2.02	0.361
APR 28	47279	0.83	4.328	3.838	2.03	0.342
MAY 8	47289	1.20	4.307	4.041	1.93	0.330
MAY 18	47299	1.38	4.333	4.159	1.93	0.385
MAY 28	47309	1.53	4.346	4.288	1.91	0.361
JUN 7	47319	1.71	4.345	4.388	1.90	0.266
JUN 17	47329	1.96	4.372	4.538	2.00	0.176
JUN 27	47339	2.19	4.349	4.660	2.04	0.075
JUL 7	47349	2.21	4.339	4.796	1.93	0.159
JUL 17	47359	2.30	4.298	4.964	1.98	0.181
JUL 27	47369	2.52	4.303	5.162	1.91	0.292
AUG 6	47379	2.61	4.203	5.324	1.86	0.363
AUG 16	47389	2.89	4.233	5.477	1.82	0.294
AUG 26	47399	2.85	4.251	5.625	1.76	0.246
SEP 5	47409	2.86	4.258	5.766	1.79	0.157
SEP 15	47419	2.62	4.241	5.892	1.83	0.10
SEP 25	47429	2.66	4.232	6.054	1.84	-0.04
OCT 5	47439	2.42	4.211	6.209	1.87	-0.22
OCT 15	47449	2.47	4.195	6.379	1.93	-0.38
OCT 25	47459	2.77	4.178	6.561	1.88	-0.51
NOV 4	47469	2.87	4.146	6.776	1.95	-0.71
NOV 14	47479	2.73	4.176	6.966	2.11	-0.73
NOV 24	47489	2.60	4.188	7.159	2.12	-0.86
DEC 4	47499	3.14	4.128	7.328	2.18	-0.90
DEC 14	47509	3.71	4.106	7.437	2.33	-0.94
DEC 24	47519	4.71	4.113	7.425	2.40	-0.478

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1988	MJD	UTC - UTC(k)				
		SU (21)	TAO (6)	TL (7)(22)	TP (23)	TUG (24)
JAN 9	47169	21.46	-1.846	260.28	-0.92	-3.634
JAN 19	47179	21.24	-1.881	262.06	-0.52	-3.397
JAN 29	47189	21.51	-1.881	263.06	-0.42	-3.126
FEB 8	47199	21.28	-1.912	264.49	-0.48	-2.859
FEB 18	47209	21.13	-1.931	266.00	-0.23	-2.588
FEB 28	47219	21.04	-1.977	267.48	0.02	-2.306
MAR 9	47229	20.75	-2.005	268.94	0.24	-2.050
MAR 19	47239	20.55	-2.038	270.40	0.55	-1.781
MAR 29	47249	20.38	-2.072	271.85	0.85	-1.515
APR 8	47259	20.16	-2.085	273.28	0.94	-1.260
APR 18	47269	20.08	-2.085	274.87	1.17	-1.014
APR 28	47279	19.62	-2.104	276.25	1.13	-0.730
MAY 8	47289	19.62	-2.100	277.35	1.57	-0.453
MAY 18	47299	19.52	-2.137	278.56	1.75	-0.181
MAY 28	47309	19.18	-2.152	280.00	1.93	0.082
JUN 7	47319	19.32	-2.192	281.48	2.23	0.328
JUN 17	47329	19.42	-2.190	282.74	2.53	0.600
JUN 27	47339	19.44	-2.209	-5.23	2.34	0.889
JUL 7	47349	19.34	-2.232	-5.48	2.04	1.172
JUL 17	47359	19.13	-2.262	-5.41	1.29	1.391
JUL 27	47369	18.79	-2.272	-5.63	0.29	1.663
AUG 6	47379	18.98	-2.307	-5.66	-0.93	1.927
AUG 16	47389	18.84	-2.321	-5.60	-1.82	2.208
AUG 26	47399	18.69	-2.320	-5.52	-2.54	2.466
SEP 5	47409	18.55	-2.341	-5.56	-3.22	2.707
SEP 15	47419	18.40	-2.389	-5.55	-3.28	2.986
SEP 25	47429	18.26	-2.411	-5.61	-3.30	3.239
OCT 5	47439	18.11	-2.440	-5.667	-3.18	3.523
OCT 15	47449	17.97	-2.432	-5.715	-3.12	3.783
OCT 25	47459	17.83	-2.439	-5.776	-2.99	4.061
NOV 4	47469	17.70	-2.454	-5.789	-2.72	4.329
NOV 14	47479	17.58	-2.466	-5.835	-2.28	4.562
NOV 24	47489	17.36	-2.468	-5.849	-2.00	4.788
DEC 4	47499	17.25	-2.491	-5.877	-1.79	5.024
DEC 14	47509	17.03	-2.528	-5.920	-1.43	-4.758
DEC 24	47519	16.75	-2.541	-5.995	-1.05	-4.493

TABLE 9 - (CONT.)

Unit is one microsecond

DATE 1988		MJD	UTC - UTC(k) USNO	VSL	YUZM	ZIPE (3)
JAN	9	47169	-4.529	4.158	1.84	-0.24
JAN	19	47179	-4.510	4.124	1.61	-0.08
JAN	29	47189	-4.460	4.060	1.20	0.12
FEB	8	47199	-4.427	3.960	0.99	0.28
FEB	18	47209	-4.371	3.930	0.72	0.41
FEB	28	47219	-4.317	3.932	0.34	0.37
MAR	9	47229	-4.255	3.902	-0.18	0.42
MAR	19	47239	-4.181	3.878	-0.71	0.45
MAR	29	47249	-4.116	3.838	-0.97	0.46
APR	8	47259	-4.048	3.840	-1.00	0.47
APR	18	47269	-3.970	3.848	-1.19	0.48
APR	28	47279	-3.911	3.810	-1.46	0.47
MAY	8	47289	-3.841	3.754	-1.36	0.38
MAY	18	47299	-3.768	3.783	-1.19	0.35
MAY	28	47309	-3.679	3.809	-0.75	0.23
JUN	7	47319	-3.587	3.751	-0.11	0.24
JUN	17	47329	-3.478	3.743	0.63	0.26
JUN	27	47339	-3.373	3.744	1.24	0.21
JUL	7	47349	-3.264	3.669	2.41	0.25
JUL	17	47359	-3.144	3.675	3.34	0.34
JUL	27	47369	-3.015	3.729	4.10	0.45
AUG	6	47379	-2.907	3.723	4.38	0.32
AUG	16	47389	-2.790	3.760	4.63	0.21
AUG	26	47399	-2.668	3.732	5.34	0.06
SEP	5	47409	-2.532	3.687	5.87	0.05
SEP	15	47419	-2.403	3.710	6.25	0.09
SEP	25	47429	-2.279	3.714	6.98	0.12
OCT	5	47439	-2.151	3.723	7.63	0.21
OCT	15	47449	-2.022	3.672	7.95	0.37
OCT	25	47459	-1.904	3.683	8.26	0.19
NOV	4	47469	-1.797	3.678	8.29	0.08
NOV	14	47479	-1.701	3.673	8.02	-0.02
NOV	24	47489	-1.618	3.697	7.87	-0.13
DEC	4	47499	-1.549	3.704	7.44	-0.15
DEC	14	47509	-1.484	3.757	7.41	-0.07
DEC	24	47519	-1.402	3.770	6.96	0.00

TABLE 9 - (CONT.)

NOTES

(1) AOS . UTC(AOS) being linked to UTC(ZIPE) by TV, the published values of UTC-UTC(AOS) have a time step of 610 ns between MJD=47389 and MJD=47399, due to the change of delay correction of the link PTB-ZIPE (see note 3 below).

(2) APL . Time steps of UTC(APL) of -1150 ns and -180 ns respectively on MJD=47159.00 and MJD=47369.00

(3) ASMW, ZIPE. Recalibration of the TV links ASMW-PTB and ZIPE-PTB and change of the delay corrections on MJD=47399. In order to keep the continuity of the published values of UTC-UTC(ASMW) and UTC-UTC(ZIPE), the UTC(ASMW) and UTC(ZIPE) have been shifted at MJD=47399 according to :
UTC(ASMW)new - UTC(ASMW)old = 770 ns
UTC(ZIPE)new - UTC(ZIPE)old = 610 ns

(4) BEV . Time step of UTC(BEV) of -20000 ns on MJD = 47353.35

(5) CRL . Communications Research Laboratory (previously RRL).

(6) CRL, TAO . As a result of NIST campaign of GPS receivers comparison from 2 June to 11 June 1988, the delays of the receivers at CRL and TAO have been modified. The results UTC-UTC(CRL) and UTC-UTC(TAO) for the whole year 1988 have been computed with the new delays. Steps of -90 ns and -100 ns appear respectively for CRL and TAO between MJD=47159 and MJD=47169 (beginning of 1988).

(7) CSAO, JATC, KSRI, NIM, SO, TL. On MJD=47239 interpolated values for LORAN-C time link.

(8) DPT . No data available for 1988.

(9) IEN . Change of master clock on MJD=47193.0

(10) IFAG. LORAN-C instead of GPS from MJD=47229 to MJD=47259, and from MJD=47419 to MJD=47459. Time steps of UTC(IFAG) of 5000 ns and 2000 ns respectively on MJD=47263.50 and MJD=47438.27

(11) IGMA. GPS link with USNO. Time step of UTC(IGMA) of -8684 ns on MJD=47161.

(12) INTI. TV link with IGMA.

TABLE 9 - (CONT.)

NOTES

(13) KSRI. Time step of the published values of UTC-UTC(KSRI) due to introduction of GPS link on MJD=47349. Interpolated value on MJD=47499.

(14) NAOM. National Astronomical Observatory, Mizusawa (previously ILOM).

(15) NIST. National Institute of Standards and Technology (previously NBS).

(16) NPLI. Time step of UTC(NPLI) on MJD=47430.

(17) ONBA. The listed values, referred to clock ONBA1, use the TV link with IGMA. Time step of UTC(ONBA) of -100000 ns on MJD=47221.

(18) ORB . Time step of UTC(ORB) of -40000 ns on MJD=47232.40 Interpolated value on MJD=47379.

(19) ROA . Real Instituto y Observatorio de la Armada (previously OMSF).

(20) STA . LORAN-C instead of GPS from MJD=47419 to MJD=47509. The time step of UTC-UTC(STA) between MJD=47509 and MJD=47519 of 500 ns is an adjustment made by the BIPM, as a consequence of the reintroduction of the GPS time link for STA.

(21) SU . From MJD=47379 to MJD=47449, the UTC-UTC(SU) values have been obtained by linear interpolation of UTC-UTC(SU) obtained from the following clock transportations by SU :
1988 May 19, to ASMW (see Table 6)
1988 Oct. 20, to TUG (see Table 6)
From MJD=47459 to MJD=47479, the UTC-UTC(SU) values have been obtained by linear interpolation of UTC-UTC(SU) obtained from the following clock transportations by SU :
1988 Oct. 20, to TUG (see Table 6)
1988 Nov. 18, to OP (see Table 6)
From MJD=47489 LORAN-C time link.

(22) TL . Time step of UTC(TL) of 288000 ns and change of master clock on MJD=47329.125 . Introduction of GPS time link on MJD=46439. Interpolated value on MJD=47499.

(23) TP . Time step of UTC(TP) of 5000 ns on MJD=47161.00 Interpolated value for the TV time link on MJD=47239.

(24) TUG . Time step of UTC(TUG) of 10000 ns on MJD=47504.70

TABLE 9 A - COORDINATED UNIVERSAL TIME (VLF)

UTC(k) DENOTES THE APPROXIMATION TO UTC KEPT BY THE LABORATORY k

Unit is one microsecond

DATE 1988		MJD	UTC - UTC(k)
JAN	9	47169	
JAN	19	47179	
JAN	29	47189	
FEB	8	47199	
FEB	18	47209	
FEB	28	47219	
MAR	9	47229	
MAR	19	47239	
MAR	29	47249	
APR	8	47259	
APR	18	47269	
APR	28	47279	
MAY	8	47289	
MAY	18	47299	
MAY	28	47309	
JUN	7	47319	No data available for 1988
JUN	17	47329	
JUN	27	47339	
JUL	7	47349	
JUL	17	47359	
JUL	27	47369	
AUG	6	47379	
AUG	16	47389	
AUG	26	47399	
SEP	5	47409	
SEP	15	47419	
SEP	25	47429	
OCT	5	47439	
OCT	15	47449	
OCT	25	47459	
NOV	4	47469	
NOV	14	47479	
NOV	24	47489	
DEC	4	47499	
DEC	14	47509	
DEC	24	47519	

TABLE 9 B . TAI - GPS TIME and UTC - GPS TIME

TAI - GPS TIME = 19 s + Co + DC
UTC - GPS TIME = -5 s + Co + DC
at the instant of observations at Paris Observatory
(see explanations, Part A)

Date		Co (ns)	DC(ns)					
			PRN 3	PRN 6	PRN 9	PRN11	PRN12	PRN13
			NAV11	NAV 3	NAV 6	NAV 8	NAV10	NAV 9
1987/88	MJD	0hUTC	0h40m	19h32m	20h49m	13h19m	23h32m	0h24m
DEC 31	47160	-4826	0	3	0	8	-5	-6
JAN 1	47161	-4811	-1	-8	-5	5	-12	-9
JAN 2	47162	-4782	11	-7	-5	20	-13	2
JAN 3	47163	-4756	-5	-15	-11	53	-10	-4
JAN 4	47164	-4731	-1	-9	-6	-	-7	-7
JAN 5	47165	-4713	3	-7	-8	18	-10	-10
JAN 6	47166	-4693	2	-8	-2	18	-5	-1
JAN 7	47167	-4668	-6	-6	-6	11	1	4
JAN 8	47168	-4638	2	-2	9	8	-8	-10
JAN 9	47169	-4620	2	-9	4	10	5	6
JAN 10	47170	-4600	-	-10	11	11	-8	6
JAN 11	47171	-4597	-1	-10	-4	7	3	6
JAN 12	47172	-4597	3	-10	-5	11	4	-4
JAN 13	47173	-4595	6	-3	0	8	-10	-1
JAN 14	47174	-4591	3	8	-1	11	-7	-7
JAN 15	47175	-4593	3	-5	-4	1	-3	-4
JAN 16	47176	-4595	-1	-9	-6	15	5	-3
JAN 17	47177	-4586	10	0	-1	13	-13	-7
JAN 18	47178	-4580	-3	3	-2	16	-12	-2
JAN 19	47179	-4580	-7	0	-10	13	-1	-6
JAN 20	47180	-4578	-3	14	4	10	-3	-7
JAN 21	47181	-4567	-1	-1	-5	7	14	-20
JAN 22	47182	-4567	0	-1	-3	12	-9	2
JAN 23	47183	-4560	2	0	-2	8	-1	-4
JAN 24	47184	-4552	-1	-1	-2	0	4	0
JAN 25	47185	-4544	3	-3	-10	15	-1	-8
JAN 26	47186	-4543	0	-3	-3	-	1	-6
JAN 27	47187	-4536	-	3	15	5	-3	-15
JAN 28	47188	-4530	1	2	-4	5	1	-11
JAN 29	47189	-4525	-2	-1	-	13	4	-13
JAN 30	47190	-4519	-2	-1	15	-4	4	-2
JAN 31	47191	-4514	5	1	8	-6	-1	-17
FEB 1	47192	-4520						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) OhUTC	DC(ns) PRN 3 NAV11 22h32m	PRN 6 NAV 3 17h28m	PRN 9 NAV 6 18h45m	PRN11 NAV 8 11h15m	PRN12 NAV10 21h28m	PRN13 NAV 9 22h16m
JAN 31	47191	-4514	5	1	8	-6	-1	-17
FEB 1	47192	-4520	9	15	0	0	-6	-4
FEB 2	47193	-4522	-	-8	-9	-10	-4	-
FEB 3	47194	-4527	9	1	-6	15	-10	-13
FEB 4	47195	-4522	7	7	-	9	2	-10
FEB 5	47196	-4513	-4	14	1	2	-6	-8
FEB 6	47197	-4512	7	3	-1	6	-2	-9
FEB 7	47198	-4508	4	10	-2	1	6	-8
FEB 8	47199	-4509	-4	0	-8	11	-9	-11
FEB 9	47200	-4517	12	2	5	14	21	-1
FEB 10	47201	-4516	2	7	-1	-3	2	-3
FEB 11	47202	-4560	-1	-4	-5	6	-6	7
FEB 12	47203	-4609	-3	-2	-3	15	-12	-11
FEB 13	47204	-4658	-1	-8	-4	11	3	-7
FEB 14	47205	-4690	5	-4	-6	12	-14	-5
FEB 15	47206	-4715	2	-1	-4	10	0	-8
FEB 16	47207	-4727	-1	9	-7	6	0	-8
FEB 17	47208	-4738	-2	-2	11	2	-11	-11
FEB 18	47209	-4744	-4	-9	0	12	2	1
FEB 19	47210	-4742	26	-11	-1	1	-9	-15
FEB 20	47211	-4735	-7	-2	10	8	-4	-7
FEB 21	47212	-4725	13	-7	3	8	-2	-4
FEB 22	47213	-4714	5	-14	4	2	-1	5
FEB 23	47214	-4710	-1	-7	4	-1	0	-9
FEB 24	47215	-4706	3	-9	7	11	3	-11
FEB 25	47216	-4697	-3	2	7	-3	4	-13
FEB 26	47217	-4687	1	0	0	5	-11	1
FEB 27	47218	-4673	9	16	-5	3	3	-8
FEB 28	47219	-4661	-6	-5	-7	12	-5	-2
FEB 29	47220	-4659	-12	13	-3	10	-15	-4
MAR 1	47221	-4648						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) 0hUTC	DC(ns) PRN 3 NAV11 20h36m	PRN 6 NAV 3 15h32m	PRN 9 NAV 6 16h49m	PRN11 NAV 8 9h19m	PRN12 NAV10 19h32m	PRN13 NAV 9 20h20m
FEB 29	47220	-4659	-12	13	-3	10	-15	-4
MAR 1	47221	-4648	8	8	-3	-4	1	10
MAR 2	47222	-4626	7	-	-6	-11	1	4
MAR 3	47223	-4614	2	6	0	4	-6	-3
MAR 4	47224	-4608	8	-1	-1	-1	3	1
MAR 5	47225	-4604	5	-4	-1	-11	7	-5
MAR 6	47226	-4600	19	4	-3	-11	-3	-1
MAR 7	47227	-4591	5	-6	-4	-8	10	-7
MAR 8	47228	-4585	3	3	8	-4	-6	-4
MAR 9	47229	-4576	7	5	-10	-5	-3	-5
MAR 10	47230	-4562	2	-	-6	-16	-7	-7
MAR 11	47231	-4535	5	12	-8	5	0	-4
MAR 12	47232	-4501	-14	0	-8	16	0	-10
MAR 13	47233	-4475	5	-1	-9	18	2	-5
MAR 14	47234	-4440	3	13	0	15	1	-7
MAR 15	47235	-4418	4	-2	2	-	5	-3
MAR 16	47236	-4406	12	-12	7	-9	3	6
MAR 17	47237	-4394	-2	-22	-13	14	11	-13
MAR 18	47238	-4389	-	-4	-12	16	1	-2
MAR 19	47239	-4370	4	-4	-11	15	5	1
MAR 20	47240	-4353	18	-13	-8	4	-2	1
MAR 21	47241	-4337	3	-13	4	-4	-1	-6
MAR 22	47242	-4317	-4	-10	-10	1	8	11
MAR 23	47243	-4288	8	-11	-5	14	1	1
MAR 24	47244	-4263	4	-6	-2	16	0	-3
MAR 25	47245	-4247	17	1	-1	-1	4	9
MAR 26	47246	-4237	1	-10	-10	-14	-2	3
MAR 27	47247	-4230	12	0	-7	3	5	4
MAR 28	47248	-4214	9	-1	-10	-9	8	5
MAR 29	47249	-4204	15	-6	-6	-8	0	-4
MAR 30	47250	-4192	22	-5	-9	0	8	7
MAR 31	47251	-4182	-14	-10	-6	-14	4	-2
APR 1	47252	-4173						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) 0hUTC	DC(ns) PRN 3 NAV11 18h32m	PRN 6 NAV 3 13h28m	PRN 9 NAV 6 14h45m	PRN11 NAV 8 7h15m	PRN12 NAV10 17h28m	PRN13 NAV 9 18h16m
MAR 31	47251	-4182	-14	-10	-6	-14	4	-2
APR 1	47252	-4173	18	-5	-1	3	3	12
APR 2	47253	-4152	4	-7	-2	-4	2	1
APR 3	47254	-4145	11	1	-3	-15	1	8
APR 4	47255	-4132	11	-7	-5	-12	12	-9
APR 5	47256	-4118	15	-1	-4	-9	13	0
APR 6	47257	-4104	9	-5	-10	-16	3	1
APR 7	47258	-4092	5	-4	-6	-7	12	17
APR 8	47259	-4076	8	-9	-7	-12	5	3
APR 9	47260	-4064	12	1	-3	-9	-	12
APR 10	47261	-4052	2	2	-3	-17	1	-2
APR 11	47262	-4043	4	-3	0	-1	6	6
APR 12	47263	-4032	-6	-1	3	-10	11	0
APR 13	47264	-4024	6	-4	4	-8	9	-3
APR 14	47265	-4016	6	-7	4	-1	6	1
APR 15	47266	-4015	14	-8	-1	-2	-2	-6
APR 16	47267	-4016	-1	-12	-3	3	-2	0
APR 17	47268	-4011	1	6	6	-7	1	-9
APR 18	47269	-3998	15	-3	2	-	3	-12
APR 19	47270	-3983	-1	6	2	3	-13	-1
APR 20	47271	-3973	-1	1	6	-2	6	-3
APR 21	47272	-3961	2	4	3	-4	-2	-6
APR 22	47273	-3951	7	4	6	-2	4	-15
APR 23	47274	-3941	3	8	9	-10	-2	-
APR 24	47275	-3933	2	7	2	-3	-1	-1
APR 25	47276	-3927	15	1	3	-18	6	8
APR 26	47277	-3921	9	2	7	-13	-5	-3
APR 27	47278	-3925	8	-3	-	-3	3	-1
APR 28	47279	-3931	6	-3	6	-16	1	-4
APR 29	47280	-3937	3	2	-1	-5	-7	2
APR 30	47281	-3939	11	5	5	-13	-4	1
MAY 1	47282	-3939						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) OhUTC	DC(ns) PRN 3 NAV11 16h32m	PRN 6 NAV 3 11h28m	PRN 9 NAV 6 12h45m	PRN11 NAV 8 5h15m	PRN12 NAV10 15h28m	PRN13 NAV 9 16h16m
APR 30	47281	-3939	11	5	5	-13	-4	1
MAY 1	47282	-3939	5	-6	2	-8	-4	-5
MAY 2	47283	-3938	11	3	4	-5	0	-4
MAY 3	47284	-3933	-7	-6	-3	-5	-1	-6
MAY 4	47285	-3925	10	-3	0	7	-9	-1
MAY 5	47286	-3908	14	3	9	-2	1	-9
MAY 6	47287	-3896	12	6	5	-43	-1	1
MAY 7	47288	-3872	7	5	3	0	-11	-10
MAY 8	47289	-3851	10	1	-1	-2	5	0
MAY 9	47290	-3830	2	0	5	-11	-4	2
MAY 10	47291	-3811	8	-	6	1	-1	3
MAY 11	47292	-3798	5	2	11	-9	-5	-5
MAY 12	47293	-3789	7	1	0	-14	7	-6
MAY 13	47294	-3776	14	-4	1	-10	0	-4
MAY 14	47295	-3761	1	8	4	-4	5	-1
MAY 15	47296	-3752	-7	-4	-3	-2	0	7
MAY 16	47297	-3746	8	5	5	-11	-3	-11
MAY 17	47298	-3732	-5	9	11	-6	-12	-16
MAY 18	47299	-3712	10	9	5	-5	1	-1
MAY 19	47300	-3689	-5	10	3	-6	-4	-9
MAY 20	47301	-3672	8	5	10	-13	-3	4
MAY 21	47302	-3649	7	7	4	-5	4	-6
MAY 22	47303	-3636	-5	8	-1	-11	-1	-11
MAY 23	47304	-3619	-1	3	4	-6	-7	11
MAY 24	47305	-3595	19	12	8	-3	14	3
MAY 25	47306	-3590	-7	11	-5	-15	-4	-12
MAY 26	47307	-3594	2	9	0	-4	-9	-6
MAY 27	47308	-3585	10	3	2	-4	-5	9
MAY 28	47309	-3576	-6	8	5	-9	-	-8
MAY 29	47310	-3571	14	-2	4	-13	5	-20
MAY 30	47311	-3554	8	7	1	-4	2	-6
MAY 31	47312	-3541	8	1	-3	2	6	1
JUN 1	47313	-3536						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) 0hUTC	DC(ns) PRN 3 NAV11 14h28m	PRN 6 NAV 3 9h24m	PRN 9 NAV 6 10h41m	PRN11 NAV 8 3h11m	PRN12 NAV10 13h24m	PRN13 NAV 9 14h12m
MAY 31	47312	-3541	8	1	-3	2	6	1
JUN 1	47313	-3536	-1	1	-2	-8	-3	13
JUN 2	47314	-3534	3	-	-	-11	-5	-19
JUN 3	47315	-3526	1	-1	3	-5	-13	-2
JUN 4	47316	-3505	-4	-5	11	-15	11	-7
JUN 5	47317	-3470	-4	7	15	-1	2	-7
JUN 6	47318	-3441	-8	-15	5	-3	-5	-2
JUN 7	47319	-3404	-1	12	4	-6	-8	2
JUN 8	47320	-3358	21	13	1	-7	11	6
JUN 9	47321	-3327	12	0	5	6	-1	-5
JUN 10	47322	-3324	1	-7	-3	1	-5	-3
JUN 11	47323	-3321	13	-	2	-7	-2	5
JUN 12	47324	-3312	8	3	0	-8	-8	-13
JUN 13	47325	-3303	10	4	5	-1	10	7
JUN 14	47326	-3303	12	-5	0	-10	3	-6
JUN 15	47327	-3310	-1	-5	6	-9	-5	5
JUN 16	47328	-3313	16	5	0	-3	-10	-7
JUN 17	47329	-3317	20	-3	-4	-2	-4	-4
JUN 18	47330	-3321	6	-1	1	-	5	3
JUN 19	47331	-3330	16	-7	11	-2	-2	4
JUN 20	47332	-3350	6	-6	-2	-12	-12	0
JUN 21	47333	-3365	7	-18	-3	-13	-14	-18
	*	0hUTC	12h16m	8h 8m	9h 8m	3h 0m	11h24m	11h40m
JUN 22	47344	-3370	21	-10	-7	-8	7	-2
JUN 23	47335	-3373	12	0	-2	-12	-7	-4
JUN 24	47336	-3372	10	-3	-7	-4	2	3
JUN 25	47337	-3369	18	-1	-5	-2	4	-1
JUN 26	47338	-3374	-20	21	-2	-14	1	-
JUN 27	47339	-3377	15	-1	-5	-3	3	3
JUN 28	47340	-3381	13	4	-4	-10	-12	3
JUN 29	47341	-3386	15	2	-2	-5	7	7
JUN 30	47342	-3399	17	-18	-11	-13	-1	-6
JUL 1	47343	-3400						

* Change of tracking schedule.

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) OhUTC	DC(ns) PRN 3 NAV11 11h44m	PRN 6 NAV 3 7h36m	PRN 9 NAV 6 8h36m	PRN11 NAV 8 2h28m	PRN12 NAV10 10h52m	PRN13 NAV 9 11h 8m
JUN 30	47342	-3399	17	-18	-11	-13	-1	-6
JUL 1	47343	-3400	25	2	-4	-10	5	5
JUL 2	47344	-3405	10	-2	-8	-4	-5	-1
JUL 3	47345	-3415	19	-7	-12	-12	2	0
JUL 4	47346	-3416	24	0	-9	-3	3	18
JUL 5	47347	-3432	16	-8	-11	-12	10	-7
JUL 6	47348	-3451	10	-5	-16	-14	-7	11
JUL 7	47349	-3457	26	-7	-10	1	1	13
JUL 8	47350	-3470	12	-12	-16	2	-1	0
JUL 9	47351	-3484	8	-7	-10	-1	-4	14
JUL 10	47352	-3493	8	-9	9	-10	-	6
JUL 11	47353	-3495	82	-19	2	-15	-21	13
JUL 12	47354	-3508	-1	-11	-9	-4	-10	-1
JUL 13	47355	-3524	16	-1	-4	1	0	-8
JUL 14	47356	-3533	8	-17	-8	-6	-10	1
JUL 15	47357	-3525	9	-6	-7	9	1	3
JUL 16	47358	-3517	19	-10	-2	-10	9	18
JUL 17	47359	-3518	-8	-16	-5	-7	-3	-8
JUL 18	47360	-3505	21	-7	-1	5	-1	16
JUL 19	47361	-3497	14	-13	-4	0	-5	-5
JUL 20	47362	-3491	9	-17	-6	7	0	5
JUL 21	47363	-3481	27	-13	4	-7	2	25
JUL 22	47364	-3487	11	-21	-9	-19	-7	14
JUL 23	47365	-3486	23	-21	-5	0	6	9
JUL 24	47366	-3486	-1	-7	-5	-14	1	11
JUL 25	47367	-3482	13	-4	1	-20	-12	1
JUL 26	47368	-3460	22	0	1	-26	5	12
JUL 27	47369	-3436	12	-11	-4	-1	-6	11
JUL 28	47370	-3426	4	-14	-7	-8	-10	-2
JUL 29	47371	-3392	-3	-17	-18	-36	-3	-16
JUL 30	47372	-3284	14	-4	-4	-13	-6	18
JUL 31	47373	-3156	24	-3	-4	5	-1	22
AUG 1	47374	-3061						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) 0hUTC	DC(ns) PRN 3 NAV11 9h40m	PRN 6 NAV 3 5h32m	PRN 9 NAV 6 6h32m	PRN11 NAV 8 0h24m	PRN12 NAV10 8h48m	PRN13 NAV 9 9h 4m
JUL 31	47373	-3156	24	-3	-4	5	-1	22
AUG 1	47374	-3061	23	-10	0	-19	-1	-2
AUG 2	47375	-2969	7	-6	3	-5	-8	12
AUG 3	47376	-2881	25	-24	-11	9	5	14
AUG 4	47377	-2806	27	-19	-8	0	-2	10
AUG 5	47378	-2740	14	-12	-7	-8	10	10
AUG 6	47379	-2679	16	-7	-3	-14	7	6
AUG 7	47380	-2624	14	-6	-3	-7	9	16
AUG 8	47381	-2580	17	-8	-13	-6	12	1
AUG 9	47382	-2545	16	-10	-3	-9	11	-1
AUG 10	47383	-2515	16	-14	-3	-6	4	2
AUG 11	47384	-2483	24	-11	-2	-9	0	13
AUG 12	47385	-2463	21	-13	2	-4	9	-13
AUG 13	47386	-2447	22	-13	-9	-7	-	4
AUG 14	47387	-2430	37	-16	3	-18	-2	3
AUG 15	47388	-2426	23	-13	7	-14	5	4
AUG 16	47389	-2429	13	-14	-4	-5	18	-
AUG 17	47390	-2436	22	-5	-	0	1	5
AUG 18	47391	-2462	23	-39	-	-10	7	6
AUG 19	47392	-2490	20	-18	-	-2	-2	7
AUG 20	47393	-2514	17	-20	-	-3	-3	2
AUG 21	47394	-2532	21	-29	-	-3	-1	11
AUG 22	47395	-2545	11	-4	-	3	-6	4
AUG 23	47396	-2564	0	-12	-	4	-11	5
AUG 24	47397	-2572	24	-4	-	-5	0	-7
AUG 25	47398	-2590	7	-19	-	23	4	0
AUG 26	47399	-2601	35	7	-	-5	-2	9
AUG 27	47400	-2582	1	-13	-12	7	0	6
AUG 28	47401	-2567	13	-7	-5	-7	-2	1
AUG 29	47402	-2554	9	-2	-3	5	-1	10
AUG 30	47403	-2545	9	-11	-6	0	-4	7
AUG 31	47404	-2537	10	-7	-6	1	3	5
SEP 1	47405	-2532						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) OhUTC	DC(ns) PRN 3 NAV11 7h36m	PRN 6 NAV 3 3h28m	PRN 9 NAV 6 4h28m	PRN11 NAV 8 22h16m	PRN12 NAV10 6h44m	PRN13 NAV 9 7h 0m
AUG 31	47404	-2537	10	-7	-6	1	3	4
SEP 1	47405	-2531	14	-13	-12	21	0	15
SEP 2	47406	-2531	14	-7	-14	5	-10	-7
SEP 3	47407	-2536	16	-13	-8	-8	-4	8
SEP 4	47408	-2537	4	1	5	-17	5	3
SEP 5	47409	-2544	18	-2	-	-5	-7	9
SEP 6	47410	-2554	18	-17	3	-28	-6	-4
SEP 7	47411	-2556	22	10	-12	0	7	11
SEP 8	47412	-2561	5	-4	-3	-19	4	-3
SEP 9	47413	-2572	9	2	1	-21	0	-2
SEP 10	47414	-2570	10	12	-4	-10	-4	10
SEP 11	47415	-2571	8	8	-6	-16	1	9
SEP 12	47416	-2582	8	13	-1	-11	-	4
SEP 13	47417	-2603	13	-9	-4	-11	2	-7
SEP 14	47418	-2609	12	-4	4	-18	3	9
SEP 15	47419	-2622	13	-10	5	1	0	0
SEP 16	47420	-2628	25	-10	-10	-4	1	1
SEP 17	47421	-2642	20	-19	-7	-7	11	8
SEP 18	47422	-2662	-5	-13	3	-7	-3	-1
SEP 19	47423	-2664	11	-3	0	-14	6	2
SEP 20	47424	-2664	17	-7	-3	-18	0	-1
SEP 21	47425	-2656	20	-4	5	1	1	1
SEP 22	47426	-2654	-9	-13	-9	9	9	1
SEP 23	47427	-2639	14	-11	-8	-8	7	0
SEP 24	47428	-2628	3	-14	-4	0	1	16
SEP 25	47429	-2613	10	-11	0	-6	6	-1
SEP 26	47430	-2603	8	-6	-5	-6	1	-15
SEP 27	47431	-2572	23	-6	3	-5	-2	3
SEP 28	47432	-2551	16	-9	-4	-10	-3	6
SEP 29	47433	-2534	5	-12	3	3	-2	0
SEP 30	47434	-2505	10	-7	2	11	-12	1
OCT 1	47435	-2474						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) 0hUTC	DC(ns) PRN 3 NAV11 5h36m	PRN 6 NAV 3 1h28m	PRN 9 NAV 6 2h28m	PRN11 NAV 8 20h16m	PRN12 NAV10 4h44m	PRN13 NAV 9 5h 0m
SEP 30	47434	-2505	9	-6	1	11	-12	0
OCT 1	47435	-2474	3	-12	0	6	-4	5
OCT 2	47436	-2445	6	-	-2	7	-7	8
OCT 3	47437	-2418	7	-7	0	5	-11	1
OCT 4	47438	-2388	7	-2	-3	1	2	-1
OCT 5	47439	-2366	4	-3	-1	5	-4	0
OCT 6	47440	-2335	7	-3	-5	4	-10	18
OCT 7	47441	-2315	-2	-12	-1	4	-8	3
OCT 8	47442	-2282	12	-1	-2	-14	-5	6
OCT 9	47443	-2257	10	-11	-7	8	8	5
OCT 10	47444	-2222	3	-16	2	-3	11	-4
OCT 11	47445	-2193	3	-4	2	1	-7	2
OCT 12	47446	-2160	5	-6	-1	2	-5	3
OCT 13	47447	-2120	12	-7	-13	-3	2	10
OCT 14	47448	-2081	18	-6	-7	-12	0	13
OCT 15	47449	-2059	11	-8	-6	5	-3	3
OCT 16	47450	-2024	13	-2	0	5	-9	0
OCT 17	47451	-1999	6	-6	0	8	-1	0
OCT 18	47452	-1981	1	-2	-10	7	1	7
OCT 19	47453	-1967	5	-11	0	1	-1	6
OCT 20	47454	-1961	5	-15	-4	0	17	-3
OCT 21	47455	-1956	-1	-3	2	-1	7	-4
OCT 22	47456	-1956	5	-5	2	-10	0	-5
OCT 23	47457	-1947	13	-6	1	-4	5	8
OCT 24	47458	-1949	10	-15	2	-1	-15	10
OCT 25	47459	-1950	26	-7	-4	7	3	-7
OCT 26	47460	-1956	1	-13	2	-5	-4	-3
OCT 27	47461	-1955	27	-5	-1	-11	5	-5
OCT 28	47462	-1956	1	-2	5	-2	-7	8
OCT 29	47463	-1951	11	-11	-5	0	4	-4
OCT 30	47464	-1949	2	1	0	-7	2	0
OCT 31	47465	-1934	5	-12	0	-3	1	-4
NOV 1	47466	-1911						

TABLE 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988	MJD	Co (ns) OhUTC	DC(ns) PRN 3 NAV11 3h32m	PRN 6 NAV 3 23h20m	PRN 9 NAV 6 0h24m	PRN11 NAV 8 17h20m	PRN12 NAV10 2h40m	PRN13 NAV 9 2h54m
OCT 31	47465	-1934	5	-12	0	-3	1	-4
NOV 1	47466	-1911	0	3	-2	8	19	4
NOV 2	47467	-1912	5	-11	-13	9	-6	-6
NOV 3	47468	-1902	2	0	0	13	-4	0
NOV 4	47469	-1888	1	-1	-6	22	1	-10
NOV 5	47470	-1877	-11	-10	1	7	0	-9
NOV 6	47471	-1863	-4	-6	-	13	2	-1
NOV 7	47472	-1835	-4	-9	-3	7	7	-8
NOV 8	47473	-1815	6	-7	-5	5	-1	7
NOV 9	47474	-1804	0	-3	-5	7	3	7
NOV 10	47475	-1799	-1	-4	-2	5	8	-12
NOV 11	47476	-1786	9	-7	0	7	-7	-5
NOV 12	47477	-1765	-8	-10	-6	9	11	5
NOV 13	47478	-1757	2	-7	3	10	2	-3
NOV 14	47479	-1737	0	-1	4	10	6	-12
NOV 15	47480	-1718	-8	-4	0	11	-1	-2
NOV 16	47481	-1704	1	-12	-6	16	-9	1
NOV 17	47482	-1689	9	-5	-3	10	-7	0
NOV 18	47483	-1672	4	-11	-12	12	5	-10
NOV 19	47484	-1656	15	-6	-8	9	1	-5
NOV 20	47485	-1638	11	-12	-6	9	1	-4
NOV 21	47486	-1626	6	-9	-5	16	5	-4
NOV 22	47487	-1614	-12	-11	-12	12	5	6
NOV 23	47488	-1600	9	-7	-2	11	15	1
NOV 24	47489	-1612	-8	-5	-3	18	-13	8
NOV 25	47490	-1612	4	-9	-4	4	7	-12
NOV 26	47491	-1613	11	-4	-6	-1	-8	5
NOV 27	47492	-1611	13	-9	-2	8	6	-7
NOV 28	47493	-1617	1	-3	-2	4	2	3
NOV 29	47494	-1628	10	-30	-4	1	-8	-5
NOV 30	47495	-1627	11	-2	-6	12	6	10
DEC 1	47496	-1631						

TABLES 9 B. TAI - GPS TIME and UTC - GPS TIME (CONT.)

Date 1988/89	MJD	Co (ns) OhUTC	DC(ns) PRN 3 NAV11 1h32m	PRN 6 NAV 3 21h20m	PRN 9 NAV 6 22h20m	PRN11 NAV 8 15h20m	PRN12 NAV10 0h40m	PRN13 NAV 9 0h54m
NOV 30	47495	-1627	11	-2	-6	12	6	10
DEC 1	47496	-1631	5	-1	-3	4	-7	-2
DEC 2	47497	-1628	16	-6	-4	3	-9	-11
DEC 3	47498	-1616	6	-3	-3	4	0	5
DEC 4	47499	-1614	0	-7	-6	5	1	-5
DEC 5	47500	-1602	20	0	-4	-1	-7	-1
DEC 6	47501	-1592	7	-5	5	11	-10	0
DEC 7	47502	-1576	-	-5	-7	-	-	-
DEC 8	47503	-1556	14	-2	-6	-	4	-3
DEC 9	47504	-1551	4	-6	-9	17	-5	-2
DEC 10	47505	-1545	7	-1	-5	6	-8	-1
DEC 11	47506	-1533	11	-3	-8	3	-9	-5
DEC 12	47507	-1516	17	-4	-4	1	-7	2
DEC 13	47508	-1502	7	4	-9	5	12	3
DEC 14	47509	-1482	2	8	-4	8	-13	-10
DEC 15	47510	-1475	9	-9	-6	4	-4	-5
DEC 16	47511	-1466	13	-6	-5	10	-4	4
DEC 17	47512	-1447	-3	-8	-6	24	0	-1
DEC 18	47513	-1430	12	-3	3	-4	4	23
DEC 19	47514	-1429	-	-2	16	-	-16	6
	*	OhUTC	23h58m	19h38m	20h38m	14h26m	23h18m	23h 2m
DEC 20	47515	-1428	-	-1	-1	-	-1	-14
DEC 21	47516	-1420	-8	-8	4	17	-5	8
DEC 22	47517	-1415	8	6	5	-10	-1	-2
DEC 23	47518	-1406	-1	3	10	0	-14	-5
DEC 24	47519	-1413	-6	-1	7	-2	9	-5
DEC 25	47520	-1403	3	5	8	2	-18	-5
DEC 26	47521	-1400	-5	6	14	5	9	-16
DEC 27	47522	-1394	16	3	-3	-12	-7	-8
DEC 28	47523	-1389	4	13	2	-1	-6	-5
DEC 29	47524	-1381	13	-7	3	-3	7	-12
DEC 30	47525	-1378	13	7	3	-6	-5	-6
DEC 31	47526	-1377	38	4	8	9	2	-14
JAN 1	47527	-1375						

* Change of tracking schedule.

TABLE 10 - COMPARISONS BETWEEN ABSOLUTE TIME COMPARISONS AND THE BIPM RESULTS

The Table gives the differences between absolute time comparisons results and those derived from the data of Table 9 (before rounding-off)

A - CLOCK TRANSPORTATION

DATE 1988	MJD	TIME COMPARISONS	DIFFERENCE CLOCK TR. - BIPM (Unit : 1 microsecond)
JAN 6	47166.06	UTC(CRL) - UTC(TAO)	-0.007
JAN 27	47187.05	UTC(TAO) - UTC(CRL)	-0.022
MAR 4	47224.23	UTC(CRL) - UTC(TAO)	0.009
MAR 28	47248.22	UTC(TAO) - UTC(CRL)	-0.037
APR 28	47279.05	UTC(CRL) - UTC(TAO)	0.026
MAY 18	47299.01	UTC(TAO) - UTC(NRLM)	-0.024
MAY 19	47300.94	UTC(SU) - UTC(ASMW)	-0.66
MAY 24	47305.02	UTC(TAO) - UTC(NAOM)	-0.270
MAY 26	47307.05	UTC(TAO) - UTC(CRL)	-0.001
JUN 30	47342.06	UTC(CRL) - UTC(TAO)	-0.010
JUL 19	47361.05	UTC(TAO) - UTC(CRL)	0.032
AUG 10	47383.56	UTC(ASMW) - UTC(PTB)	-0.704
SEP 7	47411.54	UTC(PKNM) - UTC(ASMW)	-0.900
AUG 31	47404.00	UTC(OMH) - UTC(SU)	-0.89
OCT 20	47454.50	UTC(SU) - UTC(BEV)	0.69
OCT 20	47454.50	UTC(SU) - UTC(TUG)	0.0 *
NOV 9	47474.08	UTC(TAO) - UTC(NRLM)	-0.035
NOV 14	47479.05	UTC(TAO) - UTC(CRL)	0.044
NOV 18	47483.38	UTC(SU) - UTC(OP)	0.0 *
NOV 24	47489.38	UTC(SU) - UTC(TP)	0.98

* New origin. See Table 9.

B - GPS TIME COMPARISONS WITH DIFFERENTIAL CALIBRATION OF RECEIVER DELAYS

DATE 1988	MJD	TIME COMPARISONS	DIFFERENCE GPS COMP. - BIPM (Unit : 1 microsecond)
MAY 8	47289.00	UTC(OP) - UTC(TUG)	-0.002
MAY 25	47306.38	UTC(OP) - UTC(ORB)	0.021
MAY 27	47308.74	UTC(OP) - UTC(VSL)	0.007
JUN 1	47313.36	UTC(OP) - UTC(PTB)	-0.016
JUN 3	47315.03	UTC(NIST) - UTC(TAO)	-0.001
JUN 5	47317.03	UTC(NIST) - UTC(CRL)	0.008

TABLE 11 - INTERNATIONAL ATOMIC TIME , BI-MONTHLY RATES OF TAI-CLOCK FOR 1988

THE RATES ARE AVERAGED OVER INTERVALS OF TWO MONTHS ENDING AT THE GIVEN DATES

UNIT IS NS/DAY , *** DENOTES THAT THE CLOCK WAS NOT USED

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
AOS	19	7	-200.78	-203.98	-209.28	-218.96	-191.75	***
APL	14	773	-131.66	-131.98	-129.53	-130.14	-131.11	-126.59
APL	42	6	0.47	0.24	-0.14	-2.18	-0.97	***
APL	42	13	0.25	-0.84	-1.06	-2.64	-3.17	-1.55
APL	42	14	0.52	-0.34	-1.18	-3.20	-3.02	-1.84
ASMW	16	76	***	-12.66	-24.29	-40.27	35.76	58.98
AUS	12	338	42.88	38.87	50.72	47.02	***	***
AUS	12	590	127.33	127.40	***	***	180.17	180.24
AUS	12	1823	-19.38	-17.55	-32.48	-25.80	-3.67	4.26
AUS	14	870	***	***	***	***	-4.19	2.31
AUS	14	902	-107.42	-93.20	-84.47	***	***	***
AUS	14	1443	-6.24	-6.70	-12.94	-20.05	-23.80	-17.96
AUS	14	1777	-139.95	-140.87	-142.92	-154.51	-150.99	-144.39
AUS	14	1844	39.26	38.66	38.40	***	***	***
AUS	14	2010	-40.66	-41.17	-45.18	-46.04	-41.87	-39.55
AUS	14	2020	-31.27	-29.02	-28.11	-27.83	-26.80	-22.31
AUS	44	1	1.52	2.85	2.57	2.31	4.47	6.45
AUS	44	2	38.86	39.42	37.97	38.39	38.31	40.02
AUS	44	3	***	***	-26.42	***	***	***
BEV	16	71	-43.47	-61.64	-67.08	-69.25	-73.90	-50.42
CAO	16	183	16.39	27.70	24.01	9.05	4.13	-2.81
CAO	30	384	***	***	***	***	***	-12.53
CH	12	285	-12.43	-28.66	***	-16.48	-20.38	***
CH	12	863	-29.64	-35.63	-49.02	-49.82	-46.08	-27.02
CH	16	64	11.31	4.34	-15.29	-17.75	-12.38	-0.89
CH	16	69	-110.00	-115.71	-118.26	-117.47	***	***
CH	16	77	3.50	8.76	6.78	3.13	2.68	-0.04
CH	16	114	-1.42	1.70	-3.12	-2.48	0.35	4.94
CH	16	140	94.17	***	***	-42.36	-34.44	-6.10
CH	17	206	***	***	-105.21	-103.22	-105.26	-105.61
CH	17	208	-36.38	-35.38	-32.71	-28.81	-31.63	***
CH	21	179	-48.12	-51.03	-53.80	-54.95	-53.62	-45.49
CH	21	194	97.80	95.35	92.24	101.73	96.29	96.18
CH	21	217	-91.77	-85.38	-75.98	-73.46	***	***
CH	21	243	-2.13	-7.76	-9.36	-10.32	-5.72	13.52

TABLE 11 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
CH	21	265	15.78	2.02	5.69	14.07	1.49	4.90
CRL	14	764	-111.40	***	***	***	***	***
CRL	14	865	-112.14	-106.19	-100.94	-98.86	-100.48	-101.12
CRL	14	932	-140.70	-120.77	-117.70	-113.47	-114.62	-110.99
CRL	14	1729	-131.19	-126.32	-122.49	-119.01	-115.87	-112.82
CRL	14	2456	-34.25	***	***	-24.95	-29.92	-39.44
CRL	31	131	-17.58	-17.10	***	***	***	***
CRL	45	3	69.12	72.45	80.88	83.24	87.42	92.80
CSAO	12	1646	72.42	70.05	70.18	65.14	61.39	28.55
CSAO	12	1647	72.12	82.10	126.80	151.69	146.26	123.40
CSAO	12	1648	72.75	79.63	89.77	91.55	86.16	75.10
F	12	206	-280.06	-288.43	-278.97	-242.52	-248.66	-264.67
F	12	439	-160.22	-159.70	-152.18	-144.12	-157.19	-172.50
F	12	2405	-350.47	-361.06	-348.41	***	***	***
F	14	51	-206.33	-213.50	-236.51	***	***	***
F	14	134	-24.66	-20.92	-14.03	-9.47	-12.17	-24.54
F	14	158	55.03	59.64	60.81	58.23	***	65.57
F	14	195	***	***	-103.92	-108.34	-104.15	-103.21
F	14	500	***	***	***	***	***	11.94
F	14	560	-92.67	***	***	***	***	-97.48
F	14	753	209.16	211.70	***	***	***	***
F	14	1120	-59.56	-58.36	-57.89	-56.88	***	-59.53
F	14	1407	-141.45	-144.11	-143.24	-144.11	-145.19	-140.08
F	14	1645	-14.11	***	***	***	***	***
F	14	1712	-113.21	***	-107.38	-109.64	-108.37	-112.50
F	16	106	***	***	***	-261.89	***	***
F	16	178	***	***	***	-157.43	-168.05	-151.89
F	16	187	-34.78	-41.55	-25.34	-24.20	-36.68	-29.52
FTZ	14	312	16.13	14.68	14.62	3.03	***	***
FTZ	14	895	21.77	13.13	13.06	12.08	12.17	14.89
FTZ	14	1217	24.62	15.49	13.48	3.38	-0.56	-2.87
FTZ	14	1482	40.74	43.35	10.58	7.39	5.08	7.14
FTZ	14	1656	22.02	***	11.53	20.10	6.18	3.03
FTZ	14	1674	18.39	13.37	18.22	13.00	11.89	12.63
FTZ	16	130	26.04	27.22	33.50	27.87	29.15	***
IEN	12	303	123.66	122.15	121.85	120.63	***	***
IEN	12	609	***	***	***	***	65.62	***
IEN	14	893	***	***	***	***	***	-52.62
IEN	14	1230	-87.14	-67.53	-47.39	-37.52	-14.30	-53.59
IFAG	14	1105	-129.85	-123.17	-130.74	-112.34	-122.11	-125.98

TABLE 11 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
IFAG	16	131	80.67	64.90	67.92	74.41	78.46	83.34
IFAG	16	138	23.97	20.06	15.07	-5.56	12.42	35.11
IFAG	16	274	143.63	158.01	183.61	181.13	176.46	172.29
INPL	14	2308	-89.14	-74.31	-76.59	-88.52	***	***
INPL	31	145	-106.44	-120.62	-112.90	-112.25	-113.70	-103.68
KSRI	12	1403	-246.94	-224.31	-234.80	-236.93	***	***
KSRI	12	1406	146.12	172.40	176.07	177.89	177.95	166.60
KSRI	12	1903	***	***	***	***	***	-153.70
KSRI	14	1516	-45.11	-25.23	-35.45	-47.07	-57.14	-63.20
NAOM	11	176	7570.12	9800.23	9316.11	***	***	***
NAOM	14	614	-281.43	-236.98	-243.79	-231.80	-226.26	-248.33
NAOM	14	885	-14.13	-8.75	-6.18	2.19	3.98	-11.13
NAOM	14	1315	-95.41	-81.78	-81.85	-76.38	-76.68	-90.80
NAOM	14	2146	***	-81.44	-84.30	-85.42	-87.86	-91.57
NIM	12	1615	-205.76	-118.01	-550.59	-176.11	-954.14	-739.44
NIM	12	1633	14.37	6.49	18.26	19.13	17.18	15.54
NIM	12	1640	18.69	8.92	24.50	7.35	-8.57	15.19
NIST	11	167	***	***	-36.05	-30.86	-27.71	-23.60
NIST	11	169	***	***	***	***	-1126.37	-1158.15
NIST	12	352	-268.88	-265.52	-247.39	-241.18	-251.18	-258.13
NIST	13	61	-76.58	-92.41	-125.28	-134.74	***	***
NIST	14	323	-186.14	-187.18	-188.28	-191.58	-188.75	-189.71
NIST	14	324	-0.95	9.67	***	***	***	***
NIST	14	601	***	-45.74	-45.33	-40.08	-36.31	-39.09
NIST	14	1316	-113.93	-113.99	-114.65	-114.32	-113.88	-109.36
NIST	14	1343	***	***	***	***	-378.74	-373.62
NIST	14	2165	***	-17.54	-23.81	-14.83	-12.47	-8.36
NIST	14	2315	-44.00	-43.43	-36.02	-37.20	-39.69	-42.45
NIST	16	217	***	-44.97	-51.53	-51.23	-36.13	-53.15
NIST	18	113	-382.73	-392.37	-398.66	-405.58	-411.70	-423.12
NIST	41	4	-585.29	-584.39	-586.77	***	***	***
NPL	12	316	-140.19	-141.68	-151.58	-150.07	-138.03	-138.84
NPL	12	418	-128.85	-177.67	-158.30	-160.16	-170.48	-171.61
NPL	12	832	-276.41	***	***	***	***	***
NPL	14	1334	-34.77	-40.54	-42.75	-42.33	-49.72	-54.24
NPL	14	1813	9.73	9.22	5.05	3.54	7.64	***
NPL	14	2064	***	***	***	-7.41	-2.60	-5.05
NPL	31	328	***	***	***	8.24	-1.20	-8.62
NRC	14	267	-44.24	-45.23	-44.73	-43.11	-52.07	-69.74
NRC	90	5	13.86	3.88	0.46	8.92	-31.45	-28.70

TABLE 11 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
NRC	90	61	22.35	-2.87	-8.20	-18.43	-27.66	-34.43
NRC	90	63	0.64	-5.41	-4.47	-6.19	-7.73	-28.88
NRLM	12	363	163.81	157.84	147.03	129.88	118.96	114.39
NRLM	14	906	-86.14	-92.68	***	***	***	***
NRLM	14	1632	-18.27	-18.04	-23.69	-32.37	-38.27	-40.18
NRLM	31	312	***	***	***	12.92	21.55	47.10
ORB	12	205	-157.52	-160.59	-162.91	-158.32	-163.80	-176.40
ORB	12	804	-92.77	-79.65	-87.41	-84.92	-85.76	-91.96
PKNM	14	1144	-48.25	-42.76	-28.11	-12.17	-26.16	***
PKNM	16	124	-0.86	-0.25	-18.43	-18.21	-4.32	24.61
PKNM	16	125	-74.70	-55.50	-31.67	8.40	***	***
PKNM	16	154	-109.00	-80.65	-82.31	-58.88	-72.57	-85.03
PTB	12	320	-64.04	-62.21	-61.39	-68.35	-59.73	-59.10
PTB	12	462	4.02	1.80	-13.52	-11.09	15.19	***
PTB	14	394	-32.29	-29.54	-24.02	-19.85	-23.34	-30.81
PTB	14	867	-190.16	-190.47	-185.93	-182.75	-188.66	-201.51
PTB	14	1103	***	***	***	-27.25	-32.43	-44.54
PTB	14	2379	-44.58	-45.81	-46.03	-43.68	-42.75	-45.62
PTB	16	119	5.07	19.62	6.33	***	***	***
PTB	92	1	-0.27	1.38	0.97	-1.72	-1.54	-1.15
PTB	92	2	-1.31	-1.78	-2.10	-3.11	-3.27	-2.04
ROA	12	1223	***	***	3.37	***	***	***
ROA	14	896	***	***	-11.26	-14.42	-18.02	-21.71
ROA	14	1569	-23.71	-18.28	-12.96	-5.12	0.55	2.04
ROA	16	121	40.11	37.86	32.20	34.26	37.26	44.38
ROA	16	177	23.94	30.99	26.71	-11.21	-5.42	-18.83
SO	12	997	-110.94	-95.36	-99.32	-107.98	-101.18	-72.40
SO	14	574	-73.48	-49.19	-18.17	-49.14	-17.14	-30.99
SO	16	180	31.50	46.43	44.17	43.87	50.46	57.27
STA	14	900	-63.43	-60.66	-62.25	-54.53	-71.07	-65.21
STA	14	1376	-77.36	-79.82	-71.78	-71.20	***	***
STA	16	137	-92.97	-90.42	-85.83	-85.71	-83.58	-84.14
SU	40	381	-7.33	-21.33	-3.81	-12.06	-14.26	-17.80
SU	40	382	-7.16	-21.37	-3.81	-12.06	-14.22	-17.87
TAO	14	390	-70.15	***	-70.15	-72.92	-74.17	-78.47
TAO	14	1075	-30.04	-25.04	-36.47	-37.21	-36.56	-34.19
TAO	14	1498	-157.70	-158.48	-161.14	-164.60	-170.04	-162.30
TAO	14	2494	-8.24	-8.15	-8.02	-8.02	-8.15	-7.72
TAO	31	283	***	-58.19	-77.44	-89.40	-76.88	-82.70
TAO	31	284	***	***	***	***	***	-170.11

TABLE 11 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
TAO	31	285	***	-41.76	-43.34	-39.81	-35.76	-48.13
TAO	31	286	***	-106.08	-104.54	-102.00	-115.17	-143.74
TL	12	477	***	***	***	***	-42.17	-44.26
TL	12	1145	136.56	146.52	134.48	140.58	140.28	139.44
TL	12	1455	162.22	158.50	157.28	157.65	156.47	143.40
TL	12	2276	-53.37	-57.34	-64.93	-59.21	-60.40	-59.47
TL	31	317	***	***	***	***	-64.26	-67.64
TP	12	335	15.92	19.92	21.73	-87.71	-119.00	-99.71
TP	17	101	***	***	***	***	***	-112.25
TUG	12	524	82.96	65.83	63.63	59.15	61.60	60.68
TUG	14	1654	27.18	26.16	26.84	26.23	26.70	23.71
TUG	18	108	267.99	281.95	347.39	395.25	432.03	464.08
USNO	12	752	84.74	97.11	***	***	***	***
USNO	14	116	-100.04	-90.15	-74.46	-80.52	-71.75	-84.98
USNO	14	218	***	250.46	***	***	***	***
USNO	14	444	99.17	***	***	***	***	46.63
USNO	14	583	15.49	16.13	-27.65	-31.06	-8.03	21.33
USNO	14	656	-178.99	-159.76	-155.66	-162.14	***	***
USNO	14	761	***	***	***	8.72	-24.19	39.84
USNO	14	787	***	-4.44	-2.99	11.81	15.60	20.19
USNO	14	834	-89.18	-90.63	-86.24	-94.18	***	***
USNO	14	837	-15.90	***	***	***	***	***
USNO	14	862	259.85	***	133.60	138.12	140.37	146.68
USNO	14	871	***	69.83	56.53	48.68	45.28	***
USNO	14	1028	***	***	***	58.80	68.66	90.68
USNO	14	1035	-84.71	-76.73	-86.05	***	***	***
USNO	14	1094	-172.41	-168.02	-173.98	-157.07	-151.43	-157.23
USNO	14	1104	-44.12	-40.63	-33.79	-18.55	1.88	-27.02
USNO	14	1114	***	***	-132.64	-129.65	-124.06	-118.90
USNO	14	1117	-48.42	-57.30	-55.64	-48.00	-50.06	-58.55
USNO	14	1255	***	***	***	***	***	-59.99
USNO	14	1300	-287.23	-286.96	-284.07	-273.06	-272.69	-281.32
USNO	14	1301	***	***	***	***	***	-73.55
USNO	14	1362	-31.46	***	***	29.57	61.96	46.63
USNO	14	1605	37.45	37.29	***	48.13	42.93	39.90
USNO	14	1809	***	-57.99	-72.49	-63.16	-64.10	-76.94
USNO	14	1846	-33.72	-31.86	-31.14	***	***	***
USNO	14	2098	23.59	19.04	***	***	***	-56.82
USNO	14	2100	-130.37	-130.94	-129.50	***	***	***
USNO	14	2157	***	***	***	***	***	-100.49

TABLE 11 - (CONT.)

LAB.	CLOCK	47219	47279	47339	47399	47459	47519
USNO	14 2312	-81.95	-50.86	-78.43	-88.03	-87.73	-62.17
USNO	14 2313	***	***	-8.87	2.74	***	***
USNO	14 2314	-33.99	-41.94	-43.49	-31.79	-33.15	-37.81
USNO	14 2481	***	***	-18.69	-17.10	-13.58	-24.33
USNO	14 2482	-36.52	-31.32	-26.85	-20.98	-14.86	-28.12
USNO	14 2483	-41.63	-46.17	-43.56	-41.78	-39.52	-41.89
USNO	14 2484	***	-119.89	-117.38	-106.80	-105.30	-86.18
USNO	14 2485	-174.42	-163.67	-184.80	-177.91	-175.03	-176.61
USNO	14 2486	-27.35	-28.12	-26.06	-21.21	-32.05	-38.53
USNO	14 2488	***	-137.23	-138.23	-132.41	***	***
USNO	31 222	***	***	***	***	***	-164.52
USNO	31 333	***	***	***	-5.11	-6.13	-1.84
USNO	31 334	***	***	***	53.73	48.81	30.30
USNO	31 335	***	***	***	-47.63	-41.59	-43.94
USNO	31 339	***	***	***	16.04	34.10	38.87
USNO	31 340	***	***	***	-5.17	7.61	-4.81
USNO	31 342	***	***	***	6.83	***	25.22
USNO	40 22	***	***	***	***	***	-475.15
USNO	40 23	28.30	27.81	3.98	-10.19	-26.00	-40.91
USNO	43 8	***	1.04	-18.72	5.08	14.12	29.39
VSL	12 349	56.92	60.16	63.99	58.80	43.56	40.25
VSL	12 1489	-589.61	-609.39	***	-293.07	-291.17	-277.99
VSL	14 503	-140.82	-122.81	***	***	***	***
VSL	14 1034	-86.65	-83.04	-81.72	-79.87	-81.63	-78.81
VSL	31 288	***	***	***	-74.38	-63.62	-56.71
YUZM	12 1189	-29.00	-27.49	47.23	63.46	51.11	-22.22
ZIPE	12 979	-223.91	-219.66	-223.85	-183.61	-147.37	-136.36

The clocks are designated by their type (2 digits) and serial number in the type.

The codes for the types are

11 HEWLETT-PACKARD 5060A
12 HEWLETT-PACKARD 5061A
13 EBAUCHES , OSCILLATOM B5000
14 HEWLETT-PACKARD 5061A OPT.4

16 OSCILLOQUARTZ 3200
17 OSCILLOQUARTZ 3000
18 FREQ. AND TIME SYSTEMS INC. 4000
19 ROHDE AND SCHWARZ XSC

20 FREQ. AND TIME SYSTEMS INC. 5000
21 OSCILLOQUARTZ 3210
25 HEWLETT-PACKARD 5062C
30 HEWLETT-PACKARD 5061B
31 HEWLETT-PACKARD 5061B OPT. 4

4x HYDROGEN MASERS
9x PRIMARY CLOCKS AND PROTOTYPES

TABLE 12 - INTERNATIONAL ATOMIC TIME , WEIGHTS OF THE CLOCKS FOR 1988

THE WEIGHTS ARE GIVEN FOR INTERVALS OF TWO MONTHS ENDING AT THE GIVEN DATES

*** DENOTES THAT THE CLOCK WAS NOT USED

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
AOS	19	7	2	9	10	10	7	***
APL	14	773	31	23	54	84	100	100
APL	42	6	100	100	100	100	100	***
APL	42	13	100	100	100	100	100	100
APL	42	14	100	100	100	100	100	100
ASMW	16	76	***	0	0	3	0	0
AUS	12	338	0	0	14	25	***	***
AUS	12	590	90	84	***	***	0	0
AUS	12	1823	6	8	12	12	8	5
AUS	14	870	***	***	***	***	0	0
AUS	14	902	8	8	7	***	***	***
AUS	14	1443	0	73	32	17	14	19
AUS	14	1777	13	21	36	27	29	29
AUS	14	1844	58	68	71	***	***	***
AUS	14	2010	89	100	100	100	100	100
AUS	14	2020	0	14	13	13	19	100
AUS	44	1	0	100	100	100	100	100
AUS	44	2	100	100	100	100	100	100
AUS	44	3	***	***	0	***	***	***
BEV	16	71	52	0	7	5	5	7
CAO	16	183	9	7	6	6	8	7
CAO	30	384	***	***	***	***	***	0
CH	12	285	100	0	***	0	0	***
CH	12	863	21	28	17	13	13	10
CH	16	64	2	2	2	5	7	7
CH	16	69	28	53	30	39	***	***
CH	16	77	54	100	100	100	100	100
CH	16	114	0	18	37	61	79	100
CH	16	140	0	***	***	0	0	0
CH	17	206	***	***	0	0	100	100
CH	17	208	38	33	34	34	80	***
CH	21	179	51	55	94	100	100	72
CH	21	194	40	100	81	74	82	100
CH	21	217	4	4	5	8	***	***
CH	21	243	12	40	59	57	79	0

TABLE 12 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
CH	21	265	0	0	10	15	18	27
CRL	14	764	45	***	***	***	***	***
CRL	14	865	0	15	22	28	39	40
CRL	14	932	12	15	13	10	9	9
CRL	14	1729	0	18	31	35	33	22
CRL	14	2456	4	***	***	0	0	9
CRL	31	131	7	10	***	***	***	***
CRL	45	3	24	20	17	17	15	12
CSAO	12	1646	5	4	4	4	24	0
CSAO	12	1647	1	1	1	1	1	1
CSAO	12	1648	16	16	19	15	18	16
F	12	206	0	0	19	0	2	3
F	12	439	7	10	16	25	25	11
F	12	2405	5	4	5	***	***	***
F	14	51	1	1	1	***	***	***
F	14	134	6	6	6	7	19	23
F	14	158	100	81	75	100	***	0
F	14	195	***	***	0	0	80	100
F	14	500	***	***	***	***	***	0
F	14	560	0	***	***	***	***	0
F	14	753	33	34	***	***	***	***
F	14	1120	98	95	100	100	***	0
F	14	1407	13	11	12	47	100	100
F	14	1645	3	***	***	***	***	***
F	14	1712	22	***	0	0	100	100
F	16	106	***	***	***	0	***	***
F	16	178	***	***	***	0	0	7
F	16	187	41	71	28	23	22	22
FTZ	14	312	0	100	100	0	***	***
FTZ	14	895	33	41	38	40	39	73
FTZ	14	1217	12	13	15	14	8	9
FTZ	14	1482	9	12	0	3	3	3
FTZ	14	1656	60	***	0	0	10	12
FTZ	14	1674	100	100	100	100	100	100
FTZ	16	130	41	26	14	21	40	***
IEN	12	303	20	27	62	100	***	***
IEN	12	609	***	***	***	***	0	***
IEN	14	893	***	***	***	***	***	0
IEN	14	1230	2	2	2	2	1	2
IFAG	14	1105	18	19	51	0	20	22

TABLE 12 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
IFAG	16	131	33	24	21	22	21	19
IFAG	16	138	1	2	3	4	10	5
IFAG	16	274	0	0	1	2	3	4
INPL	14	2308	0	4	7	10	***	***
INPL	31	145	0	5	10	16	23	28
KSRI	12	1403	1	1	1	2	***	***
KSRI	12	1406	0	0	0	1	3	7
KSRI	12	1903	***	***	***	***	***	0
KSRI	14	1516	0	0	1	1	7	5
NAOM	11	176	0	0	0	***	***	***
NAOM	14	614	0	1	2	2	3	3
NAOM	14	885	38	44	50	32	20	19
NAOM	14	1315	39	33	35	24	20	17
NAOM	14	2146	***	0	0	100	94	57
NIM	12	1615	0	0	0	0	0	0
NIM	12	1633	78	38	38	44	47	47
NIM	12	1640	3	4	9	23	0	8
NIST	11	167	***	***	0	0	28	24
NIST	11	169	***	***	***	***	0	0
NIST	12	352	6	7	11	9	8	9
NIST	13	61	1	1	2	2	***	***
NIST	14	323	100	100	100	100	100	100
NIST	14	324	9	9	***	***	***	***
NIST	14	601	***	0	0	50	33	49
NIST	14	1316	100	100	100	100	100	100
NIST	14	1343	***	***	***	***	0	0
NIST	14	2165	***	0	0	23	28	25
NIST	14	2315	0	0	25	39	65	89
NIST	16	217	***	0	0	37	13	17
NIST	18	113	9	8	7	8	7	5
NIST	41	4	0	0	0	***	***	***
NPL	12	316	7	5	6	7	14	29
NPL	12	418	4	1	1	3	3	3
NPL	12	832	9	***	***	***	***	***
NPL	14	1334	100	48	37	43	26	21
NPL	14	1813	100	100	100	100	100	***
NPL	14	2064	***	***	***	0	0	86
NPL	31	328	***	***	***	0	0	7
NRC	14	267	100	100	100	100	64	0
NRC	90	5	0	8	8	9	0	3

TABLE 12 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
NRC	90	61	0	8	7	5	3	2
NRC	90	63	16	25	35	36	70	0
NRLM	12	363	0	6	9	6	4	2
NRLM	14	906	28	55	***	***	***	***
NRLM	14	1632	100	100	100	0	13	10
NRLM	31	312	***	***	***	0	0	2
ORB	12	205	49	35	35	71	90	0
ORB	12	804	3	5	15	39	49	42
PKNM	14	1144	6	6	8	6	6	***
PKNM	16	124	2	2	5	5	14	0
PKNM	16	125	1	1	1	1	***	***
PKNM	16	154	2	5	5	3	3	4
PTB	12	320	63	100	100	100	100	87
PTB	12	462	100	100	0	21	9	***
PTB	14	394	65	65	54	36	37	41
PTB	14	867	100	100	100	89	100	0
PTB	14	1103	***	***	***	0	0	6
PTB	14	2379	4	6	9	9	16	100
PTB	16	119	11	6	7	***	***	***
PTB	92	1	100	100	100	100	100	100
PTB	92	2	100	100	100	100	100	100
ROA	12	1223	***	***	0	***	***	***
ROA	14	896	***	***	0	0	44	33
ROA	14	1569	14	13	15	11	9	9
ROA	16	121	16	14	41	51	100	54
ROA	16	177	100	53	50	0	3	2
SO	12	997	0	10	12	11	28	0
SO	14	574	0	2	2	2	2	2
SO	16	180	15	22	31	35	23	14
STA	14	900	49	34	42	24	27	34
STA	14	1376	41	53	75	84	***	***
STA	16	137	3	3	3	4	38	71
SU	40	381	0	0	0	0	0	0
SU	40	382	0	0	0	0	0	0
TAO	14	390	36	***	0	0	100	56
TAO	14	1075	100	66	55	47	41	43
TAO	14	1498	7	8	15	42	32	49
TAO	14	2494	100	100	100	100	100	100
TAO	31	283	***	0	0	2	4	6
TAO	31	284	***	***	***	***	***	0

TABLE 12 - (CONT.)

LAB.	CLOCK		47219	47279	47339	47399	47459	47519
TAO	31	285	***	0	0	100	62	40
TAO	31	286	***	0	0	100	0	0
TL	12	477	***	***	***	***	0	0
TL	12	1145	4	5	7	21	59	59
TL	12	1455	19	15	14	17	24	0
TL	12	2276	67	92	56	56	66	70
TL	31	317	***	***	***	***	0	0
TP	12	335	53	48	46	0	0	0
TP	17	101	***	***	***	***	***	0
TUG	12	524	65	0	6	5	6	13
TUG	14	1654	100	100	100	100	100	100
TUG	18	108	1	1	0	0	0	0
USNO	12	752	0	0	***	***	***	***
USNO	14	116	0	18	6	8	8	9
USNO	14	218	***	0	***	***	***	***
USNO	14	444	0	***	***	***	***	0
USNO	14	583	0	0	1	1	2	2
USNO	14	656	0	10	13	12	***	***
USNO	14	761	***	***	***	0	0	0
USNO	14	787	***	0	0	0	6	7
USNO	14	834	35	100	80	76	***	***
USNO	14	837	12	***	***	***	***	***
USNO	14	862	5	***	0	0	42	22
USNO	14	871	***	0	0	4	6	***
USNO	14	1028	***	***	***	0	0	2
USNO	14	1035	57	23	24	***	***	***
USNO	14	1094	50	43	66	0	8	11
USNO	14	1104	0	14	22	9	0	3
USNO	14	1114	***	***	0	0	26	18
USNO	14	1117	17	38	45	31	34	45
USNO	14	1255	***	***	***	***	***	0
USNO	14	1300	34	100	100	0	17	23
USNO	14	1301	***	***	***	***	***	0
USNO	14	1362	0	***	***	0	0	2
USNO	14	1605	66	51	***	0	0	29
USNO	14	1809	***	0	0	9	18	14
USNO	14	1846	85	69	82	***	***	***
USNO	14	2098	0	70	***	***	***	0
USNO	14	2100	0	19	26	***	***	***
USNO	14	2157	***	***	***	***	***	0

TABLE 12 - (CONT.)

LAB.	CLOCK	47219	47279	47339	47399	47459	47519
USNO	14 2312	0	0	1	2	2	4
USNO	14 2313	***	***	0	0	***	***
USNO	14 2314	5	4	5	8	21	42
USNO	14 2481	***	***	0	0	72	33
USNO	14 2482	100	100	84	31	15	17
USNO	14 2483	100	94	96	93	84	100
USNO	14 2484	***	0	0	0	12	5
USNO	14 2485	38	0	16	19	19	21
USNO	14 2486	10	14	22	32	49	29
USNO	14 2488	***	0	0	51	***	***
USNO	31 222	***	***	***	***	***	0
USNO	31 333	***	***	***	0	0	99
USNO	31 334	***	***	***	0	0	0
USNO	31 335	***	***	***	0	0	54
USNO	31 339	***	***	***	0	0	3
USNO	31 340	***	***	***	0	0	9
USNO	31 342	***	***	***	0	***	0
USNO	40 22	***	***	***	***	***	0
USNO	40 23	0	0	0	0	0	0
USNO	43 8	***	0	0	0	0	0
VSL	12 349	0	0	40	74	0	11
VSL	12 1489	0	0	***	0	0	0
VSL	14 503	14	0	***	***	***	***
VSL	14 1034	100	100	100	100	100	100
VSL	31 288	***	***	***	0	0	6
YUZM	12 1189	0	3	0	0	1	1
ZIPE	12 979	6	12	17	0	0	1

The clocks are designated by their type (2 digits) and serial number in the type.

The codes for the types are

11 HEWLETT-PACKARD 5060A	20 FREQ. AND TIME SYSTEMS INC. 5000
12 HEWLETT-PACKARD 5061A	21 OSCILLOQUARTZ 3210
13 EBAUCHES , OSCILLATOM B5000	25 HEWLETT-PACKARD 5062C
14 HEWLETT-PACKARD 5061A OPT.4	30 HEWLETT-PACKARD 5061B
	31 HEWLETT-PACKARD 5061B OPT. 4
16 OSCILLOQUARTZ 3200	
17 OSCILLOQUARTZ 3000	
18 FREQ. AND TIME SYSTEMS INC. 4000	4x HYDROGEN MASERS
19 ROHDE AND SCHWARZ XSC	9x PRIMARY CLOCKS AND PROTOTYPES

TABLE 13 - MEASUREMENTS OF THE EAL AND TAI FREQUENCY

GRAVITATIONAL FREQUENCY CORRECTIONS ARE APPLIED . THE FREQUENCIES ARE EXPRESSED AT SEA LEVEL .

f(EAL) - f(STANDARD) IN 10**-13

INTERVAL MJD	CENTRAL DATE	NRC CsV	NRC CsVIA	NRC CsVIB	NRC CsVIC	PTB CS1	PTB CS2
45699-45759	1984 JAN30	8.58	8.50	8.36	8.23	8.59	
45759-45819	1984 MAR30	8.49	8.43	8.21	8.26	8.65	
45819-45879	1984 MAY29	-	5.78	7.41	7.38	8.43	
45879-45939	1984 JUL28	7.18	7.30	6.84	6.57	7.91	
45939-45999	1984 SEP26	7.04	7.45	8.08	6.38	8.19	
45999-46059	1984 NOV25	6.40	7.07	8.20	6.95	8.43	
46059-46119	1985 JAN24	7.19	8.81	8.45	7.72	8.66	
46119-46179	1985 MAR25	7.51	7.52	8.05	7.82	8.19	
46179-46239	1985 MAY24	8.27	8.03	6.52	8.17	8.36	
46239-46299	1985 JUL23	8.47	8.04	7.03	7.08	8.17	
46299-46369	1985 SEP26	8.58	6.86	7.55	7.03	7.93	
46369-46429	1985 NOV30	8.47	9.22	9.90	6.74	8.57	
46429-46489	1986 JAN29	8.70	8.93	9.69	8.21	8.58	
46489-46549	1986 MAR30	8.62	8.68	9.62	8.16	8.36	
46549-46609	1986 MAY29	8.81	8.39	8.78	8.63	8.05	
46609-46669	1986 JUL28	8.11	9.25	9.02	8.80	7.85	
46669-46729	1986 SEP26	8.05	9.77	9.35	9.17	8.02	7.61
46729-46789	1986 NOV25	8.56	8.53	8.99	8.79	8.06	7.85
46789-46849	1987 JAN24	7.99	8.01	9.18	8.90	8.18	7.98
46849-46909	1987 MAR25	8.33	8.13	8.41	8.65	8.36	7.91
46909-46969	1987 MAY24	7.03	7.46	8.70	8.26	7.99	7.69
46969-47029	1987 JUL23	6.40	7.01	8.38	7.00	8.20	7.64
47029-47099	1987 SEP26	6.50	7.79	7.55	6.43	7.82	7.68
47099-47159	1987 NOV30	7.11	8.78	10.48	6.87	8.04	7.79
47159-47219	1988 JAN29	9.71	10.70	-	8.18	7.97	7.85
47219-47279	1988 MAR29	8.56	7.78	-	7.48	8.16	7.79
47279-47339	1988 MAY28	8.16	7.16	-	7.59	8.11	7.76
47339-47399	1988 JUL27	-	5.98	-	7.39	7.80	7.64
47399-47459	1988 SEP25	4.47	4.91	-	7.22	7.82	7.62
47459-47519	1988 NOV24	4.79	4.13	-	4.77	7.87	7.76

TABLE 13 - (CONT.)

f(EAL) - f(STANDARD) IN 10**-13

INTERVAL MJD	CENTRAL DATE	CRL CS1	NBS NBS6	SU MCsR 101	SU MCsR 102
45702-45722	1984 JAN13			6.02	
45789-45849	1984 APR29	6.45			
45794-45836	1984 APR25			6.74	
45889-45949	1984 AUG17		7.24		
45949-45967	1984 SEP15				6.22
45959-46019	1984 OCT16		7.70		
45983-46004	1984 OCT21				5.93
45999-46059	1984 NOV25	7.53			
46005-46034	1984 NOV16				6.12
46054-46059	1984 DEC23				6.37
46079-46139	1985 FEB13	7.54			
46080-46096	1985 JAN23				6.14
46100-46110	1985 FEB 9				5.78
46156-46159	1985 APR 3				6.23
46201-46216	1985 MAY24			5.87	
46230-46244	1985 JUN21			7.04	
46247-46277	1985 JUL16			6.39	
46279-46300	1985 AUG13			5.75	
46312-46335	1985 SEP16			6.84	
46339-46367	1985 OCT15			5.90	
46370-46381	1985 NOV 7			5.83	
46502-46516	1986 MAR20				5.87
46509-46569	1986 APR19	7.22			
46521-46543	1986 APR12				5.61
46563-46580	1986 MAY22				5.76
46585-46600	1986 JUN11				5.28
46684-46732	1986 OCT 5			5.99	
46737-46762	1986 NOV16			5.58	
46773-46794	1986 DEC19				5.35
46801-46816	1987 JAN14				5.06
46859-46919	1987 APR 5	8.73			
46886-46914	1987 APR14			5.37	
46919-46941	1987 MAY15			5.67	
46947-46976	1987 JUN15			6.11	
46959-47019	1987 JUL13		9.65		
46977-46998	1987 JUL11			6.09	
47061-47063	1987 SEP24			5.59	
47083-47097	1987 OCT21				5.76
47098-47124	1987 NOV13				5.76
47130-47150	1987 DEC11				5.36
47164-47173	1988 JAN 9				5.37
47215-47222	1988 FEB28			5.45	
47256-47278	1988 APR16				5.87
47286-47288	1988 MAY 6				5.67
47354-47361	1988 JUL16				5.77
47416-47433	1988 SEP20				5.57

TABLE 13 - (CONT.)

f(TAI) - f(STANDARD) IN 10**-13

INTERVAL MJD	CENTRAL DATE	NRC CsV	NRC CsVIA	NRC CsVIB	NRC CsVIC	PTB CS1	PTB CS2
45699-45759	1984 JAN30	0.78	0.70	0.56	0.43	0.79	
45759-45819	1984 MAR30	0.49	0.43	0.21	0.26	0.65	
45819-45879	1984 MAY29	-	-2.22	-0.59	-0.62	0.43	
45879-45939	1984 JUL28	-0.82	-0.70	-1.16	-1.43	-0.09	
45939-45999	1984 SEP26	-0.96	-0.55	0.08	-1.62	0.19	
45999-46059	1984 NOV25	-1.60	-0.93	0.20	-1.05	0.43	
46059-46119	1985 JAN24	-0.81	0.81	0.45	-0.28	0.66	
46119-46179	1985 MAR25	-0.49	-0.48	0.05	-0.18	0.19	
46179-46239	1985 MAY24	0.27	0.03	-1.48	0.18	0.36	
46239-46299	1985 JUL23	0.47	0.04	-0.97	-0.92	0.17	
46299-46369	1985 SEP26	0.58	-1.14	-0.45	-0.97	-0.07	
46369-46429	1985 NOV30	0.47	1.22	1.90	-1.26	0.57	
46429-46489	1986 JAN29	0.70	0.93	1.69	0.21	0.58	
46489-46549	1986 MAR30	0.62	0.68	1.62	0.16	0.36	
46549-46609	1986 MAY29	0.81	0.39	0.78	0.63	0.05	
46609-46669	1986 JUL28	0.11	1.25	1.02	0.80	-0.15	
46669-46729	1986 SEP26	0.05	1.77	1.35	1.17	0.02	-0.39
46729-46789	1986 NOV25	0.56	0.53	0.99	0.79	0.06	-0.15
46789-46849	1987 JAN24	-0.02	0.00	1.17	0.89	0.17	-0.04
46849-46909	1987 MAR25	0.32	0.12	0.40	0.64	0.35	-0.10
46909-46969	1987 MAY24	-0.99	-0.55	0.69	0.25	-0.03	-0.32
46969-47029	1987 JUL23	-1.61	-1.01	0.37	-1.01	0.19	-0.37
47029-47099	1987 SEP26	-1.51	-0.22	-0.46	-1.58	-0.19	-0.34
47099-47159	1987 NOV30	-0.91	0.77	2.46	-1.14	0.02	-0.23
47159-47219	1988 JAN29	1.71	2.70	-	0.18	-0.03	-0.15
47219-47279	1988 MAR29	0.56	-0.22	-	-0.52	0.16	-0.21
47279-47339	1988 MAY28	0.16	-0.84	-	-0.41	0.11	-0.24
47339-47399	1988 JUL27	-	-2.02	-	-0.61	-0.20	-0.36
47399-47459	1988 SEP25	-3.53	-3.09	-	-0.78	-0.18	-0.38
47459-47519	1988 NOV24	-3.21	-3.87	-	-3.23	-0.13	-0.24

TABLE 13 - (CONT.)

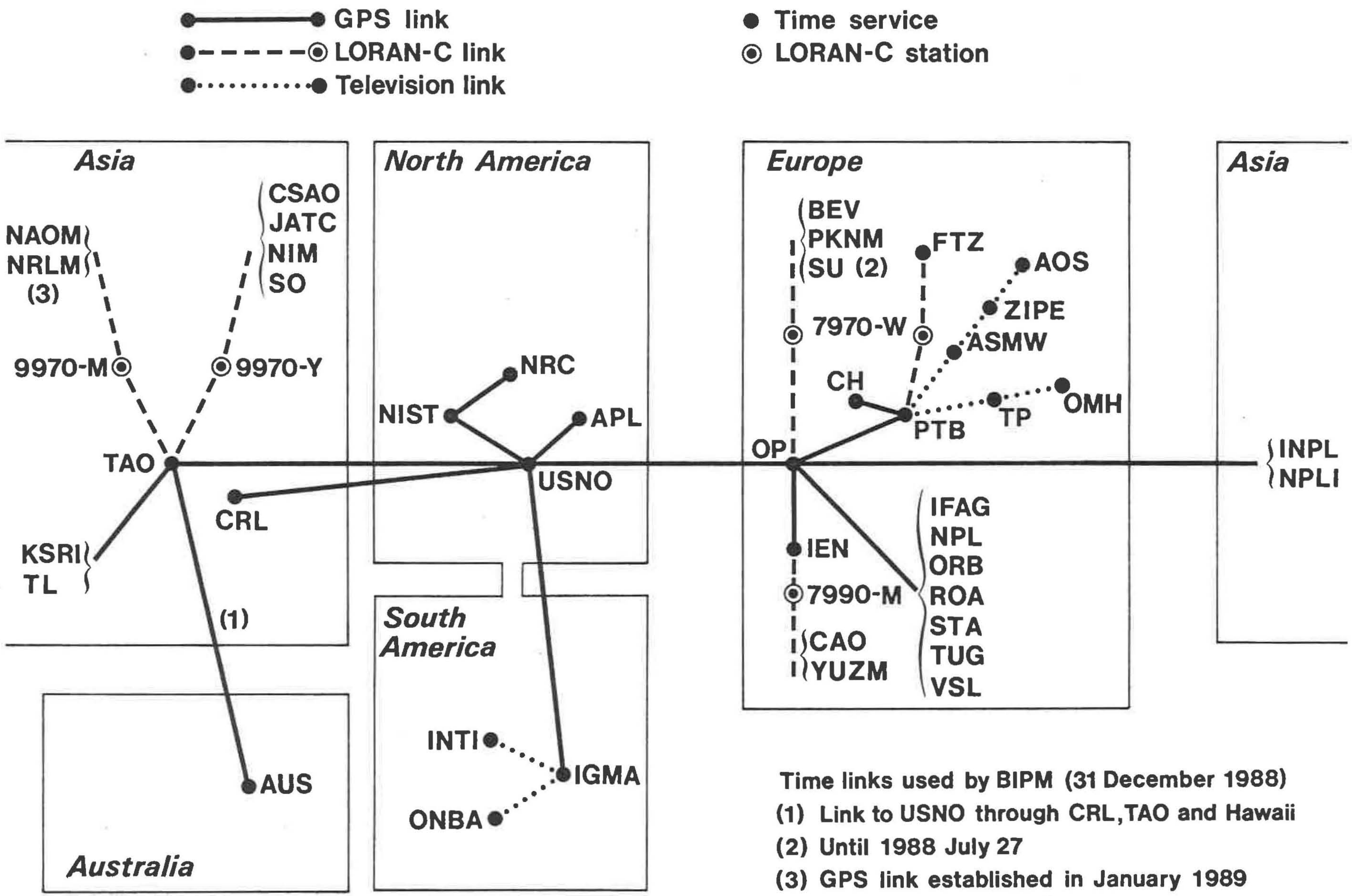
f(TAI) - f(STANDARD) IN 10**-13

INTERVAL MJD	CENTRAL DATE	CRL CS1	NBS NBS6	SU MCsR 101	SU MCsR 102
45702-45722	1984 JAN13			-1.78	
45789-45849	1984 APR29	-1.55			
45794-45836	1984 APR25			-1.26	
45889-45949	1984 AUG17		-0.76		
45949-45967	1984 SEP15				-1.78
45959-46019	1984 OCT16		-0.30		
45983-46004	1984 OCT21				-2.07
45999-46059	1984 NOV25	-0.47			
46005-46034	1984 NOV16				-1.88
46054-46059	1984 DEC23				-1.63
46079-46139	1985 FEB13	-0.46			
46080-46096	1985 JAN23				-1.86
46100-46110	1985 FEB 9				-2.22
46156-46159	1985 APR 3				-1.77
46201-46216	1985 MAY24			-2.13	
46230-46244	1985 JUN21			-0.96	
46247-46277	1985 JUL16			-1.61	
46279-46300	1985 AUG13			-2.25	
46312-46335	1985 SEP16			-1.16	
46339-46367	1985 OCT15			-2.10	
46370-46381	1985 NOV 7			-2.17	
46502-46516	1986 MAR20				-2.13
46509-46569	1986 APR19	-0.78			
46521-46543	1986 APR12				-2.39
46563-46580	1986 MAY22				-2.24
46585-46600	1986 JUN11				-2.72
46684-46732	1986 OCT 5			-2.01	
46737-46762	1986 NOV16			-2.42	
46773-46794	1986 DEC19				-2.65
46801-46816	1987 JAN14				-2.94
46859-46919	1987 APR 5	0.73			
46886-46914	1987 APR14			-2.64	
46919-46941	1987 MAY15			-2.34	
46947-46976	1987 JUN15			-1.09	
46959-47019	1987 JUL13		1.64		
46977-46998	1987 JUL11			-1.92	
47061-47063	1987 SEP24			-2.42	
47083-47097	1987 OCT21				-2.26
47098-47124	1987 NOV13				-2.26
47130-47150	1987 DEC11				-2.66
47164-47173	1988 JAN 9				-2.63
47215-47222	1988 FEB28			-2.55	
47256-47278	1988 APR16				-2.13
47286-47288	1988 MAY 6				-2.33
47354-47361	1988 JUL16				-2.23
47416-47433	1988 SEP20				-2.43

TABLE 14 - MEAN DURATION OF THE TAI SCALE INTERVAL IN SI SECOND AT SEA LEVEL.

FOR THE MONTHS	MEAN DURATION	UNCERTAINTY (one sigma)
1983 JAN - FEB	1 - 1*10**-14	4*10**-14
1983 MAR - APR	- 2	4
1983 MAY - JUN	- 1	4
1983 JUL - AUG	+ 1	4
1983 SEP - OCT	+ 1	4
1983 NOV - DEC	+ 0	4
1984 JAN - FEB	1 - 2*10**-14	4*10**-14
1984 MAR - APR	- 0	4
1984 MAY - JUN	+ 2	4
1984 JUL - AUG	+ 3	4
1984 SEP - OCT	+ 4	4
1984 NOV - DEC	+ 3	4
1985 JAN - FEB	1 + 0.9*10**-14	2.1*10**-14
1985 MAR - APR	+ 1.8	2.0
1985 MAY - JUN	+ 1.3	2.0
1985 JUL - AUG	+ 1.3	2.0
1985 SEP - OCT	+ 0.8	2.0
1985 NOV - DEC	- 1.6	2.0
1986 JAN - FEB	1 - 2.9*10**-14	2.0*10**-14
1986 MAR - APR	- 2.2	2.0
1986 MAY - JUN	- 0.9	1.9
1986 JUL - AUG	+ 0.4	1.9
1986 SEP - OCT	+ 2.1	1.3
1986 NOV - DEC	+ 0.6	1.3
1987 JAN - FEB	1 - 0.4*10**-14	1.3*10**-14
1987 MAR - APR	- 0.1	1.3
1987 MAY - JUN	+ 2.1	1.3
1987 JUL - AUG	+ 2.6	1.3
1987 SEP - OCT	+ 2.7	1.3
1987 NOV - DEC	+ 1.5	1.3
1988 JAN - FEB	1 + 0.9*10**-14	1.3*10**-14
1988 MAR - APR	+ 1.0	1.3
1988 MAY - JUN	+ 1.5	1.3
1988 JUL - AUG	+ 2.6	1.3
1988 SEP - OCT	+ 3.0	1.3
1988 NOV - DEC	+ 2.6	1.3

In the BIH Annual Reports from 1984 to 1987, the uncertainty was conservatively estimated to 5*10**-14 since 1979. In the above table, the uncertainty is strictly the output of the computation and is based on the uncertainties reported by the laboratories.



Time links used by BIPM (31 December 1988)

(1) Link to USNO through CRL, TAO and Hawaii

(2) Until 1988 July 27

(3) GPS link established in January 1989

Fig. 1

PART C

TIME SIGNAL (1989)

The time signal emissions reported thereafter follow the UTC system, in accordance with the Recommendation 460-4 of the International Radio Consultative Committee (CCIR), unless otherwise stated.

Their maximum departure from the Universal Time UT1 is thus 0.9 second.

The following tables are based on information received at BIPM in February and March 1989, except in the cases indicated by a note.

AUTHORITIES RESPONSIBLE FOR THE TIME SIGNAL EMISSIONS

Signal	Authority
ATA	National Physical Laboratory Hillside Road New Delhi - 110012, India
BPM	Shaanxi Astronomical Observatory Academia Sinica P.O. Box 18 - Lintong Shaanxi, China
BSF	Telecommunication Laboratories Directorate General of Telecommunications Ministry of Communications P.O. Box 71 - Chung-Li 32099 Taiwan, R.O.C.
CHU	National Research Council, Time and Length Standards Section Physics Division (M-36) Ottawa K1A OR6, Ontario, Canada Attn : Dr. J. Vanier
DCF77	Physikalisch-Technische Bundesanstalt, Lab. Zeiteinheit Bundesallee 100 D-3300 Braunschweig Federal Republic of Germany
DGI, Y3S	Amt für Standardisierung, Messwesen und Warenprüfung Zeit - und Frequenzdienst der DDR Fürstenwalder Damm 388 DDR 1162 Berlin
EBC	Real Instituto y Observatorio de la Armada San Fernando Cadiz, Spain

Signal	Authority
HBG	Service horaire HBG Observatoire Cantonal CH - 2000 Neuchâtel, Suisse
HLA	Time and Frequency Laboratory Korea Standards Research Institute P. O. Box 3, Taedok Science Town Taejon 302-340 Republic of Korea
IAM	Istituto Superiore delle Poste e delle Telecomunicazioni Ufficio 8°, Rep.2° - Viale Europa 190 00144 - Roma, Italy
IBF	Istituto Elettrotecnico Nazionale Galileo Ferraris Strada delle Cacce, 91 10135 - Torino, Italy
JJY, JG2AS	Standards and Measurements Division Communications Research Laboratory Ministry of Posts and Telecommunications Koganei, Tokyo 184, Japan
LOL	Director Observatorio Naval Av. Espana 2099 1107 - Buenos-Aires, Republica Argentina
MSF	National Physical Laboratory Electrical Science Division Teddington, Middlesex TW11 OLW United Kingdom

Signal	**Authority**
OLB5, OMA	1/ Time information : Astronomický ústav ČSAV, Budečská 6 120 23 Praha 2, Vinohrady, Czechoslovakia. TELEX : 122 486 2/ Standard frequency information : Ústav radiotechniky a elektroniky ČSAV, Lumumbova 1, 182 51 Praha 8, Kobylisy, Czechoslovakia. TELEX : 122 646
PPE, PPR	Departemento Serviço da hora Observatorio Nacional (CNPq) Rua General Bruce, 586 20921 Rio de Janeiro - RJ, Brasil
RBU, RCH, RID, RTA, RTZ, RWM, UNW3, UPD8, UQC3, USB2, UTR3	Comité d'Etat des Normes Conseil des Ministres de l'URSS Moscou 117049, URSS, Leninski prosp., 9
TDF	Centre National d'Etudes des Télécommunications PAB - STC - Etalons de fréquence et de temps 196 avenue Henri Ravera - 92220 Bagneux, France
WWV,WWVH WWVB	Time and Frequency Division, 524.00 National Institute of Standards and Technology 325 Broadway Boulder, Colorado 80303, U.S.A.
YVTO	Direccion de Hidrografia y Navegacion Observatori Cagigal Apartado Postal No 6745 Caracas, Venezuela
Y3S	See DGI
ZUO	Division of Production Technology CSIR P.O. Box 395 - Pretoria 0001 South Africa

TIME - SIGNALS EMITTED IN THE UTC SYSTEM

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
ATA	Greater Kailash New Delhi India 28° 34'N 77° 19'E	5 000 10 000 15 000	12 h 30 m to 3 h 30 m continuous 3 h 30 m to 12 h 30 m	Second pulses of 5 cycles of a 1 kHz modulation. Minute pulses of 100 ms duration. (the time signals are advanced by 50 ms on UTC).
BPM	Pucheng China 35° 0'N 109° 31'E	2 500 5 000 10 000 15 000	7 h 30 m to 1 h continuous continuous 1 h to 9 h	UTC time signals (the signals are emitted in advance on UTC by 20 ms). Second pulses of 10 ms of 1 kHz modulation. Minute pulses of 300 ms of 1 kHz modulation. From minutes 0 to 10, 15 to 25, 30 to 40, 45 to 55. UT1 time signals are emitted from minutes 25 to 29, 55 to 59.
BSF	Chung-Li Taiwan ROC 24° 57'N 121° 9'E	5 000 15 000	continuous except interruption between minutes 35 and 40	(a) From min. 5 to 10, 15 to 20, 25 to 30, 45 to 50, 55 to 60, second pulses of 5 ms duration without 1 kHz modulation. (b) From min. 0 to 5, 10 to 15, ..., 50 to 55, second pulses of 5 ms duration with 1 kHz modulation. The 1 kHz modulation is interrupted 40 ms before and after the pulses. (c) Minute pulses are extended to 300 ms. (d) DUT1, CCIR code by lengthening.
CHU	Ottawa Canada 45° 18'N 75° 45'W	3 330 7 335 14 670	continuous	Second pulses of 300 cycles of a 1 kHz modulation, with 29th and 51st to 59th pulses of each minute omitted. Minute pulses are 0.5 s long. Hour pulses are 1.0 s long, with the following 1st to 10th pulses omitted. A bilingual (Fr. Eng.) announcement of time (UTC-5 hours) is made each minute following the 50th second pulse. FSK time code after 10 cycles of 1 kHz on the 31st to 39th seconds. Broadcast is single sideband; upper sideband with carrier reinsert. DUT1 : CCIR code by split pulses.
DCF77	Mainflingen Germany, F.R. 50° 1'N 9° 0'E	77.5	continuous	At the beginning of each second (except the 59th second) the carrier amplitude is reduced to about 25 % for a duration of 0.1 s or 0.2 s. Coded transmission of year, month, day, hour, minute and day of the week in a BCD code from second marker No 21 to No 58 (the second marker durations of 0.1 s or 0.2 s correspond to a binary 0 or a binary 1 respectively). The coded time information is related to legal time of FRG and second markers 17 and 18 indicate if the transmitted time refers to UTC(PTB) + 2 h (summer time) or UTC(PTB) + 1 h. Second marker No 15 is prolonged to 0.2 s, if the reserve antenna is in use. To achieve a more accurate time transfer and better use of the frequency spectrum available, an additional pseudo random phase - shift keying of the carrier is superimposed to the AM second markers. No transmission of DUT1.
DGI	Oranienburg Germ.Dem.Rep. 52° 48'N 13° 24'E	182	5 h 59 m 30 s to 6 h 00, 11 h 59 m 30 s to 12 h 00, 17 h 59 m 30 s to 18 h 00	A2 type second pulses of 0.1 s duration for seconds 30-40, 45-50, 55-60. The last pulse is prolonged. (one hour earlier in summer time)

Notes : see p. C-10

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
EBC	San Fernando Spain 36° 28'N 6° 12'W	12 008 6 840	10 h 00 m to 10 h 25 m 10 h 30 m to 10 h 55 m	Second pulses of 0.1 s duration of a 1 kHz modulation. Minute pulses of 0.5 s duration of 1 250 Hz modulation. DUT1, CCIR code, double pulse. Type A3H.
HBG	Prangins Switzerland 46° 24'N 6° 15'E	75	continuous	Interruption of the carrier at the beginning of each second, during 100 ms. The minutes are identified by a double pulse, the hours by a triple pulse. No transmission of DUT1. Time code and other coded information.
HLA	Taedok Science Town Republic of Korea 36° 23'N 127° 22'E	5 000	1 h to 8 h on Monday to Friday (Except National Holidays in Korea)	Pulses of 9 cycles of 1800 Hz modulation. 59th and 29th second pulses omitted. Hour identified by 0.8 second long 1500 Hz tone. Beginning of each minute identified by 0.8 second long 1800 Hz tone. Voice announcement of hours and minutes each minute following 52nd second pulse. BCD time code given on 100 Hz subcarrier. DUT1 : CCIR code by double pulse.
IAM (1)	Rome Italy 41° 47'N 12° 27'E	5 000	7 h 30 m to 8 h 30 m 10 h 30 m to 11 h 30 m Except Sunday and National Holidays	Second pulses of 5 cycles of 1 kHz modulation. Minute pulses of 20 cycles. Voice announcements every 15 m beginning at 0 h 0 m. Time announcement by Morse code beginning at 0 h 5 m. DUT1 : CCIR code by double pulse.
IBF	Torino Italy 45° 2'N 7° 42'E	5 000	During 15 m preceding 7 h, 9 h, 10 h, 11 h, 12 h, 13 h, 14 h, 15h, 16 h, 17 h, 18 h. Advanced by 1 hour in summer.	Second pulses of 5 cycles of 1 kHz modulation. These pulses are repeated 7 times at the minute. Voice announcements at the beginning and end of each emission. Time announcement (C.E.T.) by Morse code every ten minutes beginning at 0 h 0 m. DUT1 : CCIR code by double pulse.
JG2AS	Sanwa Ibaraki Japan 36° 11'N 139° 51'E	40	continuous, except interruptions during communications.	A1 type second pulses of 0.5 s duration. Second 59 is of 0.2 s. No DUT1 code. During experimental coded transmission of the total day, hour, minute and DUT1, second pulses are 0.2 s, 0.5 s and 0.8 s duration.
JJY	Sanwa Ibaraki Japan 36° 11'N 139° 51'E	2 500 5 000 8 000 10 000 15 000	continuous, except interruption between minutes 35 and 39.	Second pulses of 8 cycles of 1 600 Hz modulation. Minute pulses are preceded by a 600 Hz modulation. DUT1 : CCIR code by lengthening.
LOL1	Buenos-Aires Argentina 34° 37'S 58° 21'W	5 000 10 000 15 000	11 h to 12 h, 14 h to 15 h, 17 h to 18 h, 20 h to 21 h, 23 h to 24 h	Second pulses of 5 cycles of 1 000 Hz modulation. Second 59 is omitted. Announcement of hours and minutes every 5 minutes, followed by 3 m of 1 000 Hz or 440 Hz modulation. DUT1 : CCIR code by lengthening.
LOL2 LOL3	Buenos-Aires Argentina 34° 37'S 58° 21'W	4 856 8 030 17 180	1 h, 13 h, 21 h	A1 second pulses during the 5 minutes preceding the indicated times. Second 29 is omitted. Minute pulses are prolonged. DUT1 : CCIR code by double pulse.

Notes : see p. c-10

Station	Location Latitude Latitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
MSF	Rugby United Kingdom 52° 22'N 1° 11'W	60	continuous except for an interruption for maintenance from 10 h 0 m to 14 h 0 m on the first Tuesday in each month.	Interruptions of the carrier of 100 ms for the second pulses, of 500 ms for the minute pulses. The signal is given by the beginning of the interruption. BCD NRZ code, 100 bits/s (month, day of month, hour, minute), during minute interruption. BCD PWM code, 1 bit/s (year, month, day of month, day of week, hour, minute) from seconds 17 to 59 in each minute. DUT1 : CCIR code by double pulse.
OLB5	Liblice Czechoslovakia 50° 4'N 14° 53'E	3 170	continuous except from 9 h to 14 h on the first Wednesday of every month	A1 type, second pulses. No transmission of DUT1.
OMA (2)	Liblice Czechoslovakia 50° 4'N 14° 53'E	50	continuous (from 6 h to 12 h on the first Wednesday in each month, emitted from Podebrady with reduced power)	Interruption of the carrier of 100 ms at the beginning of every second, of 500 ms at the beginning of every minute. The precise time is given by the beginning of the interruption. Phase coded announcement of date, UT and local civil time. No DUT1 code.
OMA	Liblice Czechoslovakia 50° 4'N 14° 53'E	2 500	continuous except from 9 h to 14 h on the first Wednesday of every month	Pulses of 100 cycles of 1 kHz modulation (prolonged for the minutes) No DUT1 code.
PPE	Rio-de-Janeiro Brasil 22° 54'S 43° 13'W	8 721	0 h 30 m, 11 h 30 m, 13 h 30 m, 19 h 30 m, 20 h 30 m, 23 h 30 m	Second ticks, of A1 type, during the five minutes preceding the indicated times. The minute ticks are longer. DUT1 : CCIR code by double pulse.
PPR	Rio-de-Janeiro Brasil 22° 59'S 43° 11'W	435 4 244 8 634 13 105 17 194.4 22 603	1 h 30 m, 14 h 30 m, 21 h 30 m	Second ticks, of A1 type, during the five minutes preceding the indicated times. The minute ticks are longer.
RBU (3)	Moscow USSR 55° 48'N 38° 18'E	66 2/3	continuous	From 0 h to 9 h, 11 h to 19 h, 23 h to 24 h, DXXXW type signals. The time of day in hours, minutes and seconds is transmitted in BCD code. From 9 h to 11 h, 19 h to 23 h, NON type signals.
RCH (3)	Tashkent USSR 41° 19'N 69° 15'E	 2 500 5 000 10 000	Winter schedule : between minutes 0 and 10, 30 and 40 0 h to 3 h 40 m 5 h to 23 h 40 m 0 h to 3 h 40 m 14 h to 23 h 40 m 5 h to 13 h 10 m In summer add one hour.	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
RID (3)	Irkutsk USSR 52° 26'N 104° 2'E	5 004 10 004 15 004	The station simultaneously operates on three frequencies between minutes 20 and 30, 50 and 60	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.

Notes : see p. c-10

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
RTA (3)	Novosibirsk USSR 55° 4'N 82° 58'E	10 000 15 000	Winter schedule : between minutes 0 and 10, 30 and 40, 14 h to 5 h 10 m 6 h 30 m to 13 h 10 m In summer add one hour.	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
RWM (3)	Moscow USSR 55° 48'N 38° 18'E	4 996 9 996 14 996	The station simultaneously operates on three frequencies between minutes 10 and 20, 40 and 50	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
RTZ (3)	Irkutsk USSR 52° 26'N 104° 2'E	50	between minutes 0 and 5 0 h to 20 h 05 m 22 h to 23 h 05 m	A1X type second pulses. The pulses at the beginning of the minute are prolonged to 0.5 s.
TDF	Allouis France 47° 10'N 2° 12'E	162	continuous except every Tuesday from 1 h to 5 h	Phase modulation of the carrier by + and - 1 radian in 0.1 s every second except the 59th second of each minute. This modulation is doubled to indicate binary 1. The numbers of the minute, hour, day of the month, day of the week, month and year are transmitted each minute from the 21st to the 58th second, in accordance with the French legal time scale. In addition a binary 1 at the 17th second indicates that the local time is 2 hours ahead of UTC(summer time), a binary 1 at the 18th second indicates when the local time is one hour ahead of UTC(winter time) ; a binary 1 at the 14th second indicates that the current day is a public holiday (Christmas, 14 July, etc...); a binary 1 at the 13th second indicates that the current day is a day before a public holiday.
UNW3	Molodechno USSR 54° 26'N 26° 48'E	25	7 h 43 m to 7 h 52 m 19 h 43 m to 19 h 52 m in winter 8 h 43 m to 8 h 52 m 21 h 43 m to 21 h 52 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
UPD8	Arkhangelsk USSR 64° 24'N 41° 32'E	25	Winter schedule : 8 h 43 m to 8 h 52 m 11 h 43 m to 11 h 52 In summer, add one hour.	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
UQC3	Chabarovsk USSR 48° 30'N 134° 51'E	25	0 h 43 m to 0 h 52 m 6 h 43 m to 6 h 52 m 17 h 43 m to 17 h 52 m in winter 2 h 43 m to 2 h 52 m 6 h 43 m to 6 h 52 m 18 h 43 m to 18 h 52 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.

Notes : see p. C-10

Station	Location Latitude Longitude	Frequency (kHz)	Schedule (UTC)	Form of time signals
USB2	Frunze USSR 43° 04'N 73° 39'E	25	4 h 43 m to 4 h 52 m 9 h 43 m to 9 h 52 m 21 h 43 m to 21 h 52 m in winter 5 h 43 m to 5 h 52 m 11 h 43 m to 11 h 52 m 23 h 43 m to 23 h 52 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s. 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
UTR3	Gorki USSR 56° 11'N 43° 58'E	25	5 h 43 m to 5 h 52 m 13 h 43 m to 13 h 52 m 18 h 43 m to 18 h 52 m in winter 7 h 43 m to 7 h 52 m 14 h 43 m to 14 h 52 m 19 h 43 m to 19 h 52 m in summer	A1N type 0.1 second pulses of 0.025 s duration. Second pulses are prolonged to 0.1 s 10 second pulses are prolonged to 1 s and minute pulses are prolonged to 10 s. No transmission of DUT1 code.
WWV	Fort-Collins, CO USA 40° 41'N 105° 2'W	2 500 5 000 10 000 15 000 20 000	continuous	Pulses of 5 cycles of 1 kHz modulation. 59th and 29th second pulses omitted. Hour is identified by 0.8 second long 1 500 Hz tone. beginning of each minute identified by 0.8 second long 1 000 Hz tone. DUT1 : CCIR code by double pulse. BCD time code given on 100 Hz subcarrier, includes DUT1 correction.
WWVB	Fort-Collins, CO USA 40° 40'N 105° 3'W	60	continuous	Second pulses given by reduction of the amplitude of the carrier. Coded announcement of the date, time, correction to obtain UT1, daylight savings time in effect and leap year. No CCIR code.
WWVH	Kauai, HI USA 21° 59'N 159° 46'W	2 500 5 000 10 000 15 000	continuous	Pulses of 6 cycles of 1 200 Hz modulation. 59th and 29th second pulses omitted. Hour identified by 0.8 second long 1 500 Hz tone. Beginning of each minute identified by 0.8 second long 1 200 Hz tone. DUT1 : CCIR code by double pulse. BCD time code given on 100 Hz subcarrier, includes DUT1 correction.
YVTO (4) (1)	Caracas Venezuela 10° 30'N 66° 56'W	6 100	continuous	Second pulses of 1 kHz modulation with 0.1 s duration. The minute is identified by a 800 Hz tone and a 0.5 s duration. Second 30 is omitted. Between seconds 40 and 50 of each minute, voice announcement of the identification of the station. Between seconds 52 and 57 of each minute, voice announcement of hour, minute and second.
Y3S (5)	Nauen Germ. Dem. Rep. 52° 39'N 12° 55'E	4 525	continuous except from 8 h 15 m to 9 h 45 m for maintenance if necessary	A1 type second pulses of 0.1 s duration. Minute pulses prolonged to 0.5 s. DUT1 : CCIR code by double pulse.
ZUO	Olifantsfontein South Africa 25° 58'S 28° 14'E	2 500 5 000	18 h to 4 h continuous	Pulses of 5 cycles of 1 kHz modulation. Second 0 is prolonged.
ZUO	Johannesburg South Africa 26° 11'S 28° 4'E	100 000	continuous	Pulses of 5 cycles of 1 kHz modulation. Second 0 is prolonged.

Notes : see p. C-10

NOTES ON THE CHARACTERISTICS OF THE SIGNALS

(1) No recent information on these time signals.

(2) OMA, 50 kHz

a. The main transmitter in Liblice radiates approx. 7 kW and the stand-by transmitter in Podebrady (50° 9'N, 15° 9'E) approx. 50 W.

b. The details of the time code were published in Nomenclature des stations de radiorepérage et des stations effectuant des services spéciaux - Liste VI, Volume I, édition 7 de U.I.T. in Geneva in July 1980.

(3) The radiostations of the USSR emit DUT1 information in accordance with the CCIR code. Furthermore they give an additional information dUT1 specifying more precisely the difference UT1 - UTC down to multiples of 0.02 s, the total value of the correction being DUT1 + dUT1. Positive values of dUT1 are transmitted by the marking of p second markers within the range between the 21th an 24th second so that dUT1 = + 0.02 s x p. Negative values of dUT1 are transmitted by the marking of q second markers within the range between the 31th and the 34th second, so that dUT1 = -0.02 s x q.

(4) YVTO. The frequency may have changed to 5000 kHz during 1988.

(5) DUT1 information in CCIR code.
dUT1 information. This additional information specifies more precisely the difference UT1 - UTC down to multiples of 0.02 s, the total value of the correction being DUT1 + dUT1.

A positive value of dUT1 is indicated by doubling a number (p) of consecutive seconds markers from second marker 21 to second marker (20 + p) inclusive ; (p) being an integer from 1 to 5 inclusive.

$$dUT1 = p.0.02 \text{ s.}$$

A negative value of dUT1 is indicated by doubling a number (q) of consecutive seconds markers following the minute marker from second marker 31 to second marker (30 + q) inclusive ; (q) being an integer from 1 to 5 inclusive.

$$dUT1 = -(q.0.02) \text{ s.}$$

The second marker 28 following the minute marker is doubled as parity bit, if the value of (p) or (q) is an even number or if dUT1 = 0.

Time-information. During the last 20 seconds of each minute in a BCD-Code an information about the value "minute" and "hour" in the UTC time scale of the following minute marker is given.

UNCERTAINTY OF THE CARRIER FREQUENCY

The carriers of the following time signals are standard frequencies.

Station	Relative uncertainty of the carrier frequency in 10^{-10}
ATA	0.1
BPM	0.1
BSF	0.2
CHU	0.05
DCF77	0.005 (10d-mean)
EBC	0.1
HBG	0.005
HLA	0.1
IAM	0.5
IBF	0.1
JJY, JG2AS	0.1
LOL1	0.1
MSF	0.02
OMA (all frequencies)	0.5
RBU, RTZ	0.05
RCH, RID, RTA, RWM	0.5
TDF	0.02
UNW3, UPD8, UQC3, USB2, UTR3	0.05
WWV	0.1
WWVB	0.1
WWVH	0.1
ZUO	0.1

TIME OF EMISSION OF THE TIME SIGNALS IN THE UTC SYSTEM, IN 1988

The following deviations of the time of emission of the time signals, from UTC, have been reported to the BIPM, or observed.

ATA	UTC-ATA = -0.0500 s
BPM	UTC-BPM = -0.0200 s
OLB5	UTC-OLB5= 0.0008 s

PART D

SCIENTIFIC CONTRIBUTIONS

PARTIE D

CONTRIBUTIONS SCIENTIFIQUES

Establishment of
International Atomic Time

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1. Introduction

International Atomic Time TAI has been defined by the 14th Conférence Générale des Poids et Mesures (CGPM) as "the time reference coordinate established by the Bureau International de l'Heure [now by the Bureau International des Poids et Mesures] on the basis of the readings of atomic clocks operating in various establishments in accordance with the definition of the second, the unit of time of the International System of Units".

The relativistic aspect of the definition of TAI has been considered in a "declaration" of the Comité Consultatif pour la Définition de la Seconde (CCDS), 9th session, 1980, stating that "TAI is a coordinate time scale defined in a geocentric reference frame with the SI second as realized on the rotating geoid as the scale unit".

The combination of data of clocks at different locations on the Earth requires a definition of the synchronization and of the clock reading comparisons. This is accomplished by associating with each clock, which is assumed to give the proper time along its world line, the coordinate time in the frame of the TAI definition. It is then possible to give a definition of the comparison of these coordinate times which leads to results independent of the method of measurement.

For clocks fixed on the Earth, the conversion from proper time to coordinate time is merely a constant frequency offset, which is easily applied. [In some cases there is no need to distinguish between the relativistic fixed offset and the systematic frequency offsets due to physical causes; this is, in particular, the case for industrial cesium clocks and hydrogen masers, which are stable, but not accurate.] The time comparaisons are corrected for the relativistic effects, using, for instance, formulas given in BIPM Com. Cons. Déf. Seconde, 9, pp. S16-S17 and CCIR Report 439 (Recommendations and Reports of the CCIR, 1986, pp. 134-137).

It is not within the scope of this note to discuss further these matters. We will assume that all the necessary corrections have been made.

2. General structure of the computation of TAI

2.1. Definitions

UTC : Coordinated Universal Time, an approximation to Universal Time UT1 derived from TAI by an agreed procedure.

UTC(k) : Approximation to UTC kept by laboratory "k".

TA(k) : Independent local atomic time scale established by laboratory "k", or country "k", from the readings of clocks belonging to this laboratory or country.

$H_{k,p}$: p-th clock of laboratory "k". When there is no need to state the laboratory to which the clock belongs, a single index is used : H_m, running sequentially.

S : Time marker from a terrestrial or space emitter, which is received by two or more laboratories, the corrections for the propagation, having been applied.

The same symbol is used for clocks (and time scales) and for their readings. However, notations such as $H_m(t)$, will be used in some formulas, to indicate the reading at date t.

Time scales are considered as fictitious clocks to which the usual characterization of clocks is applied: frequency stability, frequency accuracy etc. All the frequencies are normalized.

2.2. Data used for establishing TAI

The following data are received at BIPM :

(a) for Modified Julian Dates (MJD) ending by 9, at 0 h UTC, designated thereafter as "standard dates",

$$UTC(k) - H_{k,p}$$
$$UTC(k) - TA(k), \text{ if } TA(k) \text{ exists},$$

(b) at the instant of measurement, usually several times per day,

$$UTC(k) - S, \qquad UTC(j) - S, \ldots,$$

from which BIPM evaluates, at the standard dates,

$$UTC(k) - UTC(j), \ldots$$

(c) when a primary frequency standard P_k is used in laboratory k, the mean normalized frequency difference, over stated intervals,

$$f[P_k] - f[UTC(k)].$$

In some cases P_k operates continuously as a primary clock and produces a time scale designated also as P_k; the frequency evaluations are then derived from $UTC(k) - P_k$.

2.3. Structure of the computation of TAI

From clock data and time comparisons [data of types (a) and (b) above], a stability algorithm, designated as ALGOS, produces an intermediate time scale EAL (Echelle atomique libre, i.e. free atomic scale). ALGOS puts the emphazis on long-term frequency stability, for averaging times of two months and more, but does not provide the accuracy of the unitary scale interval of EAL, which differs significantly from the best realizations of the SI second at sea level.

TAI is linked to EAL by a relationship which includes a variable frequency offset determined from the data of primary standards [data of type (c) above]. The method for changing the frequency offset between EAL and TAI has been chosen so that it does not bring a significant degradation to the stability of EAL. This method is usually called "frequency steering".

3. The stability algorithm ALGOS, theory

3.1. Formal development

To show the principles of ALGOS, we will first consider a formal development where one assumes that the readings of clocks and time scales are available at instants t of an ideal, uniform time scale.

We will then consider the equivalent form of the equations where only time differences, slowly varying with time, appear, so that the requirements on the uniformity and precision of reading of t are greatly relaxed.

In the data, real clocks H_m and time scales UTC(k), TA(k) play a symetrical role. It is convenient to consider these time scales as fictitious clocks, to which a null weight is given.

We consider consecutive intervals $I_{i-1}(t_{i-1}, t_{i-1} + q_{i-1})$, $I_i(t_i, t_i + q_i)$, ..., with $t_i = t_{i-1} + q_{i-1}$, ... During each interval, the statistical weights $w_{m,i}$ of clocks H_m are kept constant ($w_{m,i} = 0$, for time scales), but the weights may vary from one interval to another. Therefore, the entries and exits of clocks must be made only at common dates of adjacent intervals, t_{i-1}, t_i ...

Let us designate the weighted averages during I_i with weights $w_{m,i}$ by the symbol $[\ \ ]_i$. At date t belonging to I_i, EAL is defined by

$$\mathrm{EAL}(t) = [H_m(t)]_i + \mathbf{A}_i + \mathbf{B}_i(t - t_i). \qquad (1)$$

The role of the constants $\mathbf{A}_i$ and $\mathbf{B}_i$, relative to interval I_i, is to avoid time and rate steps of EAL, when moving from interval I_{i-1} to I_i. These constants must be expressed as functions of the previous $\mathbf{A}_{i-1}$, $\mathbf{B}_{i-1}$ to ensure these continuity conditions.

The time continuity at t_i is written

$$[H_m(t_i)]_{i-1} + \mathbf{A}_{i-1} + \mathbf{B}_{i-1}q_{i-1} = [H_m(t_i)]_i + \mathbf{A}_i. \qquad (2)$$

The rate continuity leads to

$$\left[\frac{dH_m(t)}{dt}\right]_{i-1} + \mathbf{B}_{i-1} = \left[\frac{dH_m(t)}{dt}\right]_i + \mathbf{B}_i, \text{ at } t = t_i. \qquad (3)$$

However, equation (3) has no practical value, since the instantaneous rate of the clocks has no physical meaning: it is necessary to consider mean rates. For the reasons explained below, the mean rates, in ALGOS, are evaluated over the whole duration of intervals I_{i-1}, I_i. Thus the continuity condition (3) transforms into

$$\mathbf{B}_i = \mathbf{B}_{i-1} + \frac{[H_m(t_i)]_{i-1} - [H_m(t_{i-1})]_{i-1}}{q_{i-1}} - \frac{[H_m(t_{i+1})]_i - [H_m(t_i)]_i}{q_i}. \qquad (4)$$

3.2. Use of time differences

Equations (1), (2) and (4) must be transformed for the clock differences to appear such as

$$H_u(t) - H_v(t) = \xi_{uv}(t). \quad (5)$$

Let us designate by $z_{u,i}(t)$ the raw clock correction during I_i:

$$z_{u,i}(t) = [H_m(t)]_i - H_u(t). \quad (6)$$

At some date t of interval I_i, the clock comparison and the definition of $z_{u,i}$ lead to the system

$$\begin{aligned} & z_{u,i}(t) - z_{v,i}(t) = - \xi_{uv}(t) \\ & [z_{m,i}(t)]_i = 0 \qquad , \qquad t_i < t < t_i + q_i, \end{aligned} \quad (7)$$

which has a solution $\hat{z}_{m,i}(t)$, $m = 1, \ldots, n_i$, (n_i, total number of clocks (real or fictitious) in I_i) obtained by the least squares method, for instance, if the system is redundant. Then, a value of EAL, $(EAL(t))_u$ is available through the reading of clock H_u by

$$(EAL(t))_u = H_u(t) + \hat{z}_{u,i}(t) + \mathbf{A}_i + \mathbf{B}_i(t - t_i). \quad (8)$$

$z_{u,i}(t)$ is not strictly a solution of (7) in case of redundancy:

$$z_{u,i}(t) - \hat{z}_{u,i}(t) = \varepsilon_{u,i}(t). \quad (9)$$

Writing (8) for a clock H_v and substracting to (8) gives

$$(EAL(t))_u - (EAL(t))_v = \varepsilon_{v,i}(t) - \varepsilon_{u,i}(t) \neq 0. \quad (10)$$

To avoid this difficulty, which, after a few months of experiment, was found to be especially harmful when the network of time links was modified, it was decided to apply ALGOS with a non-redundant system of the best links. It this case, the solution strictly fulfils system (7) and $\varepsilon = 0$ in (9). The solution is thus designated by $z_{u,i}(t)$ and at any date t of interval I_i, EAL(t) is available through any clock reading by

$$EAL(t) = H_u(t) + z_{u,i}(t) + \mathbf{A}_i + \mathbf{B}_i(t - t_i).$$

In all what follows we adopt the hypothesis that the time links are not redundant.

The time continuity condition (2) is fulfilled by considering a clock H_u (real or fictitious) which functioned during I_{i-1} and I_i, for which one has computed the raw clock corrections $z_{u,i-1}$ and $z_{u,i}$. Equation (2) becomes, after substracting $H_u(t_i)$ to both members

$$z_{u,i-1}(t_i) + \mathbf{A}_{i-1} + \mathbf{B}_{i-1}q_{i-1} = z_{u,i}(t_i) + \mathbf{A}_i \qquad (11)$$

and gives $\mathbf{A}_i$. Writing the same equation for H_v and substracting to (11) shows that $\mathbf{A}_i$ is unique.

The mean rate continuity is similarly expressed by letting the raw clock corrections of a particular clock H_u appear in equation (4). One has

$$\mathbf{B}_i - \mathbf{B}_{i-1} = \frac{z_{u,i-1}(t_i) - z_{u,i-1}(t_{i-1})}{q_{i-1}} - \frac{z_{u,i}(t_{i+1}) - z_{u,i}(t_i)}{q_i}$$
$$+ \frac{H_u(t_i) - H_u(t_{i-1})}{q_{i-1}} - \frac{H_u(t_{i+1}) - H_u(t_i)}{q_i}. \qquad (12)$$

As the time scale EAL is computed for I_i, the necessary data for computing the first two terms of the right hand member of (12) are available, but the third and fourth terms which represent the true mean frequencies of clocks H_u with respect to the ideal time t are not known. Equation (12) can then be solved only if the change from interval I_{i-1} to interval I_i, of the true mean frequency of clock H_u is <u>predicted</u>. [Intended frequency changes are taken into account prior to the computations.] In ALGOS, one assumes that the mean frequency of any clock is the same during I_i as during I_{i-1}, which leads to n_i estimations $(\mathbf{B}_i)_u$ of $\mathbf{B}_i$, each obtained from a given clock H_u, written as

$$(\mathbf{B}_i)_u = \mathbf{B}_{i-1} + \frac{z_{u,i-1}(t_i) - z_{u,i-1}(t_{i-1})}{q_{i-1}} - \frac{z_{u,i}(t_{i+1}) - z_{u,i}(t_i)}{q_i} . \quad (13)$$

The adopted value $\mathbf{B}_i$ can then be a weighted average of the $(\mathbf{B}_i)_u$ which emphasizes the role of clocks having the best long-term frequency stability. In principle, this weight system may differ from the w-weight system of 3.1., but in the present implementation of ALGOS it is the same and

$$\mathbf{B}_i = [(\mathbf{B}_i)_m]_i . \quad (14)$$

In this particular case, the last term of (13) cancels out in the average and $\mathbf{B}_i$ can easily be obtained from quantities belonging only to interval I_{i-1}.

One can notice the possibility of using different modes of prediction, according to the type of clock. For instance, taking into account a longer history of a very stable primary clock would lead to a less trivial estimate of its true mean frequency and to an estimation of $\mathbf{B}_i$ involving quantities calculated over several past intervals. This possibility has not yet been tried.

3.3. Use of individual time corrections and observed rates

From the definition of EAL(t) (equation 1) for any date t belonging to I_i, the raw clock correction $z_{u,i}(t)$ of clock H_u can be written as

$$z_{u,i}(t) = EAL(t) - H_u(t) - \mathbf{A}_i - \mathbf{B}_i(t - t_i). \quad (15)$$

$\mathbf{A}_i$ being unique, it can be obtained by taking the weighted average of both members of equation (11), which leads, with (15), to

$$\mathbf{A}_i = \left[EAL(t_i) - H_m(t_i) \right]_i . \tag{16}$$

$\mathbf{A}_i$ is then the weighted average of the clock time corrections to EAL at the common date t_i.

In the same way, inserting equation (15) into the estimation of $\mathbf{B}_i$ from equation (14) leads to

$$\mathbf{B}_i = \left[B_{m,i-1} \right]_i \tag{17}$$

where $B_{u,i-1}$ is the observed mean rate of clock H_u versus EAL, over interval I_{i-1}, written as

$$B_{u,i-1} = \frac{\left[EAL(t_i) - H_u(t_i) \right] - \left[EAL(t_{i-1}) - H_u(t_{i-1}) \right]}{q_{i-1}} \tag{18}$$

At any date t of interval I_i, EAL is then obtained from

$$EAL(t) = \left[H_m(t) + EAL(t_i) - H_m(t_i) + B_{m,i-1}(t - t_i) \right]_i . \tag{19}$$

To conclude, free atomic time appears to be the weighted average of individually corrected clock readings. The condition of continuity of the time scale when passing across the common date of two consecutive intervals of computation is then expressed as individual clock behaviour prediction.

3.4. The clock rate prediction in ALGOS

When there is no modification of the weight system between I_{i-1} and I_i, i.e. no change of weight, no entry or exit of clocks, equations (13) and (14) show that

$$\mathbf{B}_i = \mathbf{B}_{i-1}$$

and the algorithm for equalizing the mean rates either using the individual B_u as defined above (equation 18), or the global **B**, plays no role. One can demonstrate that this is also true when the individual values of B are obtained from the same linear combination for all clocks of past observed rates of EAL - H_m.

The role of the rate prediction in ALGOS is thus to minimize the perturbations of EAL due to the changes of the weight system, and to make EAL as close as possible to a raw average of readings of clocks of a fixed clock ensemble.

Since the true rate variations of (12) are neglected in (13) and (14), the averaging times q_{i-1}, q_i should be selected so that the rate variation be minimum. This requires that the averaging time corresponds to the frequency flicker floor of the clocks, as they appear to BIPM, including the noise of the time comparisons. As the goal of long-term stability of EAL tends to give high weights to clocks stable in the long term, the intervals I_i must be of long duration [two months in the case of ALGOS].

An important remark is that, although the predicted rates B_u are evaluated with respect to EAL, their use, as shown by (12), implies that the absolute frequency change, with respect to an ideally uniform time scale, is neglected. There is no feedback due to the reference to EAL.

These is no fundamental reason for using the w-weight system in the evaluation of $\mathbf{B}_i$ by (14). It could be advantageous to base the w-weight system on the short-term stability (here for averaging time of the order of 10 days) and to use a different weight system in (14) emphasizing the long-term. This has not yet been done in ALGOS, and the unique weight system is optimized for long-term stability.

4. Implementation of ALGOS

We present here the implementation of ALGOS in 1988. In addition to minor technical improvements, the only changes which have occurred since

1973, when ALGOS was put into use, were modifications of the weighting rules, on 1981 January 1 and 1988 January 1.

4.1. Data

Since ALGOS deals with stability only, the data of any clock, which is stable in the long-term and presumed to be free from frequency drift can be used. In practice, the participating clocks included, in 1988, industrially-made cesium clocks, laboratory cesium standards in continuous operation (primary clocks) and hydrogen masers.

Only the data of clocks which are compared with uncertainties of the order of 0.1 μs (one sigma) or less participate in the establishment of EAL. Time comparisons by simultaneous receptions of signals from the Global Positioning System (GPS) satellites link most of the participating clocks with uncertainties usually in the range of 10 to 20 ns. The simultaneous receptions of LORAN-C and television pulses are used for regional and local links. In its first application ALGOS accepted redundant links, the system (7) being solved by the least squares method. But difficulties in understanding the time steps due to changes in the system of links led to the use of a non-redundant network of the best links, as explained in 3.2.

The lists of participating laboratories and clocks, and the map of the time links appear in the Annual Report of the Bureau International de l'Heure until 1987, then in the Annual Report of the Time Section of BIPM.

4.2. Clock rate prediction

The intervals I_{i-1}, I_i of 3.2. have a duration of 60 days, or sometimes 70 days, to conform with a bi-monthly rythm. However, in order to provide TAI monthly, provisional results are computed for the months of January, March, ..., November with q_{i-1} = 60 days (or 70 days), q_i = 30 days (or 40 days). The following month the definitive computation is made with the normal value of q_i. The difference between the provisional and definitive results is small: for instance their quadratic mean for 1988 was 8 ns, with a maximum of 17 ns.

The individual clock behaviour prediction, which assumes that the rate with respect to EAL during I_i is predicted to be the same as observed during I_{i-1}, can be tested by the study of the scattering of individual values of $B_{u,i} - B_{u,i-1}$ with varying values of the interval durations. Studies with the following values of q_{i-1} and q_i have been made in 1987 and 1988

q_{i-1}	(months)	q_i
1		1
1		2
2		1
3		3
4		4

These have clearly shown that, even after the improvement of long distance time comparisons brought about by the GPS, the values $q_{i-1} = q_i = 2$ months, chosen in 1973, remain optimum.

The study of other modes of individual rate prediction, according to the clock type, has not shown sufficiently clear conclusions to justify their adoption in ALGOS.

4.3. Weights of the clocks

As for the prediction, ALGOS has the capability of applying different weighting rules, according to the type of clocks, but, in practice, a unique rule has always been used.

The basic principles of the ALGOS weighting procedure are:
- to emphazise long-term stability;

- to base the weights on rate samples including those evaluated during the interval for which EAL is being computed;
- to adopt an upper limit of weights in order to avoid a feedback effect which would lead to the indefinite increase of the weight of a single clock;
- to detect abnormal behaviour of the clocks and take appropriate action.

We present first the weighting rules adopted on 1988 January 1, then we recall the previous rules.

4.3.1. Weighting rules, as from 1988 January 1

Let us consider first the clocks having operated for at least one year. We denote by B_1, B_2, ..., B_6 the six observed mean rates (expressed in ns/day) of a clock, with respect to EAL. B_6 is the rate during the interval for which EAL is being established; it is obtained by an iterative process, the first step making use of the weights of the previous interval (5 iterations in practice). A weight w_2 is derived from the 6-sample variance of the B_i by:

$$\sigma^2(6,2\ \text{months}) = \frac{1}{5}\sum_{i=1}^{6}\left(B_i - \frac{1}{6}\sum_{j=1}^{6} B_j\right)^2, \tag{15}$$

$$w_1 = 1000/\sigma^2(6,2\ \text{months}), \tag{16}$$

$$\begin{aligned} w_2 &= w_1 && \text{if } w_1 \leq 100,\\ w_2 &= 100 && \text{if } w_1 > 100. \end{aligned} \tag{17}$$

For clocks having operated for less than a year and for which N samples B_{6-N+1}, B_{6-N+2}, ..., B_6 are available, $3 \leq N \leq 5$, the N-samples variance σ^2(N,2 months) is first calculated. Then, assuming a random walk frequency modulation (Barnes, 1969),

$$\sigma^2(6,2\ \text{months}) = \frac{6}{N}\sigma^2(N,2\ \text{months}). \tag{18}$$

The weights w_2 are given by (16) and (17).

$$\text{If } N = 1 \text{ or } 2,\ w_2 = 0.$$

The final weight w is attributed after a test for detection of abnormal behaviour.

Let us suppose that N consecutive samples of two-month mean rates are available, with $3 \leqq N \leqq 6$ (for N = 1, N = 2, the final weight is w = 0).

These samples are

$$B_{6-N+1},\ B_{6-N+2},\ \ldots,\ B_6.$$

One computes

$$\overline{B} = \frac{1}{N-1} \sum_{i=1}^{N-1} B_{6-N+i} \tag{19}$$

$$S_1^2 = \frac{6}{N} \frac{1}{N-2} \sum_{i=1}^{N-1} (B_{6-N+i} - \overline{B})^2, \tag{20}$$

S_1^2 being an evaluation of the 6-sample variance from available samples up to B_5. Then

$$\begin{aligned} S &= S_1 && \text{if } S_1 \geqq 3.16 \text{ ns/d},\\ S &= 3.16 \text{ ns/d} && \text{if } S_1 < 3.16 \text{ ns/d}. \end{aligned} \tag{21}$$

The safeguard is based on the quantity R:

$$R = |B_6 - \overline{B}|/S,$$

B_6 and $\overline{B}$ being expressed in ns/d.

The final weight w is

$$w = 0 \quad \text{if} \quad R \geq 3,$$
$$w = w_2 \quad \text{if} \quad R < 3. \qquad (22)$$

With this weighting procedure and safeguard, a new clock receives a null weight during a test period covering two consecutive intervals of two months of operation. Taking into account the fact that the mean rates are computed over fixed two-month intervals, in the worst cases the test period can extend to nearly 6 months.

4.3.2. Weighting rules, from 1973 to 1987

The weights were similarly based on the 6-sample variance (15), but, for $N = 2, \ldots, 5$, this variance was estimated with a frequency flicker noise model.

(a) Years 1973-1980

$$w_1 = 10^4/\sigma^2 \ (6,2 \text{ months})$$
$$w_2 = w_1 \quad \text{if } w_1 \leqslant 100$$
$$w_2 = 100 \text{ if } w_1 > 100.$$

For the safeguard, one computes

$$w_3 = 100 - 2\,(|B_6 - B_5| - 10),$$

B_6 and B_5 being expressed in ns/day, so that

$$w_3 < 0 \quad \text{when} \quad |B_6 - B_5| > 60 \text{ ns/d} \quad (6,9 \times 10^{-13}).$$

The final weight w is

$$w = w_2 \quad \text{if} \quad w_3 \geqslant w_2$$
$$w = w_3 \quad \text{if} \quad 0 \leqslant w_3 < w_2$$
$$w = 0 \quad \text{if} \quad w_3 < 0$$

(b) Years 1981-1987

$$w_1 = 10^4/\sigma^2(6,2 \text{ months})$$
$$w_2 = w_1 \quad \text{if} \quad w_1 \leq 200$$
$$w_2 = 200 \quad \text{if} \quad w_1 > 200.$$

Safeguard

$$w_3 = 200 - 5\ (|B_6 - B_5| - 7)$$

so that

$$w_3 < 0 \quad \text{when } |B_6 - B_5| > 47 \text{ ns/d} \quad (5.4 \times 10^{-13}).$$

Final weight

$$w = w_2 \quad \text{if} \quad w_3 \geq w_2$$
$$w = w_3 \quad \text{if} \quad 0 \leq w_3 < w_2$$
$$w = 0 \quad \text{if} \quad w_3 < 0.$$

(c) Evolution of the limiting weight

The limiting weight corresponds to the following values of the square root of the 6-sample variance

	σ(6,2 months)	
Interval	ns/day	10^{-14}
1973-1980	10.00	11.57
1981-1987	7.07	8.18
1988	3.16	3.66

5. Link between EAL and TAI: frequency steering

From 1973 to end 1976, TAI was equal to EAL. However, the increasing accuracy of the primary frequency standards made it clear that the unitary scale interval of TAI was too short by about 1×10^{-12} s in 1976.

It was then decided, in accordance with the recommendations of international organizations to introduce a rate step of TAI of - 86.4 ns/d (1×10^{-12} in relative frequency) on the 1st of January 1977 and to apply frequency steering to avoid further frequency offsets with respect to the primary frequency standards. The steering requires
(a) an evaluation of the frequency of EAL,
(b) a method of correction of the TAI frequency.

5.1. Evaluation of the frequency of EAL

The primary frequency standards provide measurements of the EAL mean frequency during the intervals where they functioned. We wish to obtain an estimate of the EAL frequency for a given interval, from all the available measurements which took place before, during, or sometimes after this interval. On account of its frequency stability EAL acts as a frequency memory, but this memory is not perfect and measurements made long before or long after the interval of estimation of the frequency of EAL should have a low contribution. The problem of building an optimum filter for the evaluation of the frequency of a time scale has been considered by Yoshimura (1972), then according to the same principles, but in a more general manner by Azoubib et al. (1977). This latter solution has been used at the Bureau International de l'Heure, then at the BIPM, to evaluate the frequency of EAL.

Only the salient features of the BIH/BIPM method are described here. The noise of the time scale is characterized by the levels of phase white noise, frequency white noise, frequency flicker noise and frequency random walk.

The uncertainties of the primary frequency standards are divided in two components:

(a) those which are estimated by statistics on repeated measurements;

(b) those which are estimated from the evaluation of the perturbations acting on the frequency transition, or its detection, which may bring a constant frequency error as long as these perturbations are not re-evaluated.

These types of uncertainties are analogous to uncertainties of categories A and B later defined by the Working Group on the Expression of Uncertainties of the Comité International des Poids et Mesures (BIPM, 1981). Their use is justified by the systematic frequency differences between primary frequency standards which are currently observed.

Based on the above noise levels and uncertainties a filter has been derived theoretically and is currently employed to evaluate the frequency of EAL.

5.2. Frequency steering

TAI is linked to EAL by a strict relation which includes a varying frequency offset. The principle of steering is that the frequency variations of this relation be of the same order as the changes of the frequency of EAL due to its instability.

In practice, the rule adopted in 1977 was to modify the normalized frequency of the steering correction by steps of 2×10^{-14} at intervals equal to or larger than two months. At the present level of instability of EAL, these steps are too large and should be reduced to 1 or 0.5 $\times 10^{-14}$. However, no steering has been necessary since 1984 February 29, the frequency of EAL has remained in agreement with that of primary standards.

Near the end of 1987, the discovery of an error made earlier in the year in the computation of EAL led to values being revised. In order to avoid a small step of TAI (by 27 ns), when adopting the revised EAL, the relation TAI/EAL was modified to cancel this step, the real frequency offset differing by 1.25×10^{-15} from its nominal value. Such circumstances may occur again in the future.

5.3. Annual frequency variations

It has been observed that the frequency of EAL has an annual variation with respect to the primary frequency standards (Guinot and Azoubib, 1980). The peak to peak amplitude was of the order of 1×10^{-13} in 1976-1978, then progressively decreased to about 2×10^{-14} in 1988. Although the origin of this annual difference lies probably in EAL (see, for instance, Guinot, 1988), no attempt has been made to correct it.

6. Conclusion

In the establishment of TAI, the stability algorithm ALGOS minimizes the perturbations to the frequency stability, due to modifications of the number and weights of the participating clocks, for averaging time of two months. The weighting procedure homogeneously emphasizes the role of clocks stable for the same averaging time.

The stability over periods of a few years and longer is mainly ensured by frequency steering based upon the data of primary standards.

With the reducing noise of time comparisons, we are considering the introduction of an additional weight system to optimize also the stability for 10-day averaging times.

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