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1. GENERAL BACKGROUND INFORMATION

ABBREVIATIONS AND ACRONYMS USED IN THIS BULLETIN

APL - John Hopkins University Applied Physics Laboratory
BIH - International Time Bureau, France
CCIR - International Radio Consultative Committee
CRL - Communications Research Laboratories, Japan
Cs - Cesium standard
CSIRO - Commonwealth Scientific and Industrial Research Organization, Australia
GOES - Geostationary Operational Environmental Satellite
GPS - Global Positioning System
IEN - National Institute of Electronics, Italy
INPL - National Physical Laboratory, Israel
LORAN - Long Range Navigation
MC - Master Clock
MJD - Modified Julian Date
NIST - National Institute of Standards & Technology
NPL - National Physical Laboratory, England
NRC - National Research Council, Canada
NOAA - National Oceanic and Atmospheric Administration
OP - Paris Observatory, France
PTB - Physical Technical Federal Laboratory, Germany
SI - International System of Units
SV - Space vehicle
TA - Atomic Time
TAI - International Atomic Time
TAO - Tokyo Astronomical Observatory, Japan
TUG - Technical University of Graz, Austria
USNO - United States Naval Observatory
UTC - Coordinated Universal Time
VLF - very low frequency
VSL - Van Swinden Laboratory, Netherlands

ns - nanosecond
μs - microsecond
ms - millisecond
s - second
min - minute
h - hour
d - day

2. TIME SCALE INFORMATION

The values listed below are based on data from the BIH, the USNO, and the NIST. The UTC – UTC(NIST) values are extrapolations since UTC is computed more than two months after the fact. The UTC(USNO,MC) – UTC(NIST) values are averaged measurements from NAVSTAR satellites 3,4,6, and 8 (see references on page 6).

0000 HOURS COORDINATED UNIVERSAL TIME

AUGUST 1989	MJD	UT1 – UTC(NIST) (± 5 ms)	UTC – UTC(NIST) (± 0.2 μs)	UTC(USNO,MC) – UTC(NIST) (± 0.04 μs)
3	47741	-416 ms	-0.5 μs	0.53 μs
10	47748	-424 ms	-0.5 μs	0.56 μs
17	47755	-430 ms	-0.5 μs	0.59 μs
24	47762	-441 ms	-0.5 μs	0.61 μs
31	47769	-447 ms	-0.5 μs	0.63 μs

INTERNATIONAL TIMING CENTER COMPARISONS VIA GPS COMMON-VIEW

The table below is a weighted average of the indicated GPS satellites used as transfer standards to measure the time difference of Timing Center (i) – UTC(NIST) by the simultaneous common-view approach (see references, page 6). The day-to-day variations of this technique are a few nanoseconds and the accuracy is about 10 ns. The time of the measurement is interpolated to 0000 UTC for the particular MJD ending in 9. These data are prepared for the BIPM for the computation on TAI and of UTC. All differential delays are 0 unless otherwise noted.

UTC(i) – UTC(NIST) (ns)		MJD			
UTC(i)	SV NUMBERS	47739	47749	47759	47769
UTC(APL) - UTC(NIST)	3, 12,13	1352	1409	1662	1662@
UTC(CRL) – UTC(NIST)	6, 12	809	891	855	720
UTC(CSIRO) – UTC(NIST)	**	21096*	21443	21784	22028
UTC(IEN) – UTC(NIST)	11,12,13,14	-103*	-292	-480	-696#
UTC(INPL) – UTC(NIST)	VIA OP	-127492	-128805	-130148	-131513#
UTC(NPL) – UTC(NIST)	3, 11,12,13,14	481*	518	587	677#
UTC(NRC) – UTC(NIST)***	3,6,9,11,12,13,14	13930*	14088	14250	14426#
UTC(OP) – UTC(NIST)	3, 11,12,13,14	707*	645	607	519#
UTC(PTB) – UTC(NIST)	11	-4552	-4449	-4399	-4364#
UTC(TAO) – UTC(NIST)	6, 14	3207*	3360	3544	3616
UTC(TUG) – UTC(NIST)	3, 11,12,13,14	-1442	-1664	-1872	-2096#
UTC(USNO,MC) – UTC(NIST)	3,6, 11,12,13,14	524	569	600	634#
UTC(VSL) – UTC(NIST)	3, 11,12,13,14	-1881*	-1913	-1944	-2013#

* These stations have updated values for MJD 47729 as follows: CSIRO = 20869, IEN = -57, NPL = 446, NRC = 13797, OP = 796, TAO = 3106, VSL = -1782.
** UTC(CSIRO) - UTC(NIST) is computed from the average by CRL, TAO, and WWVH.
*** UTC(NRC) - UTC(NIST) has a differential delay of 41.2 ns; all other comparisons are computed using zero (0).
@ The value for UTC(APL) - UTC(NIST) for MJD 47769 was extrapolated forward from MJD 47664.
# These values for MJD 47769 were extrapolated forward from 47768.

3. UT1 CORRECTIONS AND LEAP SECOND ADJUSTMENTS

The master clock pulses used by the WWV, WWVH, WWVB, and GOES time code transmissions are referenced to the UTC(NIST) time scale. Occasionally, 1 second is added to the UTC time scale. This second is called a leap second. Its purpose is to keep the UTC time scale within ± 0.9 s of the UT1 astronomical time scale, which changes slightly due to variations in the rotation of the earth.

Positive leap seconds, beginning at 23 h 59 min 60 s UTC and ending at 0 h 0 min 0 s UTC, were inserted in the UTC timescale on 30 June 1972, 31 December 1972-1979, 30 June 1981-1983, 30 June 1985, and 31 December 1987. When future leap seconds are scheduled, advance notice will be provided in this bulletin.

The use of leap seconds ensures that UT1 – UTC will always be held within ± 0.9 s. The current value of UT1 – UTC is called the DUT1 correction. DUT1 corrections are broadcast by WWV, WWVH, WWVB, and GOES and are printed below. These corrections may be added to received UTC time signals in order to obtain UT1.

DUT1 = UT1 - UTC
= -0.3 s beginning 0000 UTC 06 April 1989
= -0.4 s beginning 0000 UTC 08 June 1989
= -0.5 s beginning 0000 UTC 21 September 1989

4. PHASE DEVIATIONS FOR WWVB AND LORAN-C

WWVB – The values shown for WWVB are the time difference between the time markers of the UTC(NIST) time scale and the first positive-going zero voltage crossover measured at the transmitting antenna. The uncertainty of the individual measurements is ± 0.5 μs. The values listed are for 1500 UTC.

LORAN-C - The values shown for Loran-C represent the daily accumulated phase shift (in microseconds). The phase shift is measured by comparing the output of a Loran receiver to the UTC(NIST) time scale for a period of 24 hours. If data were not recorded on a particular day, the symbol (-) is printed.

The stations monitored are Dana, Indiana (8970 M) and Fallon, Nevada (9940 M). The monitoring is done from the NIST laboratories in Boulder, Colorado.

DATE	MJD	UTC(NIST) – WWVB(60 kHz) ANTENNA PHASE (in μs)	UTC(NIST) – LORAN PHASE (in μs): LORAN-C (DANA) (8970 M)	UTC(NIST) – LORAN PHASE (in μs): LORAN-C (FALLON) (9940 M)
08/01/89	47739	5.66	(-)	+0.01
08/02/89	47740	5.65	(-)	(-)
08/03/89	47741	5.63	+0.00	-0.15
08/04/89	47742	5.64	-0.13	-0.19
08/05/89	47743	5.66	-0.15	-0.21
08/06/89	47744	5.68	+0.39	+0.35
08/07/89	47745	5.70	-0.11	-0.00
08/08/89	47746	5.64	-0.05	-0.10
08/09/89	47747	5.64	+0.01	+0.05
08/10/89	47748	5.61	+0.08	+0.02
08/11/89	47749	5.61	+0.19	-0.36
08/12/89	47750	5.63	-0.69	-0.10
08/13/89	47751	5.66	+0.34	+0.32
08/14/89	47752	5.68	+0.00	-0.08
08/15/89	47753	5.63	-0.17	-0.16
08/16/89	47754	5.62	+0.08	+0.01
08/17/89	47755	5.65	+0.11	+0.11
08/18/89	47756	5.65	-0.21	-0.24
08/19/89	47757	5.63	-0.01	-0.04
08/20/89	47758	5.61	(-)	(-)
08/21/89	47759	5.60	(-)	(-)
08/22/89	47760	5.63	(-)	(-)
08/23/89	47761	5.61	(-)	(-)
08/24/89	47762	5.68	-0.19	(-)
08/25/89	47763	5.63	-0.09	-0.09
08/26/89	47764	5.59	(-)	(-)
08/27/89	47765	5.56	(-)	(-)
08/28/89	47766	5.53	(-)	(-)
08/29/89	47767	5.70	-0.83	-0.02
08/30/89	47768	5.68	+0.15	-0.83
08/31/89	47769	5.65	+0.04	-0.14

5. GOES TIME CODE INFORMATION

A. TIME CODE PERFORMANCE (1 - 31 August 1989)

GOES/East: Performance within normal limits during this period.

GOES/West: Performance within normal limits during this period.

B. ECLIPSE OPERATIONS: Current Fall 1989 eclipse operations are not expected to adversely impact any GOES time code performance aspects.

C. SPECIAL REMINDER: Current satellite locations are 65° W. for GOES/East and 135° W. for GOES/West. NOAA is still considering the possibility of moving GOES/East from 65° back to the original 75° location, but no decision has been made as of this time.

D. GOES STATUS REPORTS

A brief message from the NIST giving current GOES time code status information is available from the U.S. Naval Observatory's Automated Data Service computer system in Washington, DC. The message may be accessed 24 hours per day without charge by using a variety of terminals operating at 300, 1200, or 2400 Baud and even parity. Two different sets of telephone access numbers are available: (1) for 300 or 1200 Baud and the Bell 103 standard use (202) 653-1079 (commercial), 653-1079 (FTS), or 294-1079 (Autovon); (2) for 1200 or 2400 Baud with either the CCITT V.22 standard or the Bell standard use (202) 653-1783 (commercial), 653-1783 (FTS), or 294-1783 (Autovon). To receive the GOES status message, use the following procedure:

1. Access the USNO computer database by dialing one of the appropriate telephone numbers above;
2. In response to the prompt for identification, type your name and the name of your organization, followed by a carriage return;
3. Type "@NBSGO" followed by a carriage return to receive the status message at your terminal;
4. Disconnect by typing Control-D.

6. BROADCAST OUTAGES OVER 5 MINUTES AND WWVB PHASE PERTURBATIONS

OUTAGES

STATION	AUGUST 1989	MJD	BEGAN (UTC)	ENDED (UTC)	FREQUENCY
WWVB	NONE				
WWV	NONE				
WWVH	NONE				

PHASE PERTURBATIONS WWVB 60 kHz

AUGUST 1989	MJD	BEGAN (UTC)	ENDED (UTC)
NONE			
NONE			
NONE			

7. NOTES ON NIST TIME SCALES AND PRIMARY STANDARDS

The frequencies of the time scales, TA(NIST) and UTC(NIST), are calibrated with the NIST primary frequency standards. The UTC(NIST) scale is coordinated within a microsecond of the internationally coordinated time scale, UTC, generated at the BIH. It is used to control all of the NIST time and frequency services. The last calibration of the relative frequency offset, y, of UTC(NIST) as generated in Boulder, Colorado, gave:

1) $y_{UTC(NIST)}$ (July 1987) − y_{NBS-6} (July 1987) = $(-0.6 \pm 2$ (1 sigma)) $\times 10^{-13}$

for the date shown. This calibration includes a correction for the systematic offset due to room temperature blackbody radiation, which is approximately (delta y_{BB}) = -1.7×10^{-14}. Using GPS[1], the frequency of TAI for the dates shown were measured to be:

2) y_{TAI} (July 1987) − y_{NBS-6} (July 1987 on geoid) = $(+1.7 \pm 2$ (1 sigma)) $\times 10^{-13}$

where account has been taken of the gravitational "red shift."

Starting 1 January 1975, an accuracy algorithm was implemented to bring the second used in the generation of TA(NIST) closer to the NIST "best estimate" of the SI second (see references, p.6). The relative frequency associated with this "best estimate" is denoted $y_{Cs(NIST)}$. The last calibration (July 1987) covered the period from October 1986 through July 1987.

3) $y_{Cs(NIST)} - y_{NBS-6} = (+1.4 \pm 2) \times 10^{-13}$ (July 1987)

and

4) $y_{TAI} - y_{Cs(NIST)}$ on geoid $= (+0.3 \pm 0.7) \times 10^{-13}$ (July 1987)

This algorithm should provide nearly optimum accuracy and stability for TA(NIST) since it uses all past frequency calibrations with the NIST primary standards. These calibrations are weighted proportionately to the frequency memory of the clock ensemble that generates atomic time. This algorithm, therefore, capitalizes on a weighted combination of all the frequency calibrations with the primary standards in order to gain a "best estimate" of the SI Second while simultaneously obtaining the best uniformity available from the ensemble of working clocks in the atomic time scale system. The relative frequency of TA(NIST) is steered toward $y_{Cs(NIST)}$ by slight frequency drift corrections of the order of 1 part in 10^{13}/yr.

TA(NIST) and UTC(NIST) are no longer simply related by an equation. TA(NIST) is now computed each month using a Kalman algorithm which minimizes the mean square time dispersion. UTC(NIST) is now independently computed using a different algorithm and is steered in frequency to keep its time within a microsecond of UTC(BIH). Table 7.1 lists monthly values of the time difference between UTC(NIST) and TA(NIST). A linear interpolation between monthly values will typically be within 10 ns of the actual time difference, TA(NIST) − UTC(NIST).

The primary standards of NIST (NBS-4 and NBS-6) are used in either of two modes: as calibrators of frequency to provide a reference for the SI second; or as member clocks of the NIST clock ensemble, to help keep the proper time for TA(NIST) and the coordinated time for UTC(NIST). Operating in the clock mode, NBS-4 and NBS-6 are only used and weighted according to their stability performance. Accuracy enters only when they are used as frequency calibrators, in which case clock operation is necessarily interrupted.

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[1]GPS is the Global Positioning System, a network of navigation satellites.

Table 7.1 is a list of changes in the time scale frequencies of both TA(NIST) and UTC(NIST) as well as a list of the time and frequency differences between TA(NIST) and UTC(NIST) at the dates of leap seconds, and/or frequency or frequency drift changes.

TABLE 7.1

		FREQUENCY CHANGES			
DATE	(MJD)	TA(NIST)	UTC(NIST)	TA(NIST) - UTC(NIST)	y[UTC(NIST)] - y[TA(NIST)]
1 Mar 88	47221	0	-1.25 ns/d	24.045 107 137 s	-3.58 E-13
1 Apr 88	47252	0	-1.50 ns/d	24.045 108 130 s	-3.85 E-13
1 May 88	47282	0	-1.50 ns/d	24.045 109 170 s	-4.29 E-13
1 Jun 88	47313	0	-1.50 ns/d	24.045 110 358 s	-4.47 E-13
1 Jul 88	47343	0	-1.60 ns/d	24.045 111 523 s	-4.64 E-13
1 Aug 88	47374	0	-0.40 ns/d	24.045 112 802 s	-4.89 E-13
1 Sep 88	47405	0	-1.00 ns/d	24.045 114 144 s	-5.15 E-13
1 Oct 88	47435	0	1.00 ns/d	24.045 114 515 s	-5.15 E-13
1 Nov 88	47466	0	1.25 ns/d	24.045 116 854 s	-4.88 E-13
1 Dec 88	47496	0	1.50 ns/d	24.045 118 088 s	-4.69 E-13
1 Jan 89	47527	0	1.50 ns/d	24.045 119 325 s	-4.57 E-13
1 Feb 89	47558	0	1.00 ns/d	24.045 120 538 s	-4.51 E-13
1 Mar 89	47586	0	-1.25 ns/d	24.045 121 622 s	-4.58 E-13
1 Apr 89	47617	0	-1.50 ns/d	24.045 122 871 s	-4.66 E-13
1 May 89	47647	0	-1.50 ns/d	24.045 124 078 s	-4.75 E-13
1 Jun 89	47678	0	-1.00 ns/d	24.045 125 375 s	-4.92 E-13
1 Jul 89	47708	0	-1.00 ns/d	24.045 126 670 s	-5.09 E-13
1 Aug 89	47739	0	-1.00 ns/d	24.045 128 060 s	-5.35 E-13

UTC(NIST) is steered in time toward UTC by occasional frequency changes of the order of a few nanoseconds per day; 1 ns/d is approximately 1.16E-14. Otherwise, y[UTC(NIST)] is maintained as stable as possible.

REFERENCES

Allan, David W., et al., "An accuracy algorithm for an atomic time scale," Metrologia, Vol.11, No.3, pp.133-138 (September 1975).

Glaze, D.J., et al., "NBS-4 and NBS-6: The NIST primary frequency standards," Metrologia, Vol.13, pp.17-28 (1977).

Wineland, D.J., et al., "Results on limitations in primary cesium standard operation," IEEE Trans. on Instr. and Meas., Vol.IM-25, No.4, pp.453-458 (December 1976).

Allan, David W. and Weiss, Marc, "Accurate Time and Frequency Transfer During Common View of a GPS Satellite," Proc. 34th Annual Symposium on Frequency Control, p.334 (1980).

Allan, David W. and Barnes, James A., "Optimal Time & Frequency using GPS signals," Proc. 36th Annual Symposium on Frequency Control, p.378 (1982).

8. SPECIAL ANNOUNCEMENTS

AUTOMATED COMPUTER TIME SERVICE (ACTS)

On March 9, 1988, NIST initiated operation of a telephone time service designed to provide computers with telephone access to NIST time at accuracies approaching 1 ms. Features of the service include automated compensation for telephone-line delay, advanced alert for changes to and from daylight savings time and advanced notice of insertion of leap seconds. The ASCII-character time code should operate with standard modems and most computer systems. While the system can be used to set computer time-of-day clocks, simple hardware can also be developed to set other clock systems.

During the first six months, the service will be operated in a test phase to identify problems and obtain feedback from users on both the format and operation of the service. After completion of the test phase, there may be some revisions in the service. The service telephone number is (303) 494-4774. The number may be changed at a later date. A help message can be obtained by returning a ? during the first 6 s of transmission.

With appropriate user software, the NIST-ACTS service provides three modes for checking and/or setting computer time-of-day clocks.

1. In the simplest form of the (1200 Baud) service, the user receives the time code and an on-time marker/character which has been advanced a fixed period to nominally account for modem and telephone-line delays. Accuracy in this mode should be no worse than 0.1 s unless the connection is routed through a satellite.

2. At 1200 Baud, if the user's system echoes all characters to NIST, the round-trip line delay will be measured and the on-time marker advanced to compensate for that delay. The accuracy in this mode should be better than 10 ms. Our experience to date indicates that the asymmetry in conventional, 1200-Baud modems limits the accuracy at this level. Repeatability is about 1 ms.

3. At 300 Baud the user can obtain the same type of service as described in item 2 above, but there is generally less problem with modem asymmetry at this rate and our experience indicates that the accuracy is about 1 ms.

The accuracy statements here are based upon the assumption that the telephone connection is reciprocal, that is, that both directions of communication follow the same path with the same delay. Discussions with telephone carriers indicate that this is the general mode of operation and our tests to date indicate that the lines are both stable and reciprocal.

In order to assist users of the service, NIST has developed documentation of the features of the service, some example software which can be used in conjunction with certain popular personal computers and simple circuitry which can be used to extract an on-time pulse. This material is available on a 5¼-in, 360-kbyte DOS diskette with instructions for $35.00 from the NIST Office of Standard Reference Materials, B311-Chemistry Bldg, NIST, Gaithersburg, MD, 20899, (301) 975-6776. Specify the Automated Computer Time Service, RM8101. Further technical questions and comments should be directed to NIST-ACTS, NIST Time and Frequency Division, 325 Broadway, Boulder, CO 80303.

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