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NIST TIME & FREQUENCY BULLETIN
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NO. 401 APRIL 1991

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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
BIPM - Bureau International des Poids Mesures
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
PRN - Pseudo random numbers
SI - International System of Units
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

MARCH 1991	MJD	UT1 – UTC(NIST) (± 5 ms)	UTC – UTC(NIST) (± 0.2 μs)	UTC(USNO,MC) – UTC(NIST)* (± 0.04 μs)
7	48322	+472 ms	-0.8 μs	-0.93 μs
14	48329	+458 ms	-0.9 μs	-0.95 μs
21	48336	+441 ms	-0.9 μs	-0.97 μs
28	48343	+424 ms	-0.9 μs	-1.01 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)	PRN NUMBERS	48309	48319	48329	48339
APL	2,3, 12,13, 15,16,17,18,20,21	-1	-33	-47	-8
CRL	3,6, 11,12,	-2563	-2610	-2665	-2706
CSIRO	++	7706	6239	4836	3422
IEN	11	-672	-715	-752	-798
NPL	11,12,13	914	930	834	702
NRC+++	2,3, 11,12,13,14, 16, 18, 20,21	-1781	-1911	-1966	-2100
OP	2,3, 11,12,13,14,15,16, 20	-209	-205	-218	-243
PTB	2,3, 11,12,13,14,15,16, 20	-4370	-4389	-4399	-4415
TAO	3,6, 11,12, 14, 17,18,20	-1683	-1729	-1769	-1803
TUG	2, 11,12,13,14,15,16, 20	1039+	410	-249	-917
USNO	2,3, 11,12,13, 16,17,18,20,21	-886	-917	-947	-991
VSL	2,3, 11,12,13,14,15,16, 20	-1094	-1227	-1285	-1317

\+ This value has been updated from those printed in last month's Bulletin.
++ UTC(CSIRO) - UTC(NIST) is computed from the average via CRL, TAO, & WWVH.
+++ UTC(NRC) - UTC(NIST) has a differential delay of 41.2 ns; all other comparisons are computed using zero (0).

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, 31 December 1987, 1989, and 1990. 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
= +0.5 s beginning 0000 UTC on 7 February 1991
= +0.4 s beginning 0000 UTC on 21 March 1991
= +0.3 s beginning 0000 UTC on 26 April 1991

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 1300 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 (μs)	UTC(NIST) – LORAN PHASE (in μs): LORAN-C (DANA) (8970 M)	UTC(NIST) – LORAN PHASE (in μs): LORAN-C (FALLON) (9940 M)
03/01/91	48316	5.68	-0.05	+0.12
03/02/91	48317	5.68	-0.60	-0.12
03/03/91	48318	5.68	-0.62	+0.13
03/04/91	48319	5.68	+0.38	+0.37
03/05/91	48320	5.67	+0.01	-0.16
03/06/91	48321	5.70	+0.38	+0.14
03/07/91	48322	5.70	+0.21	+0.02
03/08/91	48323	5.71	+0.56	+0.26
03/09/91	48324	5.71	-0.16	-0.21
03/10/91	48325	5.72	-0.23	+0.01
03/11/91	48326	5.73	+0.23	+0.04
03/12/91	48327	5.75	-0.12	-0.30
03/13/91	48328	5.75	+0.22	+0.10
03/14/91	48329	5.71	+0.26	+0.21
03/15/91	48330	5.71	+0.13	-0.25
03/16/91	48331	5.71	+0.05	-0.00
03/17/91	48332	5.70	+0.18	+0.04
03/18/91	48333	5.70	-0.62	-0.15
03/19/91	48334	5.72	-0.10	-0.08
03/20/91	48335	5.70	-0.13	-0.21
03/21/91	48336	5.68	+0.23	-0.10
03/22/91	48337	5.71	-0.16	-0.36
03/23/91	48338	5.71	-0.00	+0.11
03/24/91	48339	5.70	-0.11	-0.09
03/25/91	48340	5.70	(-)	+0.15
03/26/91	48341	5.72	-0.18	+0.32
03/27/91	48342	5.70	+0.11	-0.13
03/28/91	48343	5.70	-0.41	(-)
03/29/91	48344	5.73	+0.05	(-)
03/30/91	48345	5.72	(-)	(-)
03/31/91	48346	5.71	(-)	(-)

5. GOES TIME CODE INFORMATION

A. TIME CODE PERFORMANCE (1 - 31 March 1991)

GOES/East and GOES/West: Performance within normal limits during this period except for occasional brief periods of a few minutes each when antenna-tracking problems at Wallops Island caused a temporary outage of the GOES/East signal.

B. SPECIAL REMINDER: Current satellite locations are about 60° West longitude for GOES/East and 135° West longitude for GOES/West.

C. SPRING ECLIPSE OPERATIONS: Spring 1991 eclipse operations affecting GOES/East ended on March 26, 1991.

D. FUTURE SATELLITE LAUNCHES: NOAA's present launch schedule for replacement of the current East and West satellites has been moved back to October 1992 and March 1993, respectively.

E. FUTURE PLANS: The GOES-6 satellite (GOES/West) is expected to run out of maneuvering fuel sometime during the next year and possibly as early as May 1991. At that time it will begin drifting eastward and will, within a few weeks or months thereafter, become useless for some GOES Data Collection System operations. At that time it is likely that the GOES/West time code will be transferred to GOES-7 positioned in the range of 98-108° West longitude. If and when this occurs, coverage areas will change and user antennas may have to be repointed. NOAA also states that it is possible that the GOES/East time code may have to be transferred to GOES-7 at some point due to increasing problems in maintaining proper antenna tracking at Wallops Island.

F. 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. To access the new system, dial (202) 653-0068 (commercial) or 653-0068 (FTS). Use 1200 or 2400 Baud only, 8 data bits, and no parity. At the password prompt, type "CESIUM133". At the next prompt, type your name. At the main menu, type "GOES" to get to the GOES submenu. Then type "NISTGO" to receive the status file on GOES. Type "EXIT" or "BYE" to exit the system.

6. BROADCAST OUTAGES OVER 5 MINUTES AND WWVB PHASE PERTURBATIONS

OUTAGES

STATION	MARCH 1991	MJD	BEGAN (UTC)	ENDED (UTC)	FREQUENCY
WWVB	NONE				
WWV	NONE				
WWVH	NONE				

PHASE PERTURBATIONS WWVB 60 kHz

MARCH 1991	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 ± 2 (1 sigma)) x 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 x 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 ± 2 (1 sigma)) x 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 ± 2) x 10^{-13} (July 1987)

and

4) $y_{TAI} - y_{Cs(NIST)}$ on geoid = (+0.3 ± 0.7) x 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 Oct 89	47800	0	1.00 ns/d	24.045 131 001 s	-5.68 E-13
1 Nov 89	47831	0	1.00 ns/d	24.045 132 534 s	-5.85 E-13
1 Dec 89	47861	0	1.00 ns/d	24.045 134 082 s	-6.05 E-13
1 Jan 90	47892	0	1.00 ns/d	25.045 135 724 s	-6.16 E-13
1 Feb 90	47923	0	1.00 ns/d	25.045 137 382 s	-6.21 E-13
1 Mar 90	47951	0	1.00 ns/d	25.045 138 888 s	-6.23 E-13
1 Apr 90	47982	0	1.00 ns/d	25.045 140 560 s	-6.36 E-13
1 May 90	48012	0	1.00 ns/d	25.045 142 241 s	-6.42 E-13
1 June 90	48043	0	1.00 ns/d	25.045 143 942 s	-6.34 E-13
1 July 90	48073	0	0.50 ns/d	25.045 145 580 s	-6.46 E-13
1 Aug 90	48104	0	0.00 ns/d	25.045 147 350 s	-6.62 E-13
1 Sep 90	48135	0	-1.00 ns/d	25.045 149 130 s	-6.69 E-13
1 Oct 90	48165	0	-1.00 ns/d	25.045 150 875 s	-6.82 E-13
1 Nov 90	48196	0	-1.50 ns/d	25.045 152 729 s	-6.94 E-13
1 Dec 90	48226	0	-1.50 ns/d	25.045 154 534 s	-7.04 E-13
1 Jan 91	48257	0	-1.00 ns/d	26.045 156 437 s	-7.05 E-13
1 Feb 91	48288	0	-0.50 ns/d	26.045 158 312 s	-6.92 E-13
1 Mar 91	48316	0	-0.00 ns/d	26.045 159 963 s	-6.83 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.

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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.

The test phase for this service is now complete and NIST is committed to long-term operation of the service. Additional lines will be added as use expands. NIST requests that calling times be spread out so that the system is not heavily taxed in some narrow time frame (e.g., midnight). 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 $5\frac{1}{4}$-in, 360-kbyte DOS diskette with instructions for $37.00 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.

FREQUENCY CONTROL SYMPOSIUM ANNOUNCEMENT

The 45th Annual Frequency Control Symposium will be held May 29-31, 1991 in Los Angeles Airport Marriott, CA. This symposium is the leading technical conference addressing all aspects of frequency control and precision timekeeping. Authors are invited to submit papers dealing with recent progress in research, development and applications in areas represented by the following topics:

- Fundamental properties of piezoelectric crystals
- Theory and design of piezoelectric resonators
- Resonator processing techniques
- Surface acoustic wave devices (SAW)
- Quartz crystal oscillators
- Microwave and millimeter wave oscillators
- Signal processing and frequency control circuitry
- Atomic and molecular frequency standards
- Frequency and time coordination and distribution
- Sensors and transducers
- Applications of frequency control
- Measurement and specifications

Sponsors: IEEE-UFFC and the US Army Electronics Technology and Devices Laboratory (LABCOM).
Place: Los Angeles Airport Marriott, CA
Contact: Clark Wardrip, Bendix Field Engineering Corp., P. O. Box 6147, Vandenberg AFB, CA 93437; (805) 865-3214.

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11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The Time & Frequency Bulletin provides information on performance of time scales and a variety of broadcasts (and related information) to users of the NIST services.

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