Time & Frequency Bulletin

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NIST TIME & FREQUENCY BULLETIN
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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

MARCH 1990	MJD	UT1 - UTC(NIST) (± 5 ms)	UTC - UTC(NIST) (± 0.2 μs)	UTC(USNO,MC) - UTC(NIST) (± 0.04 μs)
1	47951	+208 ms	0.3 μs	1.70 μs
8	47958	+195 ms	0.3 μs	1.70 μs
15	47965	+178 ms	0.3 μs	1.70 μs
22	47972	+164 ms	0.3 μs	1.70 μs
29	47979	+143 ms	0.3 μs	1.66 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	47949	47959	47969	47979
UTC(APL) - UTC(NIST)	3,6,9,11,12,13,14	-193+	-272	-382	-515
UTC(CRL) - UTC(NIST)	3,6,9 12	865+	850	845	840#
UTC(CSIRO) - UTC(NIST)	++	24657	24740	24806	24890##
UTC(IEN) - UTC(NIST)@	11,12,13,14	1345	1360	1370	1366#
UTC(INPL) - UTC(NIST)!	VIA OP	-156991+	-158709	-160614	-162627@@
UTC(NPL) - UTC(NIST)	3, 11,12,13	2640+	2685	2693	2728
UTC(NRC) - UTC(NIST)+++	3,6,9,11,12,13	973	958	905	804
UTC(OP) - UTC(NIST)	3, 11,12,13,14	827	914	1011	1097#
UTC(PTB) - UTC(NIST)	11	-3400+	-3366	-3327	-3280
UTC(TAO) - UTC(NIST)!!	3,6,9, 12, 14	5424	5316	5167	5006
UTC(TUG) - UTC(NIST)	3, 11,12,13,14	3515+	3314	3103	2818#
UTC(USNO,MC) - UTC(NIST)	3,6,9,11,12,13,14	1701+	1703	1700	1662
UTC(VSL) - UTC(NIST)	3, 11,12,13,14	-2119+	-2132	-2168	-2215#

\+ These values have been updated from those printed in last month's Bulletin.
++ UTC(CSIRO) - UTC(NIST) is computed from the average of CRL, TAO, & WWVH.
+++ UTC(NRC) - UTC(NIST) has a differential delay of 41.2 ns; all other comparisons are computed using zero (0).
@ IEN experiened a frequency shift of approximately -18.0 E-14 on MJD 47950.
! The value for UTC(INPL) - UTC(NIST) for MJD 47939 was incorrectly computed last month. The correct value is -155328.
!! TAO experienced a frequency shift of approximately -26.5 E-14 on MJD 47950.
\# The values for these stations for MJD 47979 were extrapolated forward from MJD 47977.
\## The value for this station for MJD 47979 was extrapolated forward from MJD 47975.
@@ The value for this station for MJD 47979 was extrapolated forward from MJD 47976.

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 and 1989. 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 on 1 January 1990 (simultaneous with insertion of the leap second.
= +0.2 s beginning 0000 UTC on 1 March 1990
= +0.1 s beginning 0000 UTC on 12 April 1990

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 (μs)	UTC(NIST) - LORAN PHASE (in μs) LORAN-C (DANA) (8970 M)	LORAN-C (FALLON) (9940 M)
03/01/90	47951	5.68	-0.19	-0.06
03/02/90	47952	5.66	-0.43	-0.14
03/03/90	47953	5.63	-0.13	-0.05
03/04/90	47954	5.61	+0.01	-0.06
03/05/90	47955	5.59	+0.35	(-)
03/06/90	47956	5.66	+0.35	-0.73
03/07/90	47957	5.64	(-)	(-)
03/08/90	47958	5.64	(-)	(-)
03/09/90	47959	5.59	-0.25	+0.08
03/10/90	47960	5.61	-0.26	+0.02
03/11/90	47961	5.63	+0.10	+0.20
03/12/90	47962	5.66	-0.06	+0.13
03/13/90	47963	5.63	-0.21	+0.03
03/14/90	47964	5.70	-0.08	-0.13
03/15/90	47965	5.69	-0.02	+0.05
03/16/90	47966	5.71	+0.02	-0.05
03/17/90	47967	5.68	+0.14	+0.05
03/18/90	47968	5.66	+0.27	+0.10
03/19/90	47969	5.64	+0.03	-0.10
03/20/90	47970	5.71	+0.25	+0.00
03/21/90	47971	5.62	-0.04	-0.12
03/22/90	47972	5.73	-0.05	+0.09
03/23/90	47973	5.68	-0.37	-0.41
03/24/90	47974	5.68	+0.12	+0.16
03/25/90	47975	5.67	+0.11	-0.02
03/26/90	47976	5.67	-0.02	+0.03
03/27/90	47977	5.65	-0.05	-0.13
03/28/90	47978	5.62	-0.23	+0.01
03/29/90	47979	5.68	+0.01	+0.00
03/30/90	47980	5.71	-0.22	-0.15
03/31/90	47981	5.69	-0.13	-0.06

5. GOES TIME CODE INFORMATION

A. TIME CODE PERFORMANCE (1 - 31 March 1990)

GOES/East: Performance within normal limits most of the time during this period. The peak-to-peak diurnal variations of the time code (corrected for satellite position) were larger-than-normal, however, and occasional deviations of slightly greater than 100 microseconds were observed. The GOES-5 satellite is still drifting westward and was at about 71 degrees West longitude on March 31.

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

B. SPECIAL REMINDER: Current satellite locations are 71° West longitude for GOES/East and 135° West longitude for GOES/West.

C. ------------------------------------ SPECIAL NOTE ------------------------------------

In response to concerns from time code users about GOES/East coverage in Europe and Africa if GOES/East operations are shifted to GOES-7, NOAA has reconsidered its previous decision. Currently, the plan is to transfer GOES/East operations from GOES-5 to GOES-2 (an older standby satellite) when GOES-2 drifts into its new location at about 60° West longitude. This transfer of operations is expected to occur about May 1, 1990 and will remain in effect indefinitely. Exact dates will be announced in the GOES status file (NBSGO) maintained in the U.S. Naval Observatory's Automated Data Service (see below for access information) as soon as it is known.

D. FUTURE SATELLITE LAUNCHES: NOAA's present launch schedule for replacement of the current East and West satellites is July 1991 and February 1992, respectively.

E. 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	MARCH 1990	MJD	BEGAN (UTC)	ENDED (UTC)	FREQUENCY
WWVB	NONE				
WWV	NONE				
WWVH	06	47956	0211:00	0300:00	2.5 MHz

PHASE PERTURBATIONS WWVB 60 kHz

MARCH 1990	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.

[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 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
1 Sep 89	47770	0	-1.00 ns/d	24.045 129 538 s	-5.58 E-13
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	24.045 135 724 s	-6.16 E-13
1 Feb 90	47923	0	1.00 ns/d	24.045 137 382 s	-6.21 E-13
1 Mar 90	47951	0	1.00 ns/d	24.045 138 888 s	-6.23 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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Allan, D.W. and Weiss, M.A., "Accurate Time and Frequency Transfer During Common View of a GPS Satellite," Proc. 34th Annual Symposium on Frequency Control, p.334 (1980).

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

8. SPECIAL ANNOUNCEMENTS

44TH ANNUAL FREQUENCY CONTROL SYMPOSIUM

The 44th Annual Frequency Control Symposium will be held May 23 - 25, 1990 in Baltimore, MD. 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
- Filters
- 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

Contact: Dr. R. L. Filler, US Army Electronics Technology and Devices Laboratory, ATTN: SLCET-EQ, Fort Monmouth, NJ 07703-5000; (201) 544-2467.

NOBEL PRIZE WINNERS to SPEAK at the 44th ANNUAL SYMPOSIUM on FREQUENCY CONTROL

The 1989 Nobel Prize in Physics was awarded to Norman Ramsey, Hans Dehmelt, and Wolfgang Paul for advancements in atomic clock technology. Professor Ramsey of Harvard University and Professor Dehmelt of the University of Washington (and possibly Professor Paul from the University of Bonn) have accepted invitations to present their Nobel lectures at the 44th Annual Symposium on Frequency Control. There will be a special reduced registration fee for the Nobel lectures. The lectures will be presented Friday morning, May 25.

Professor Ramsey's talk is titled "Experiments with Separated Oscillatory Fields and Atomic Hydrogen Masers." Professor Dehmelt's talk is titled "Experiments with an Isolated Subatomic Particle at Rest."

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

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.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

clocks; dissemination; frequency; GPS; oscillators; time

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