

Time & Frequency Bulletin

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**National
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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	ns - nanosecond
SV	-	Space vehicle	μs - microsecond
TA	-	Atomic Time	ms - millisecond
TAI	-	International Atomic Time	s - second
TAO	-	Tokyo Astronomical Observatory, Japan	min - minute
TUG	-	Technical University of Graz, Austria	h - hour
USNO	-	United States Naval Observatory	d - day
UTC	-	Coordinated Universal Time	
VLF	-	very low frequency	
VSL	-	Van Swinden Laboratory, Netherlands	

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

APRIL		UT1 - UTC(NIST) (± 5 ms)	UTC - UTC(NIST) (± 0.2 μs)	UTC(USNO,MC) - UTC(NIST) (± 0.04 μs)
1989	MJD			
6	47622	-256 ms	-0.3 μs	0.59 μs
13	47629	-264 ms	-0.3 μs	0.56 μs
20	47636	-275 ms	-0.3 μs	0.51 μs
27	47643	-282 ms	-0.3 μs	0.47 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	47609	47619	47629	47639
UTC(CRL) - UTC(NIST)	3,6,9, 12	1007	1002	994	967
UTC(CSIRO) - UTC(NIST)	**	18951	18896	18920	19029
UTC(IEN) - UTC(NIST)	9,11,12	555	504	450	346
UTC(INPL) - UTC(NIST)#	VIA OP	-1077389	-1091573	-1095762	-1120109
UTC(NPL) - UTC(NIST)	9,11,12	-493	-386	-260	-112
UTC(NRC) - UTC(NIST)***	3,6,9,11,12,13	13134	13140	13154	13229
UTC(OP) - UTC(NIST)	9,11,12	1422*	1382	1296	1200
UTC(PTB) - UTC(NIST)	9,11,12	-4669*	-4672	-4694	-4735
UTC(TAO) - UTC(NIST)	3,6,9, 12	2450	2490	2506	2528
UTC(TUG) - UTC(NIST)	9,11,12	1903*	1655	1409	1102
UTC(USNO,MC) - UTC(NIST)	3,6,9,11,12,13	655	604	558	497
UTC(VSL) - UTC(NIST)	9,11,12	-1352	-1367	-1361	-1421

* This value has been updated from that printed in last month's Bulletin.

** 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 MJD's were listed incorrectly for March 1989. They should have been 47579, 47589, 47599, and 47609, respectively.

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	= 0.0 s beginning 0000 UTC 25 August 1988
	= -0.1 s beginning 0000 UTC 10 November 1988
	= -0.2 s beginning 0000 UTC 19 January 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 $\pm 0.5 \mu\text{s}$. 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)	LORAN-C (FALLON) (9940 M)
04/01/89	47617	5.72	+0.22	-0.27
04/02/89	47618	5.72	+0.20	+0.14
04/03/89	47619	5.73	+0.04	-0.31
04/04/89	47620	5.77	-0.10	-0.04
04/05/89	47621	5.75	-0.13	+0.14
04/06/89	47622	5.75	-0.15	-0.26
04/07/89	47623	5.75	+0.02	+0.01
04/08/89	47624	5.76	-0.09	-0.11
04/09/89	47625	5.77	+0.21	+0.14
04/10/89	47626	5.78	+0.14	+0.04
04/11/89	47627	5.75	-0.14	-0.08
04/12/89	47628	5.76	-0.07	+0.17
04/13/89	47629	5.74	-0.19	+0.19
04/14/89	47630	5.76	-0.30	-0.30
04/15/89	47631	5.75	-0.03	-0.02
04/16/89	47632	5.73	+0.09	+0.17
04/17/89	47633	5.72	-0.05	+0.04
04/18/89	47634	5.74	-0.12	-0.07
04/19/89	47635	5.70	-0.15	-0.04
04/20/89	47636	5.71	+0.15	+0.09
04/21/89	47637	5.73	-0.09	-0.06
04/22/89	47638	5.73	(-)	+0.00
04/23/89	47639	5.73	+0.24	+0.32
04/24/89	47640	5.73	+0.02	-0.02
04/25/89	47641	5.74	-0.01	-0.05
04/26/89	47642	5.75	-0.19	(-)
04/27/89	47643	5.77	-0.15	(-)
04/28/89	47644	5.73	-0.01	(-)
04/29/89	47645	5.73	+0.16	(-)
04/30/89	47646	5.74	+0.01	(-)

5. GOES TIME CODE INFORMATION

A. TIME CODE PERFORMANCE (1-30 April 1989)

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

GOES/West: Performance within normal limits during most of this period. However, some reports have been received that GOES/West receivers experienced some difficulties at times in locking properly to the satellite signal, particularly, during the period around April 13-20. Possible problems included a spurious GOES/West signal from another satellite and/or corrupted time code data bits occurring at random times. NIST and Wallops Island NOAA personnel are currently checking all appropriate systems for problems.

B. SPECIAL REMINDER: Current satellite locations are 65° W. for GOES/East and 135° W. for GOES/West.

C. GOES STATUS REPORTS

A brief message from 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						PHASE PERTURBATIONS WWVB 60 kHz				
STATION	APRIL 1989	MJD	BEGAN (UTC)	ENDED (UTC)	FREQUENCY	APRIL 1989	MJD	BEGAN (UTC)	ENDED (UTC)	
WWVB	NONE					NONE				
WWV	NONE					NONE				
WWVH	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:

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

for the date shown. This calibration includes a correction for the systematic offset due to room temperature blackbody radiation, which is approximately $(\Delta y_{\text{BB}}) = -1.7 \times 10^{-14}$. Using GPS¹, the frequency of TAI for the dates shown were measured to be:

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

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 $y_{\text{Cs(NIST)}}$. The last calibration (July 1987) covered the period from October 1986 through July 1987.

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

and

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

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 $y_{\text{Cs(NIST)}}$ by slight frequency drift corrections of the order of 1 part in $10^{13}/\text{yr}$.

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, $\text{TA(NIST)} - \text{UTC(NIST)}$.

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.

¹GPS 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 Nov 87	47100	0	0.50 ns/d	23.045 103 512 s	-3.38 E-13
1 Dec 87	47130	0	0.50 ns/d	23.045 104 367 s	-3.40 E-13
1 Jan 88	47161	0	-1.00 ns/d	24.045 105 306 s	-3.56 E-13
1 Feb 88	47192	0	-1.00 ns/d	24.045 106 272 s	-3.53 E-13
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

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 $1.16\text{E-}14$. Otherwise, y[UTC(NIST)] is maintained as stable as possible.

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- 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).
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8. SPECIAL ANNOUNCEMENTS

43rd Annual Symposium on Frequency Control

The 43rd Annual Symposium on Frequency Control will be held on May 31 - June 2, 1989. The site for this years symposium will be the Marriott Hotel City Center in Denver, Colorado.

The number of summaries submitted to the technical program committee reached an all time high. The quality of these submissions proves to make the 43rd the best symposium ever. Ninety papers will be presented in 21 sessions. Highlights will be a specially organized session on environmental effects and their measurement, a session on surface preparation of quartz, including a tutorial on abrasive processes, and a session on two-way time transfer.

The symposium will begin with a plenary session at which three prestigious awards will be presented. The Cady award is presented annually by the technical program committee to frequency control devices. This year the award recipient will be Dr. D.E. Newell. The Rabi award is presented to recognize outstanding contributions related to fields such as atomic and molecular frequency standards, time transfer, and frequency and time metrology. This year's recipient is Dr. L. Cutler. The third award, sponsored by Sawyer Applied Research Products, is presented in honor of C.B. Sawyer for the most outstanding recent contribution to advancement in the field of quartz crystals and devices. The recipient of the C.B. Sawyer award is selected by an independent committee and will be announced at the symposium.

Special invited presentations will include "Spacecraft Gravitational Wave Experiments" by J.W. Armstrong, JPL; "Shear Mode Grinding" by N.J. Brown and B.A. Fuchs, LLNL; "A High Stability Microwave Oscillator Based on a Sapphire Loaded Superconducting Cavity" by D.G. Blair, A.J. Giles, and S.K. Jones, U. of Western Australia; "Stacked Crystal Filters Implemented with Thin Films" by K.M. Lakin, G.R. Kline, J.T. Martin, and K.T. McCarron, Iowa State U.; and "Low-Cost High-Performance Resonator and Coupled-Resonator Designs: NSPUDT and Other Innovative Structures" by P.V. Wright, RF Monolithics.

The social program will be extra special due to the proximity of the National Institute of Standards and Technology (formerly the National Bureau of Standards). There will be a tour of NIST, including a visit to the nation's time standard, tentatively scheduled for Wednesday evening, May 31. Dinner on Thursday, June 1, will be at a famous Denver attraction The Fort. The Fort is a restaurant specializing in authentic foods of the American West including buffalo, Rocky Mt. oysters and Rocky Mt. trout. This will be an experience to be enjoyed by all.

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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) <p style="text-align: center;">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.</p>			
12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons) <p style="text-align: center;">clocks; dissemination; frequency; GPS; oscillators; time</p>			
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