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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

FEBRUARY 1989	MJD	UT1 - UTC(NIST) (± 5 ms)	UTC - UTC(NIST) (± 0.2 μs)	UTC(USNO,MC) - UTC(NIST) (± 0.04 μs)
2	47559	-155 ms	-0.1 μs	1.01 μs
9	47566	-168 ms	-0.1 μs	0.95 μs
16	47573	-178 ms	-0.1 μs	0.89 μs
23	47580	-187 ms	-0.1 μs	0.82 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 less than 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	47549	47559	47569	47579
UTC(CRL) - UTC(NIST)	##	1372*	1295	1202	1083
UTC(CSIRO) - UTC(NIST)	##	19347	19225	19156	19115
UTC(IEN) - UTC(NIST)	9,11,12	598	604	581	562
UTC(INPL) - UTC(NIST)	VIA OP	-97665	-1021371	-1021281	-1021226
UTC(NPL) - UTC(NIST)	9,11,12	-2032	-1726	-1450	-1133
UTC(NRC) - UTC(NIST)***	3,6,9,11,12,13	13194	13211	13207	13185
UTC(OP) - UTC(NIST)	##	1682	1650	1599	1532
UTC(PTB) - UTC(NIST)	##	-4250	-4321	-4385	-4482
UTC(TAO) - UTC(NIST)	##	2492	2483	2477	2443
UTC(TUG) - UTC(NIST)	9,11,12	3605	3324	3015	2684
UTC(USNO,MC) - UTC(NIST)	##	1089	1011	922	829
UTC(VSL) - UTC(NIST)	9,11,12	-1021	-1121	-1237	-1301

* This value has been updated from that printed in last month's Bulletin.
These values have been computed using around-the-world time transfer techniques.
*** 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, 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.

	= 0.0 s beginning 0000 UTC 25 August 1988
DUT1 = UT1 - UTC	= -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 ± 0.5 μs. The values listed are for 1500 UTC.

LORAN-C - The values shown for Loran-C represent the time difference between the UTC(NIST) time pulses and the 1 Hz output of the Loran-C receiver. The stations monitored are Dana, Indiana (8970 M) and Fallon, Nevada (9940 M). The values shown are four-hour averages taken from 1600 to 2000 UTC daily. If data are lost, the symbol (-) is shown in place of the phase value.

FEBRUARY 1989	MJD	UTC(NIST) - WWVB(60 kHz) ANTENNA PHASE (in μs)	UTC(NIST) - RECEIVED PHASE (in μs) LORAN-C (DANA) (100 kHz)	LORAN-C (FALLON) (100 kHz)
1	47558	5.64	5137.55	3949.85
2	47559	5.71	5137.61	3949.94
3	47560	5.68	5137.49	3949.80
4	47561	5.68	5137.43	3949.64
5	47562	5.68	5138.35	3949.70
6	47563	5.68	5137.48	3949.76
7	47564	5.66	5137.62	3950.00
8	47565	5.62	5137.77	3950.16
9	47566	5.71	5137.81	3950.25
10	47567	5.65	5138.03	3950.29
11	47568	5.64	5138.03	(-)
12	47569	5.62	5138.18	(-)
13	47570	5.61	5138.51	3950.35
14	47571	5.58	5138.40	3950.35
15	47572	5.69	5138.18	3950.31
16	47573	5.65	5137.86	3950.33
17	47574	5.68	5137.94	3950.38
18	47575	5.66	5137.88	3950.16
19	47576	5.64	5138.09	3950.14
20	47577	5.62	5138.33	3950.16
21	47578	5.60	5138.37	3950.28
22	47579	5.69	5138.04	3950.21
23	47580	5.64	5137.90	(-)
24	47581	5.63	5138.08	3950.27
25	47582	5.63	5138.19	3950.14
26	47583	5.63	5138.23	3950.10
27	47584	5.63	5138.34	3950.20
28	47585	5.57	5138.39	3950.19

5. GOES TIME CODE INFORMATION

A. TIME CODE PERFORMANCE (1-28 February 1989)

GOES/East: Performance within normal limits during this period. Time code deviations for the corrected code as observed in Boulder were near the normal 100 microsecond limits at times due to quality of the GOES-5 orbital elements available.

GOES/West: Performance within normal limits during this period. Failure of the GOES/West visual imaging system on 21 January is not expected to impact the GOES/West time code operations in any way.

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

C. SPECIAL ANNOUNCEMENT

Spring 1989 eclipse operations are not expected to impact the time code operations for either GOES/East or GOES/West, since no time code transfers to spare satellites are being done during eclipse periods.

D. 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	FEBRUARY 1989	MJD	BEGAN (UTC)	ENDED (UTC)	FREQUENCY	FEBRUARY 1989	MJD	BEGAN (UTC)	ENDED (UTC)
WWVB	NONE					NONE			
WWV	NONE					NONE			
WWVH						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}) = -1.7×10^{-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 Sep 87	47039	0	1.25 ns/d	23.045 101 681 s	-3.44 E-13
1 Oct 87	47069	0	1.25 ns/d	23.045 102 583 s	-3.47 E-13
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

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

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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10. SUPPLEMENTARY NOTES

☐ 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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