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1. GENERAL BACKGROUND INFORMATION

ACRONYMS AND ABBREVIATIONS USED IN THIS BULLETIN

BIPM	- Bureau International des Poids et Mesures
CCIR	- International Radio Consultative Committee
Cs	- Cesium standard
GOES	- Geostationary Operational Environmental Satellite
GPS	- Global Positioning System
IERS	- International Earth Rotation Service
LORAN	- Long Range Navigation
MC	- Master Clock
MJD	- Modified Julian Date
NVLAP	- National Voluntary Laboratory Accreditation Program
NIST	- National Institute of Standards and Technology
NOAA	- National Oceanic and Atmospheric Administration
SI	- International System of Units
TA	- Atomic Time
TAI	- International Atomic Time
USNO	- United States Naval Observatory
UTC	- Coordinated Universal Time

ns	- nanosecond
µs	- microsecond
ms	- millisecond
s	- second
min	- minute

2. TIME-SCALE INFORMATION

The values listed below are based on data from the IERS, the USNO, and NIST. The UTC(USNO,MC) - UTC(NIST) values are averaged measurements from all available common-view GPS satellites (see bibliography on page 5). **UTC - UTC(NIST) data are on page 3.**

0000 HOURS COORDINATED UNIVERSAL TIME			
APRIL 2001	MJD	UT1-UTC(NIST) (±5 ms)	UTC(USNO,MC) - UTC(NIST) (±20 ns)
5	52004	+22 ms	0 ns
12	52011	+14 ms	-3 ns
19	52018	+10 ms	-6 ns
26	52025	+ 4 ms	-11 ns

The master clock pulses used by the WWV, WWVH, and WWVB time-code transmissions are referenced to the UTC(NIST) time scale. Occasionally, 1 s 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 rate of rotation of the Earth.

NOTE: NO leap second will be inserted at the end of June 2001.

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, 1981-1983, 1985, 1992, 1993, 1994, and 1997, and on 31 December 1972-1979, 1987, 1989, 1990,1995, and 1998. There have been 22 leap seconds inserted in total.

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, and WWVB and are printed below. These corrections may be added to received UTC time signals in order to obtain UT1.

DUT1 = UT1 - UTC =	+0.2 s beginning 0000 UTC 13 April 2000 +0.1 s beginning 0000 UTC 19 October 2000 +0.0 s beginning 0000 UTC 01 March 2001

The deviation of UTC(NIST) from UTC has been within +/–100 ns since July 6, 1994. The table below shows values of UTC - UTC(NIST) as supplied by the BIPM in their Circular T publication for the most recent 310-day period in which data are available. Data are given at ten day intervals. Five day interval data are available in Circular T.

0000 Hours Coordinated Universal Time

DATE	MJD	UTC-UTC(NIST) ns
June 4, 2000	51699	18
June 14, 2000	51709	20
June 24, 2000	51719	23
July 4, 2000	51729	24
July 14, 2000	51739	24
July 24, 2000	51749	24
Aug 3, 2000	51759	26
Aug 13, 2000	51769	25
Aug 23, 2000	51779	22
Sep 2, 2000	51789	12
Sep 12, 2000	51799	6
Sep 22, 2000	51809	0
Oct 2, 2000	51819	-8
Oct 12, 2000	51829	-13
Oct 22, 2000	51839	-19
Nov 1, 2000	51849	-25
Nov 11, 2000	51859	-22
Nov 21, 2000	51869	-21
Dec 1, 2000	51879	-16
Dec 11, 2000	51889	-9
Dec 21, 2000	51899	-5
Dec 31, 2000	51909	-3
Jan. 10, 2001	51919	2
Jan. 20, 2001	51929	7
Jan. 30, 2001	51939	11
Feb. 9, 2001	51949	11
Feb. 19, 2001	51959	5
Mar. 1, 2001	51969	1
Mar. 11, 2001	51979	0
Mar. 21, 2001	51989	-2
Mar. 31, 2001	51999	3

3. PHASE DEVIATIONS FOR WWVB AND LORAN-C

WWVB - The values shown for WWVB are the time differences 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 ns). The phase shift is measured by comparing the output of a Loran receiver to the UTC(NIST) time scale for a period of 24 h. If data were not recorded on a particular day, the symbol (-) is printed. The stations monitored are Dana, IN (8970) and Fallon, NV (9940). The monitoring is done from the NIST laboratories in Boulder, Colorado.

Note: The values shown for Loran-C are in nanoseconds.

		UTC(NIST)-WWVB (60 kHz)	UTC(NIST) - LORAN PHASE (ns)	
DATE	MJD	ANTENNA PHASE (µs)	LORAN-C (DANA) (8970)	LORAN-C (FALLON) (9940)
04/01/01	52000	5.47	+503	-153
04/02/01	52001	5.47	-330	+5
04/03/01	52002	5.47	-481	+73
04/04/01	52003	5.47	+89	+128
04/05/01	52004	5.47	-302	-60
04/06/01	52005	5.48	-294	+24
04/07/01	52006	5.47	+205	-303
04/08/01	52007	5.47	-126	-394
04/09/01	52008	5.45	+101	+227
04/10/01	52009	5.45	+156	+184
04/11/01	52010	5.45	-556	-30
04/12/01	52011	5.50	-152	+123
04/13/01	52012	5.50	-26	+437
04/14/01	52013	5.50	+38	-454
04/15/01	52014	5.50	-363	-89
04/16/01	52015	5.50	-144	-296
04/17/01	52016	5.47	-260	+109
04/18/01	52017	5.47	+328	-422
04/19/01	52018	5.47	-233	-176
04/20/01	52019	5.46	+370	-75
04/21/01	52020	5.55	+205	+473
04/22/01	52021	5.55	-69	+219
04/23/01	52022	5.56	-252	-232
04/24/01	52023	5.56	+250	+28
04/25/01	52024	5.56	+52	-401
04/26/01	52025	5.56	+221	-371
04/27/01	52026	5.55	+167	+461
04/28/01	52027	5.55	-217	-532
04/29/01	52028	5.55	+481	-341
04/30/01	52029	5.55	+294	-200

4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB PHASE PERTURBATIONS

WWVB 60 kHz	OUTAGES OF 5 MINUTES OR MORE						PHASE PERTURBATIONS			
Station	APR 2001	MJD	Began UTC	Ended UTC	Freq.		APR 2001	MJD	Began UTC	End UTC
WWVB	4/2/01	52001	1320	1333	60 kHz					
WWVB	4/7/01	52006	0202	1253	60 kHz					
WWVB	4/11/01	52010	1035	1105	60 kHz					
WWVB	4/11/01	52010	1155	1210	60 kHz					
WWVB	4/12/01	52011	1105	1210	60 kHz					
WWVB	4/12/01	52011	0515	0545	60 kHz					
WWVB	4/14/01	52013	0230	0250	60 kHz					
WWVB	4/23/01	52022	1917	1936	60 kHz					
WWVB	4/23/01	52022	2037	2058	60 kHz					
WWVB	4/27/01	52025	0805	0830	60 kHz					
WWVB	4/30/01	52029	0052	0125	60 kHz					
WWVB	4/30/01	52029	1523	1641	60 kHz					
WWVB	4/30/01	52029	1848	1908	60 kHz					
WWV										
WWVH										

5. NOTES ON NIST TIME SCALES AND PRIMARY STANDARDS

Primary frequency standards developed and maintained by NIST are used to provide accuracy (rate) input to the BIPM. NIST-7, which had served as the U.S. primary standard since 1994, has been replaced by NIST-F1, a cesium fountain frequency standard. The uncertainty of the new standard is currently 1.7 parts in 10^{15}.

The AT1 scale is run in real-time using data from an ensemble of cesium standards and hydrogen masers. It is a free-running scale whose frequency is maintained as nearly constant as possible by choosing the optimum weight for each clock that contributes to the computation.

UTC(NIST) is generated as an offset from our real-time scale AT1. It is steered in frequency towards UTC using data published by the BIPM in its Circular T. Changes in the steering frequency will be made, if necessary, at 0000 UTC on the first day of the month, and very occasionally at mid-month. A change in frequency is limited to no more than ± 2 ns/day. The frequency of UTC(NIST) is kept as stable as possible at other times.

UTC is generated at the BIPM using a post-processed time-scale algorithm and is not available in real-time. The parameters that we use to generate UTC(NIST) in real-time are therefore based on an extrapolation of UTC from the most recent data available.

6. BIBLIOGRAPHY

Allan, D.W.; Hellwig, H.; and Glaze, D.J., "An accuracy algorithm for an atomic time scale," Metrologia, Vol.11, No.3, pp.133-138 (September 1975).

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 and frequency using GPS signals," Proc. 36th Annual Symposium on Frequency Control, p.378 (1982).

Drullinger, R.E.; Glaze, D.J.; Lowe, J.P.; and Shirley, J.H., "The NIST optically pumped cesium frequency standard," IEEE Trans. Instrum. Meas., IM-40, 162-164 (1991).

Glaze, D.J.; Hellwig, H.; Allan, D.W.; and Jarvis, S., "NBS-4 and NBS-6: The NIST primary frequency standards," Metrologia, Vol.13, pp.17-28 (1977).

Wineland, D.J.; Allan, D.W.; Glaze, D.J.; Hellwig, H.; and Jarvis, S., "Results on limitations in primary cesium standard operation," IEEE Trans. Instrum. Meas., IM-25, pp.453-458 (December 1976).

Table 7.1 lists parameters that are used to define UTC(NIST) with respect to our real-time scale AT1. To find the value of UTC(NIST) - AT1 at any time T (expressed as a Modified Julian Day, including a fraction if needed), the appropriate equation to use is the one for which the desired T is greater than or equal to the entry in the T_0 column and less than the entry in the last column. The values of x_s, x, and y for that month are then used in the equation below to find the desired value. The parameters x and y represent the offset in time and in frequency, respectively, between UTC(NIST) and AT1; the parameter x_s is the number of leap seconds applied to both UTC(NIST) and UTC as specified by the IERS. Leap seconds are not applied to AT1.

Table 7.1

$$UTC(NIST) - AT1 = x_s + x + y*(T - T_0)$$

Month	x_s (s)	x (ns)	y (ns/d)	T_0 (MJD)	Valid until 0000 on: (MJD)
Sep 99	-32	-195426.0	-40.5	51422	51452
Oct 99	-32	-196641.0	-40.5	51452	51483
Nov 99	-32	-197896.5	-40.0	51483	51513
Dec 99	-32	-199096.5	-40.0	51513 †	51533
Dec 99	-32	-199896.5	-41.0	51533	51544
Jan 00	-32	-200347.5	-40.5	51544	51575
Feb 00	-32	-201603.0	-40.5	51575	51604
Mar 00	-32	-202777.5	-40.5	51604	51635
Apr 00	-32	-204033.0	-40.5	51635	51665
May 00	-32	-205248.0	-40.25	51665	51696
Jun 00	-32	-206495.75	-40.25	51696	51725 ††
Jul 00	-32	-207663.0	-40.0	51725 ††	51757
Aug 00	-32	-208943.0	-39.5	51757	51788
Sep 00	-32	-210167.5	-39.0	51788	51818
Oct 00	-32	-211337.5	-39.0	51818	51849
Nov 00	-32	-212546.5	-40.0	51849	51879
Dec 00	-32	-213746.5	-40.0	51879	51910
Jan 01	-32	-214986.5	-40.0	51910	51941
Feb 01	-32	-216226.5	-39.0	51941	51969
Mar 01	-32	-217318.5	-39.5	51969	52000
Apr 01	-32	-218543.0	-39.0	52000	52030
May 01	-32	-219713.0	-39.0	52030	52061
Jun 01	-32	-220937.5	-39.5 *	52061	52091

† Rate change in mid-month
†† Rate change one day early
***Provisional value**

7. SPECIAL ANNOUNCEMENTS

TRACEABLE FREQUENCY CALIBRATIONS
(Now NVLAP Certified)

Laboratories can get any needed traceable frequency calibrations by subscribing to the NIST Frequency Measurement and Analysis Service. This service is offered on a lease basis by NIST to provide an easy and inexpensive means to obtain traceability of a laboratory frequency standard and, in addition, to calibrate other devices in the lab. This service has been designed for ease of operation and as a practical calibration tool.

All necessary hardware and software is provided by NIST. Users must provide their own oscillator(s) and an ordinary telephone line so that NIST can access the system by modem. A maximum total of five oscillators can be calibrated at the same time. Radio signals from GPS satellites are used and the measurement uncertainty is $\pm 2 \times 10^{-13}$ per day. Any frequency from 1 Hz to 120 MHz (in 1 Hz increments) can be measured.

The calibration data are displayed in color, and a graph is plotted daily for each oscillator. Data are also stored on disk. The user can call up any of the data and view them onscreen or in the form of plots. Up to 5 months of data can be plotted on one graph.

The system plots are easy to read and understand. The system manual is written clearly and the NIST staff are available by telephone to assist. The modem connection allows NIST to access the data and to prepare a monthly traceability report, which is mailed to the user.

Frequency sources of any accuracy can be calibrated. The FMAS is particularly useful at the highest levels of performance. This is because each user of the system contributes information and calibration data for the others. If an uncertainty arises, it is possible for NIST to call by modem to another user nearby. In this way problems in data interpretation can be resolved.

NVLAP certification requirements for frequency measurement are met by following the NIST-FMAS operating manual. This service does not eliminate the NVLAP audits but, when installed and operated per the NIST guidelines, audit requirements are easily met.

NIST retains title to the equipment and supplies. All necessary replacement parts are replaced by overnight shipment. Training for use of the system is available if requested by the user.

The NIST Frequency Measurement and Analysis Service provides a complete solution to nearly all frequency measurement and calibration problems. For a free information package, please phone Michael Lombardi at (303) 497-3212, or E-mail him at lombardi@boulder.nist.gov, or write to Michael Lombardi, NIST, Division 847, 325 Broadway, Boulder, CO 80305.

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