NIST TIME AND FREQUENCY BULLETIN
NISTIR 6629-03

NO. 543 MARCH 2003

1. GENERAL BACKGROUND INFORMATION 2

2. TIME-SCALE INFORMATION 2

3. PHASE DEVIATIONS FOR WWVB AND LORAN-C 4

4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB PHASE PERTURBATIONS 5

5. NOTES ON NIST TIME SCALES AND PRIMARY STANDARDS 5

6. BIBLIOGRAPHY 5

7. SPECIAL ANNOUNCEMENTS 7

This bulletin is published monthly. Address correspondence to:

Eyvon M. Petty, Editor
Time and Frequency Division
National Institute of Standards and Technology
325 Broadway
Boulder, CO 8O3O5-3328
(3O3) 497-3295
Email: pettye@boulder.nist.gov

NOTE TO SUBSCRIBERS: Please include your address label (or a copy) with any correspondence regarding this bulletin.

U.S. DEPARTMENT OF COMMERCE, DONALD L. EVANS, Secretary
TECHNOLOGY ADMINISTRATION, Dr. Cheryl L. Shavers, Under Secretary of Commerce for Technology
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, Dr. Arden L. Bement, Jr., Director

1. GENERAL BACKGROUND INFORMATION

ACRONYMS AND ABBREVIATIONS USED IN THIS BULLETIN

BIPM	- Bureau International des Poids et Mesures		
Cs	- Cesium standard		
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	ns	- nanosecond
SI	- International System of Units	µs	- microsecond
TA	- Atomic Time	ms	- millisecond
TAI	- International Atomic Time	s	- second
USNO	- United States Naval Observatory	min	- minute
UTC	- Coordinated Universal Time		

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			
FEB 2003	MJD	UT1 - UTC(NIST) (±5 ms)	UTC(USNO,MC) - UTC(NIST) (±20 ns)
6	52676	-308 ms	-3 ns
13	52683	-311 ms	-3 ns
20	52690	-316 ms	-1 ns
27	52697	-321 ms	-4 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 2003.

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 =

+0.1 s beginning 0000 UTC 19 October 2000
+0.0 s beginning 0000 UTC 01 March 2001
– 0.1 s beginning 0000 UTC 04 October 2001
– 0.2 s beginning 0000 UTC 14 February 2002
– 0.3 s beginning 0000 UTC 24 October 2002
– 0.4 s beginning 0000 UTC 03 April 2003

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
Jan. 30, 2003	52669	2
Jan. 20, 2003	52659	-1
Jan. 10, 2003	52649	-5
Dec. 31, 2002	52639	-2
Dec. 21, 2002	52629	-3
Dec. 11, 2002	52619	-4
Dec. 1, 2002	52609	-3
Nov. 22, 2002	52599	2
Nov. 12, 2002	52589	3
Nov. 2, 2002	52579	4
Oct. 22, 2002	52569	5
Oct. 12, 2002	52559	4
Oct. 2, 2002	52549	4
Sept. 22, 2002	52539	3
Sept. 12, 2002	52529	0
Sept. 2, 2002	52519	-1
Aug. 23, 2002	52509	-6
Aug. 13, 2002	52499	-13
Aug. 3, 2002	52489	-11
July 24, 2002	52479	-4
July 14, 2002	52469	0
July 4, 2002	52459	3
June 24, 2002	52449	8
June 14, 2002	52439	12
June 4, 2002	52429	11
May 25, 2002	52419	12
May 15, 2002	52409	14
May 5, 2002	52399	0
Apr. 25, 2002	52389	-2
Apr. 15, 2002	52379	-7
Apr. 5, 2002	52369	-14

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 nanoseconds. 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 Baudette, ND (8970-Y) 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 *(BAUDETTE) (8970-Y)	LORAN-C (FALLON) (9940)
02/01/03	52671	5.74	-199	+75
02/02/03	52672	5.74	-52	+385
02/03/03	52673	5.74	+151	-347
02/04/03	52674	5.76	+79	-90
02/05/03	52675	5.75	+283	+201
02/06/03	52676	5.76	-162	-36
02/07/03	52677	5.73	+206	-284
02/08/03	52678	5.73	+110	+143
02/09/03	52679	5.74	+116	+255
02/10/03	52680	5.76	-34	-32
02/11/03	52681	5.75	-288	+93
02/12/03	52682	5.75	+39	-100
02/13/03	52683	5.74	+87	+168
02/14/03	52684	5.75	-77	-5
02/15/03	52685	5.75	-140	-239
02/16/03	52686	5.76	-38	+161
02/17/03	52687	5.76	-17	+43
02/18/03	52688	5.75	+296	+412
02/19/03	52689	5.75	-95	-105
02/20/03	52690	5.77	-30	-77
02/21/03	52691	5.75	+96	-86
02/22/03	52692	5.77	+250	+100
02/23/03	52693	5.76	-35	+175
02/24/03	52694	5.76	+36	+168
02/25/03	52695	5.78	-86	+153
02/26/03	52724	5.78	-225	+161
02/27/03	52725	5.77	+48	-323
02/28/03	52756	5.79	-47	+166

*NOTE: NIST began monitoring signals from Baudette (8970-Y) at 1900 UTC on May 8, 2001. The change was made to improve the quality of the received signal.

4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB PHASE PERTURBATIONS

WWVB 60 kHz	OUTAGES OF 5 MINUTES OR MORE						PHASE PERTURBATIONS 2 ms			
Station	FEB 2003	MJD	Began UTC	Ended UTC	Freq.		FEB 2003	MJD	Began UTC	End UTC
WWVB	2-17-03	52687	1100	1140	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. 33-138 (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, pp. 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_{ls}, 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_{ls} 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
$UTC(NIST) - AT1 = x_{ls} + x + y*(T - T_0)$

Month	x_{ls} (s)	x (ns)	y (ns/d)	T_0 (MJD)	Valid until 0000 on: (MJD)
Mar 03	-32	-246607.7	-40.4*	52699	52730*
Feb 03	-32	-246284.9	-40.35	52691	52699
Feb 03	-32	-245474.9	-40.5	52671	52691†
Jan 03	-32	-244906.5	-40.6	52657	52671
Jan 03	-32	-244218.0	-40.5	52640	52657†
Dec 02	-32	-243813.0	-40.5	52630	52640
Dec 02	-32	-242964.6	-40.4	52609	52630†
Nov 02	-32	-242399.0	-40.4	52595	52609
Nov 02	-32	-241751.0	-40.5	52579	52595†
Oct 02	-32	-240495.5	-40.5	52548	52579
Sep 02	-32	-240252.5	-40.5	52542	52548
Sep 02	-32	-239274.5	-40.75	52518	52542†
Aug 02	-32	-238577.5	-41.0	52501	52518
Aug 02	-32	-238014.25	-40.25	52487	52501†
Jul 02	-32	-236766.5	-40.25	52456	52487
Jun 02	-32	-236046.5	-40.0	52438	52456
Jun 02	-32	-235560.5	-40.5	52426	52438†
May 02	-32	-234960.5	-40.0	52411	52426
May 02	-32	-234296.5	-41.5	52395	52411†
Apr 02	-32	-233558.5	-41.0	52377	52395
Apr 02	-32	-233072.5	-40.5	52365	52377†
Mar 02	-32	-232829.5	-40.0	52359	52365
Mar 02	-32	-231829.5	-40.0	52334	52359†
Feb 02	-32	-231255.5	-41.0	52320	52334
Feb 02	-32	-230695.5	-40.0	52306	52320†

† 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.

IMPORTANT NOTICE!

The Time and Frequency Bulletin data are now online at

http://tf.nist.gov