NIST TIME AND FREQUENCY BULLETIN
NIST IR 6656-06

No. 618   June 2009

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

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

U.S. DEPARTMENT OF COMMERCE, GARY LOCKE, Secretary
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, Patrick D. Gallagher, Deputy Director

1. GENERAL BACKGROUND INFORMATION

ACRONYMS AND ABBREVIATIONS USED IN THIS BULLETIN

ACTS	- Automated Computer Time Service		
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		
NIST	- National Institute of Standards and Technology		
NOAA	- National Oceanic and Atmospheric Administration		
NVLAP	- National Voluntary Laboratory Accreditation Program	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			
May 2009	MJD	UT1-UTC(NIST) (±5 ms)	UTC(USNO,MC) - UTC(NIST) (±20 ns)
7	54958	277 ms	8 ns
14	54965	272 ms	8 ns
21	54972	264 ms	8 ns
28	54979	257 ms	10 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 Earth's period of rotation.

NOTE: A positive leap second was added at the end of December 2008.

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, 1992-1994, and 1997, and on 31 December 1972-1979, 1987, 1989, 1990,1995, 1998, and 2005.

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

	+0.2 s beginning 0000 UTC 11 June 2009
	+0.3 s beginning 0000 UTC 12 March 2009
	-0.6 s beginning 0000 UTC 20 November 2008
DUT1 = UT1 - UTC =	-0.5 s beginning 0000 UTC 07 August 2008
	-0.4 s beginning 0000 UTC 13 March 2008

The difference between UTC(NIST) and 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 10-day intervals. Five-day interval data are available in *Circular T*.

0000 Hours Coordinated Universal Time		
DATE	**MJD**	**UTC-UTC(NIST) ns**
Apr. 28, 2009	54949	9.7
Apr. 18, 2009	54939	7.0
Apr. 08, 2009	54929	10.0
Mar. 28, 2009	54919	7.5
Mar. 18, 2009	54909	7.1
Mar. 08, 2009	54899	4.9
Feb. 27, 2009	54889	4.3
Feb. 17. 2009	54879	2.0
Feb. 07, 2009	54869	1.7
Jan. 28, 2009	54859	3.9
Jan. 18, 2009	54849	3.9
Jan. 08, 2009	54839	4.0
Dec. 29, 2008	54829	4.1
Dec. 19, 2008	54819	2.5
Dec. 09, 2008	54809	0.7
Nov. 29, 2008	54799	0.5
Nov. 19, 2008	54789	-1.0
Nov. 09, 2008	54779	-2.1
Oct. 30, 2008	54769	-3.3
Oct. 20, 2008	54759	-5.7
Oct. 10, 2008	54749	-5.4
Sep. 30, 2008	54739	-4.7
Sep, 20, 2008	54729	-2.0
Sep. 10, 2008	54719	-1.2
Aug. 31, 2008	54709	-1.4
Aug. 21, 2008	54699	0.9
Aug. 11, 2008	54689	1.3
Aug. 01, 2008	54679	3.0

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. 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, Minnesota (8970) and Boise City, Oklahoma (9610). 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)	
		ANTENNA PHASE	LORAN-C (BAUDETTE)	LORAN-C (BOISE CITY)
DATE	MJD	(μs)	(8970)	(9610)
05/01/2009	54952	5. 65	-45	+4
05/02/2009	54953	5. 65	-67	-11
05/03/2009	54954	5. 65	-7	+22
05/04/2009	54955	5. 65	+20	+19
05/05/2009	54956	5. 65	-12	-1
05/06/2009	54957	5. 65	-23	-13
05/07/2009	54958	5. 65	-32	+21
05/08/2009	54959	5. 65	0	-28
05/09/2009	54960	5. 65	-55	-1
05/10/2009	54961	5. 65	-63	-5
05/11/2009	54962	5. 65	-57	+12
05/12/2009	54963	5. 65	-29	+17
05/13/2009	54964	5. 65	+55	-19
05/14/2009	54965	5. 65	+107	+2
05/15/2009	54966	5. 65	+37	-17
05/16/2009	54967	5. 65	-25	+9
05/17/2009	54968	5. 65	-11	+5
05/18/2009	54969	5. 65	+17	+7
05/19/2009	54970	5. 65	-6	-1
05/20/2009	54971	5. 65	+39	-14
05/21/2009	54972	5. 65	-32	-40
05/22/2009	54973	5. 65	+18	+33
05/23/2009	54974	5. 65	-3	+4
05/24/2009	54975	5. 65	+57	-10
05/25/2009	54976	5. 65	+23	+2
05/26/2009	54977	5. 65	+95	+10
05/27/2009	54978	5. 65	-52	-16
05/28/2009	54979	5. 65	-80	0
05/29/2009	54980	5. 65	+19	+20
05/30/2009	54981	5. 65	-64	+1
05/31/2009	54982	5. 65	-33	-15

4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB PHASE PERTURBATIONS

OUTAGES OF 5 MINUTES OR MORE						PHASE PERTURBATIONS 2 ms			
Station	May 2009	MJD	Began UTC	Ended UTC	Freq.	May 2009	MJD	Began UTC	End UTC
WWVB					60 kHz				
WWV									
WWVH									

5. NOTES ON NIST TIME SCALES AND PRIMARY STANDARDS

Primary frequency standards developed and operated by NIST are used to provide accuracy (rate) input to the BIPM. NIST-F1, a cold-atom cesium fountain frequency standard, has served as the U.S. primary time and frequency standard since 1999. The uncertainty of NIST-F1 is currently about 5 parts in 10^{16}.

The AT1 scale is run in real-time by use of 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 by use of 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 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 by use of 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 available data.

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 (1975).

Allan, D.W.; Davis, D.D.; Weiss, M.A.; Clements, A.; Guinot, B.; Granveaud, M.; Dorenwendt, K.; Fischer, B.; Hetzel, P.; Aoki, S.; Fujimoto, M.; Charron, L.; and Ashby, N., “Accuracy of international time and frequency comparisons via global positioning system satellites in common-view,” IEEE Transactions on Instrumentation and Measurement, Vol. IM-34, pp.118-125 (1985).

Heavner, T.P.; Jefferts, S.R.; Donley; E.A.; Shirley, J.H. and Parker, T.E., “NIST F1; recent improvements and accuracy evaluations,” Metrologia, Vol. 42, pp. 411-422 (2005).

Jefferts, S.R.; Shirley, J.; Parker, T.E.; Heavner, T.P.; Meekhof, D.M.; Nelson, C., Levi, F.; Costanza, G.; De Marchi, A.; Drullinger, R.; Hollberg, L.; Lee, W.D.; and Walls, F.L., “Accuracy evaluation of NIST-F1,” Metrologia, Vol. 39, pp. 321-336 (2002).

Lewandowski, W. and Thomas, C.; “GPS Time transfer,” Proceedings of the IEEE, Vol. 79, pp. 991-1000 (1991).

Parker, T.E.; Jefferts, S.R.; Heavner, T.P.; and Donley, E.A., “Operation of the NIST-F1 caesium fountain primary frequency standard with a maser ensemble, including the impact of frequency transfer noise,” Metrologia, Vol. 42, pp. 423-430 (2005).

Weiss, M.A.; Allan, D.W.; “An NBS Calibration Procedure for Providing Time and Frequency at a Remote Site by Weighting and Smoothing of GPS Common View Data,” IEEE Transactions on Instrumentation and Measurement, Vol. IM-36, pp. 572-578 (1987).

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 offsets in time and 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)
Jul 09	-34	-336349.8	-38.0*	55013	55044
Jun 09	-34	-335209.8	-38.0	54983	55013*
May 09	-34	-334791.8	-38.0	54972	54983
May 09	-34	-334027.8	-38.2	54952	54972*
Apr 09	-34	-333225.6	-38.2	54931	54952
Apr 09	-34	-332880.9	-38.3	54922	54931†
Mar 09	-34	-331693.6	-38.3	54891	54922
Feb 09	-34	-330621.2	-38.3	54863	54891
Jan 09	-34	-329931.8	-38.3	54845	54863
Jan 09	-34	-329432.6	-38.4	54832	54845†
Dec 08	-33	-328895.0	-38.4	54818	54832
Dec 08	-33	-328240.5	-38.5	54801	54818†
Nov 08	-33	-327085.5	-38.5	54771	54801
Oct 08	-33	-326392.5	-38.5	54753	54771
Oct 08	-33	-325894.6	-38.3*	54740	54753†
Sep 08	-33	-324745.6	-38.3	54710	54740
Aug 08	-33	-323558.3	-38.3	54679	54710
Jul 08	-33	-322792.3	-38.3	54659	54679
Jul 08	-33	-322369.9	-38.4	54648	54659†
Jun 08	-33	-321211.9	-38.6	54618	54648

† Rate change in mid-month
***Provisional value**