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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		
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			
NOV 2006	MJD	UT1-UTC(NIST) (±5 ms)	UTC(USNO,MC) - UTC(NIST) (±20 ns)
2	54041	105 ms	-6 ns
9	54048	095 ms	0 ns
16	54055	088 ms	6 ns
23	54062	081 ms	9 ns
30	54069	074 ms	12 ns

NOTE: No leap second will be added at the end of December 2006.

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 rotation.

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, 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.

DUT1 = UT1 - UTC =	-0.5 s beginning 0000 UTC 29 April 2004
	-0.6 s beginning 0000 UTC 17 March 2005
	+0.3 s beginning 0000 UTC 01 January 2006
	+0.2 s beginning 0000 UTC 27 April 2006
	+0.1 s beginning 0000 UTC 28 September 2006

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
Oct. 31, 2006	54039	-4.9
Oct. 21, 2006	54029	-11.8
Oct. 11, 2006	54019	-14.3
Oct. 01, 2006	54009	-14.4
Sep. 21, 2006	53999	-13.0
Sep. 11, 2006	53989	-8.8
Sep. 01, 2006	53979	-5.4
Aug. 22, 2006	53969	-0.2
Aug. 12, 2006	53959	2.3
Aug. 02, 2006	53949	4.2
Jul. 23, 2006	53939	6.7
Jul. 13, 2006	53929	8.6
Jul. 03, 2006	53919	8.3
Jun. 23, 2006	53909	8.5
Jun. 13, 2006	53899	6.9
Jun. 03, 2006	53889	7.1
May 24, 2006	53879	6.6
May 14, 2005	53869	6.2
May 04, 2006	53859	7.0
Apr. 24, 2006	53849	6.2
Apr. 14, 2006	53839	6.0
Apr. 04, 2006	53829	6.2
Mar. 25, 2006	53819	5.7
Mar. 15, 2006	53809	3.8
Mar. 05, 2006	53799	3.2
Feb. 23, 2006	53789	2.5
Feb. 13, 2006	53779	1.3
Feb. 03, 2006	53769	2.0
Jan. 24, 2006	53759	2.0
Jan. 14, 2006	53749	4.1
Jan. 04, 2006	53739	4.1

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)	
DATE	MJD	ANTENNA PHASE (μs)	LORAN-C (BAUDETTE) (8970)	LORAN-C (BOISE CITY) (9610)
11/01/06	54040	5. 65	+60	-6
11/02/06	54041	5. 65	-7	0
11/03/06	54042	5. 65	-42	-8
11/04/06	54043	5. 65	-67	-7
11/05/06	54044	5. 65	-5	+5
11/06/06	54045	5. 65	+9	-2
11/07/06	54046	5. 65	-19	+1
11/08/06	54047	5. 65	+58	+26
11/09/06	54048	5. 65	+73	-15
11/10/06	54049	5. 65	-63	-6
11/11/06	54050	5. 65	+208	+18
11/12/06	54051	5. 65	+25	+5
11/13/06	54052	5. 65	-6	+13
11/14/06	54053	5. 65	-17	-5
11/15/06	54054	5. 65	+31	-4
11/16/06	54055	5. 65	-38	-6
11/17/06	54056	5. 65	+57	-1
11/18/06	54057	5. 65	+136	-14
11/19/06	54058	5. 65	+31	+11
11/20/06	54059	5. 65	+212	+15
11/21/06	54060	5. 65	-15	-12
11/22/06	54061	5. 65	-54	-6
11/23/06	54062	5. 65	+130	+5
11/24/06	54063	5. 65	+57	+3
11/25/06	54064	5. 65	-52	-9
11/26/06	54065	5. 65	+47	+11
11/27/06	54066	5. 65	-30	-1
11/28/06	54067	5. 65	+86	+10
11/29/06	54068	5. 65	-259	-1
11/30/06	54069	5. 65	-271	+3

4. BROADCAST OUTAGES OVER FIVE MINUTES AND WWVB PHASE PERTURBATIONS

Notice of WWVB Station Maintenance

Improvements were made to WWVB on October 10-13, 2006, which required turning the station off for periods ranging from minutes to hours during the daytime. All outages longer than 5 minutes are recorded here. The station broadcast continuously during the nighttime hours on these dates, and radio controlled clock performance should not have been affected.

OUTAGES OF 5 MINUTES OR MORE							PHASE PERTURBATIONS 2 ms			
Station	NOV 2006	MJD	Began UTC	Ended UTC	Freq.		OCT 2006	MJD	Began UTC	End UTC
WWVB	11/06/06	54045	0108	0216	60 kHz					
WWVB	11/01/06	54040	2309	2317	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 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 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.

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.

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).

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 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)
Jan 07	-33	-301506.7	-38.8*	54101	54132
Dec 06	-33	-300303.9	-38.8	54070	54101*
Nov 06	-33	-299799.5	-38.8	54057	54070
Nov 06	-33	-299129.7	-39.4	54040	54057†
Oct 06	-33	-298459.9	-39.4	54023	54040
Oct 06	-33	-297916.7	-38.8	54009	54023†
Sep 06	-33	-297606.3	-38.8	54001	54009
Sep 06	-33	-296759.3	-38.5	53979	54001†
Aug 06	-33	-295565.8	-38.5	53948	53979
Jul 06	-33	-294911.3	-38.5	53931	53948
Jul 06	-33	-294368.80	-38.75	53917	53931†
Jun 06	-33	-293206.30	-38.75	53887	53917
May 06	-33	-292702.55	-38.75	53874	53887
May 06	-33	-292004.15	-38.8	53856	53874†
Apr 06	-33	-291422.15	-38.8	53841	53856
Apr 06	-33	-290837.9	-38.95	53826	53841†
Mar 06	-33	-289630.45	-38.95	53795	53826
Feb 06	-33	-288539.85	-38.95	53767	53795
Jan 06	-33	-287838.75	-38.95	53749	53767
Jan 06	-33	-287330.45	-38.95	53736	53749
Dec 05	-32	-286118.35	-39.1	53705	53736
Nov 05	-32	-284937.85	-39.35	53675	53705

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