NIST TIME AND FREQUENCY BULLETIN
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1. GENERAL BACKGROUND INFORMATION

ABBREVIATIONS AND ACRONYMS 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 & 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		
VLF	- very low frequency		

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 up to 10 GPS satellites (see bibliography on page 5). **UTC-UTC(NIST) data are on page 3.**

SEP 1999	MJD	UT1-UTC(NIST) (±5 ms)	UTC(USNO,MC)-UTC(NIST) (±20 ns)

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 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 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, 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 in total.
NOTE: There will NOT be a leap second on December 31, 1999.

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.

DUT1 = UT1 - UTC =
+0.6s beginning 0000 UTC 04 March 1999
+0.5s beginning 0000 UTC 27 May 1999
+0.4s beginning 0000 UTC 14 October 1999

The deviation of UTC(NIST) from UTC has been less than +/-100 ns since July 6, 1994. The table below shows values of UTC -

0000 Hours Coordinated Universal Time

DATE	MJD	UTC-UTC(NIST) ns
Sep 23, 1998	51079	-4
Oct 3, 1998	51089	-7
Oct 13, 1998	51099	-5
Oct 23, 1998	51109	-3
Nov 2, 1998	51119	-3
Nov 12, 1998	51129	-1
Nov 22, 1998	51139	0
Dec 2, 1998	51149	4
Dec 12, 1998	51159	3
Dec 22, 1998	51169	10
Jan 1, 1999	51179	10
Jan 11, 1999	51189	19
Jan 21, 1999	51199	22
Jan 31, 1999	51209	25
Feb 10, 1999	51219	25
Feb 20, 1999	51229	26
Mar 2, 1999	51239	24
Mar 12, 1999	51249	21
Mar 22, 1999	51259	15
Apr 1, 1999	51269	10
Apr 11, 1999	51279	2
Apr 21, 1999	51289	-9
May 1, 1999	51299	-18
May 11, 1999	51309	-18
May 21, 1999	51319	-18
May 31, 1999	55329	-16
Jun 10, 1999	51339	-16
Jun 20, 1999	51349	-14
Jun 30, 1999	51359	-12
Jul 10, 1999	51369	-6
Jul 20, 1999	51379	-3
Jul 30, 1999	51389	-1
Aug 9, 1999	51399	-2
Aug 19, 1999	51409	4
Aug 29, 1999	51419	12

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 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 master stations monitored are Dana, IN (8970) and Fallon, NV (9940). The monitoring is done from the NIST laboratories in Boulder, CO.

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)
9/01/99	51422	5.66	-138	+63
9/02/99	51423	5.65	+342	-85
9/03/99	51424	5.65	-28	-62
9/04/99	51425	5.66	+331	+252
9/05/99	51426	5.66	+178	-23
9/06/99	51427	5.67	+488	-89
9/07/99	51428	5.69	-306	-173
9/08/99	51429	5.69	+205	-109
9/09/99	51430	5.70	+19	-43
9/10/99	51431	5.70	+13	-72
9/11/99	51432	5.71	-342	-357
9/12/99	51433	5.71	+150	+274
9/13/99	51434	5.72	-333	-209
9/14/99	51435	5.70	+88	-59
9/15/99	51436	5.70	-287	-
9/16/99	51437	5.68	+85	+235
9/17/99	51438	5.68	(-)	-194
9/18/99	51439	5.67	(-)	+184
9/19/99	51440	5.67	(-)	+427
9/20/99	51441	5.69	(-)	-486
9/21/99	51442	5.69	-552	-274
9/22/99	51443	5.69	-272	+67
9/23/99	51444	5.68	+99	+171
9/24/99	51445	5.69	+382	+30
9/25/99	51446	5.69	-302	-31
9/26/99	51447	5.69	-186	+500
9/27/99	51448	5.69	-321	-236
9/28/99	51449	5.68	+171	+462
9/29/99	51450	5.68	-22	-14
9/30/99	51451	5.71	+120	+65

5. BROADCAST OUTAGES OVER 5 MINUTES AND WWVB PHASE PERTURBATIONS

OUTAGES							PHASE PERTURBATIONS WWVB 60 kHz			
Station	SEP 1999	MJD	Began UTC	Ended UTC	Freq.		SEP 1999	MJD	Began UTC	End UTC
WWVB	9/8		0700	0730	60 kHz		9/16	51437	0850	1330
	9/12		0140	0210						
			0240	0300						
			0450	0510						
	9/16		0750	0850						
	9/19		0540	0610						
	9/21		1030	1105						
	9/26		0550	0630						
	9/27		0320	0410						
			0830	0900						
WWV										
WWVH										

6. NOTES ON NIST TIME SCALE AND PRIMARY STANDARDS

Primary frequency standards developed and maintained by NIST are used to provide accuracy (rate) input to the BIPM. NBS-6, which served as the U.S. primary standard from 1975 through 1992, has been replaced by NIST-7, an optically pumped cesium-beam standard. The uncertainty of the new standard is currently 1 part in 10^{14}.

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 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 only at 0000 UTC on the first day of any month, and the change in frequency in any month is limited to ±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.

7. BIBLIOGRAPHY

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Table 7.1 is a list of the 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

$$\mathrm{UTC(NIST)} - \mathrm{AT1} = x_{ls} + x + y\cdot(T - T_0)$$

Month	x_{ls} (s)	x (ns)	y (ns/day)	T_0 (MJD)	Valid until 0000 on: (MJD)
Dec 97	-31	-168938	-42.5	50783	50814
Jan 98	-31	-170255	-42.5	50814	50845
Feb 98	-31	-171573	-42.5	50845	50873
Mar 98	-31	-172763	-42.5	50873	50904
Apr 98	-31	-174080.5	-42.0	50904	50934
May 98	-31	-175340.5	-42.0	50934	50965
Jun 98	-31	-176642.5	-41.5	50965	50995
Jul 98	-31	-177887.5	-41.5	50995	51025
Aug 98	-31	-179174	-41.0	51025	51057
Sep 98	-31	-180445	-41.0	51057	51087
Oct 98	-31	-181675	-41.5	51087	51118
Nov 98	-31	-182961.5	-41.5	51118	51148
Dec 98	-31	-184206.5	-41.5	51148	51179
Jan 99	-32	-185493	-41.5	51179	51210
Feb 99	-32	-186779.5	-41.0	51210	51238
Mar 99	-32	-187927.5	-40.5	51238	51269
Apr 99	-32	-189183	-40.0	51269	51299
May 99	-32	-190383	-41.0	51299	51330
Jun 99	-32	-191654	-41.0	51330	51360
Jul 99	-32	-192884	-41.0	51360	51391
Aug 99	-32	-194155	-41.0	51391	51422
Sep 99	-32	-195426	-40.5	51422	51452
Oct 99	-32	-196641	-40.5	51452	51483
Nov 99	-32	-197896.5	-40.5*	51483	51513

***Provisional rate**

8. SPECIAL ANNOUNCEMENTS

TRACEABLE FREQUENCY CALIBRATIONS
(Now NVLAP Certified)

Anyone needing traceable frequency calibrations can get them 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 main oscillator and, in addition, to calibrate other devices in the lab. This service has been designed for ease of operation and as a practical lab calibration tool.

All the equipment and software needed are 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 total of four oscillators can be calibrated at the same time. Radio signals from either Loran-C or GPS satellite are used. Results for either are at about the same accuracy.

The calibration data are displayed in color and a graph is plotted daily for each oscillator connected. 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. Many months of data can be plotted.

The system plots are easy to read and understand. The system manual is written for easy understanding and the NIST staff is 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 any needed system spares. Equipment that fails is 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 contact Michael Lombardi at (303) 497-3212, E-mail at lombardi@boulder.nist.gov, or write to: Michael Lombardi, NIST, Division 847, 325 Broadway, Boulder, CO 80303.

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