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
SI	- International System of Units
TA	- Atomic Time
TAI	- International Atomic Time
USNO	- United States Naval Observatory
UTC	- Coordinated Universal Time
VLF	- very low frequency

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

2. TIME SCALE INFORMATION

SEP 1998	MJD	UT1-UTC(NIST) ($\pm$5 ms)	UTC(USNO,MC)-UTC(NIST) ($\pm$20 ns)

3. UT1 CORRECTIONS AND LEAP SECOND ADJUSTMENTS

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 $\pm$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, and 1995. There have been 21 leap seconds in total. **The next leap second will occur on 31 December 1998.**

The use of leap seconds ensures that UT1 - UTC will always be held within $\pm$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 =
+0.0 s beginning 0000 UTC 26 March 1998
-0.1 s beginning 0000 UTC 07 May 1998
-0.2 s beginning 0000 UTC 13 August 1998

The deviation of UTC(NIST) from UTC has been less than +/-100 ns since July 6, 1994. The table below shows values of UTC - UTC(NIST) as supplied by the BIPM in Circular T for the most recent 350 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
Sep. 8, 1997	50699	30
Sep. 18, 1997	50709	31
Sep. 28, 1997	50719	31
Oct. 8, 1997	50729	29
Oct. 18, 1997	50739	23
Oct. 28, 1997	50749	16
Nov. 7, 1997	50759	8
Nov. 17, 1997	50769	3
Nov. 27, 1997	50779	1
Dec. 7, 1997	50789	2
Dec. 17, 1997	50799	-1
Dec. 27, 1997	50809	3
Jan. 6, 1998	50819	2
Jan. 16. 1998	50829	2
Jan. 26, 1998	50839	6
Feb. 5, 1998	50849	7
Feb. 15, 1998	50859	11
Feb. 25, 1998	50869	15
Mar 7, 1998	50879	18
Mar 17, 1998	50889	22
Mar 27, 1998	50899	25
Apr 6, 1998	50909	25
Apr 16, 1998	50919	26
Apr 26, 1998	50929	26
May 6, 1998	50939	26
May 16, 1998	50949	28
May 26, 1998	50959	26
June 5, 1998	50969	30
June 15, 1998	50979	27
June 25, 1998	50989	26
July 5, 1998	50993	24
July 15, 1998	51009	23
July 25, 1998	51019	22
Aug. 4, 1998	51029	15
Aug. 14, 1998	51039	16
Aug. 24, 1998	51049	11

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)
9/01/98	51057	5.72	+424	-18
9/02/98	51058	5.71	+383	-324
9/03/98	51059	5.73	+327	-16
9/04/98	51060	5.66	+4	+279
9/05/98	51061	5.65	+0	-29
9/06/98	51062	5.65	-2	+83
9/07/98	51063	5.66	+136	+663
9/08/98	51064	5.72	-82	-203
9/09/98	51065	5.74	+39	+148
9/10/98	51066	5.71	-275	-417
9/11/98	51067	5.70	-129	-227
9/12/98	51068	5.69	-176	+337
9/13/98	51069	5.70	+14	-456
9/14/98	51070	5.67	-82	-8
9/15/98	51071	5.65	-96	-138
9/16/98	51072	5.63	-198	+170
9/17/98	51073	5.64	-63	+149
9/18/98	51074	5.65	-24	+11
9/19/98	51075	5.64	+597	+299
9/20/98	51076	5.63	-495	-23
9/21/98	51077	5.61	+644	+385
9/22/98	51078	5.69	+85	+197
9/23/98	51079	5.74	-445	-197
9/24/98	51080	5.72	+289	-84
9/25/98	51081	5.70	+57	+319
9/26/98	51082	5.69	-47	-209
9/27/98	51083	5.68	-96	-108
9/28/98	51084	5.63	-213	+534
9/29/98	51085	5.74	-52	-355
9/30/98	51086	5.74	+269	+247

5. BROADCAST OUTAGES OVER 5 MINUTES AND WWVB PHASE PERTURBATIONS

OUTAGES						PHASE PERTURBATIONS WWVB 60 kHz			
Station	SEP 1998	MJD	Began UTC	Ended UTC	Freq.	SEP 1998	MJD	Began UTC	End UTC
WWVB									
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}.

Since 1981, TA(NIST) has been computed retrospectively each month using a Kalman algorithm. The purpose of TA(NIST) was to provide a flywheel that realized our best estimate of the SI second between calibrations of our primary frequency standard, but the algorithm we have been using is not optimum for this purpose and is particularly unsuited to our new higher-accuracy environment. We therefore stopped computing TA(NIST) on 31 October 1993. We are studying alternate methods for incorporating the rate accuracy of NIST-7 into our time-scale algorithm, but no changes are likely until a thorough evaluation of the new procedure has been completed.

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

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

Month	x_{ls} (s)	x (ns)	y (ns/day)	T_0 (MJD)	Valid until 0000 on: (MJD)
Dec 96†	-30 -30	-153366 -154066.8	-43.8 -42.6	50418 50434	50434 50449
Jan 97	-30	-154705.8	-42.5	50449	50480
Feb 97	-30	-156023.3	-42.5	50480	50508
Mar 97	-30	-157213.3	-42.7	50508	50539
Apr 97	-30	-158537	-42.5	50539	50569
May 97	-30	-159812	-43.0	50569	50600
Jun 97	-30	-161145	-43.0	50600	50630
Jul 97	-31	-162435	-43.0	50630	50661
Aug 97	-31	-163768	-43.0	50661	50692
Sep 97	-31	-165101	-42.5	50692	50722
Oct 97	-31	-166376	-42.0	50722	50753
Nov 97	-31	-167678	-42.0	50753	50783
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	-41.0	51087	51118
Nov 98	-31	-182961.5	-41.5*	51118	51148

***Provisional rate**

†Note rate change in mid-month

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 call Michael Lombardi at (303) 497-3212, or write to: Michael Lombardi, NIST, Division 847, 325 Broadway, Boulder, CO 80303.

WWVB 60 kHz UPGRADE INFORMATION

As of 19 December, WWVB has been radiating 23 kilowatts of power, up from the previous value of 10 kilowatts. Due to mechanical problems associated with antenna tuning, the radiated power may be reduced on rare occasions to 10 kilowatts for periods of a few hours.

You can obtain current information about WWVB on the Internet at

http://www.boulder.nist.gov/timefreq/wwvstatus.htm