**NIST TIME AND FREQUENCY BULLETIN**
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## 1. GENERAL BACKGROUND INFORMATION

### ACRONYMS AND ABBREVIATIONS 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 and 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 |

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

## 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 | | | |
|---|---|---|---|
| JUN 2000 | MJD | UT1-UTC(NIST) (±5 ms) | UTC(USNO,MC) - UTC(NIST) (±20 ns) |
| 1 | 51696 | +215 ms | 15 ns |
| 8 | 51703 | +211 ms | 16 ns |
| 15 | 51710 | +206 ms | 21 ns |
| 22 | 51717 | +207 ms | 24 ns |
| 29 | 51724 | +204 ms | 28 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.

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 = | +0.4 s beginning 0000 UTC 14 October 199<br>+0.3 s beginning 0000 UTC 06 January 2000<br>+0.2 s beginning 0000 UTC 13 April 2000 |

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 |
|---|---|---|
| Jul 30, 1999 | 51389 | -1 |
| Aug 9, 1999 | 51399 | -2 |
| Aug 19, 1999 | 51409 | 4 |
| Aug 29, 1999 | 51419 | 12 |
| Sep 8, 1999 | 51429 | 15 |
| Sep 18, 1999 | 51439 | 13 |
| Sep 28, 1999 | 51449 | 15 |
| Oct 8, 1999 | 51459 | 9 |
| Oct 18, 1999 | 51469 | 9 |
| Oct 29, 1999 | 51479 | 10 |
| Nov 7, 1999 | 51489 | 7 |
| Nov 17, 1999 | 51499 | 6 |
| Nov 27, 1999 | 51509 | -1 |
| Dec 7, 1999 | 51519 | -1 |
| Dec 17, 1999 | 51529 | -5 |
| Dec 27, 1999 | 51539 | -3 |
| Jan 6, 2000 | 51549 | 0 |
| Jan 16, 2000 | 51559 | 2 |
| Jan 26, 2000 | 51569 | 0 |
| Feb 5, 2000 | 51579 | 6 |
| Feb 15, 2000 | 51589 | 5 |
| Feb 25, 2000 | 51599 | 7 |
| Mar 6, 2000 | 51609 | 8 |
| Mar 16, 2000 | 51619 | 15 |
| Mar 26, 2000 | 51629 | 15 |
| Apr 5, 2000 | 51639 | 20 |
| Apr 15, 2000 | 51649 | 20 |
| Apr 25, 2000 | 51659 | 17 |
| May 5, 2000 | 51669 | 17 |
| May 15, 2000 | 51679 | 17 |
| May 25, 2000 | 51689 | 18 |

## 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 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, 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 (DANA) (8970) | LORAN-C (FALLON) (9940) |
| 06/01/00 | 51696 | 5.63 | +43 | +227 |
| 06/02/00 | 51697 | 5.59 | +384 | +76 |
| 06/03/00 | 51698 | 5.60 | +487 | -373 |
| 06/04/00 | 51699 | 5.60 | (-) | +23 |
| 06/05/00 | 51700 | 5.60 | -283 | +63 |
| 06/06/00 | 51701 | 5.70 | -137 | +280 |
| 06/07/00 | 51702 | 5.68 | +462 | -319 |
| 06/08/00 | 51703 | 5.70 | +134 | +147 |
| 06/09/00 | 51704 | 5.70 | -65 | +475 |
| 06/10/00 | 51705 | 5.71 | +396 | +346 |
| 06/11/00 | 51706 | 5.72 | -467 | +125 |
| 06/12/00 | 51707 | 5.72 | -170 | +328 |
| 06/13/00 | 51708 | 5.72 | +316 | +518 |
| 06/14/00 | 51709 | 5.72 | -672 | -13 |
| 06/15/00 | 51710 | 5.71 | -400 | -297 |
| 06/16/00 | 51711 | 5.72 | -108 | +245 |
| 06/17/00 | 51712 | 5.71 | +50 | -326 |
| 06/18/00 | 51713 | 5.71 | +367 | +356 |
| 06/19/00 | 51714 | 5.71 | +389 | -180 |
| 06/20/00 | 51715 | 5.73 | -243 | +96 |
| 06/21/00 | 51716 | 5.69 | -63 | -368 |
| 06/22/00 | 51717 | 5.70 | -358 | -509 |
| 06/23/00 | 51718 | 5.71 | -93 | +272 |
| 06/24/00 | 51719 | 5.71 | +530 | -531 |
| 06/25/00 | 51720 | 5.71 | -507 | -304 |
| 06/26/00 | 51721 | 5.71 | -340 | -196 |
| 06/27/00 | 51722 | 5.72 | -362 | +174 |
| 06/28/00 | 51723 | 5.73 | +42 | -120 |
| 06/29/00 | 51724 | 5.73 | -434 | +374 |
| 06/30/00 | 51725 | 5.73 | +191 | +448 |

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

| WWVB 60 kHz | OUTAGES OF 5 MINUTES OR MORE | | | | | | PHASE PERTURBATIONS 2 ms | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Station | JUN 2000 | MJD | Began UTC | Ended UTC | Freq. | | JUN 2000 | MJD | Began UTC | End UTC |
| WWVB | 6-9-00 | 51704 | 2200 | 2230 | 60 kHz | | | | | |
| WWVB | 6-15-00 | 51710 | 1940 | 2020 | 60 kHz | | | | | |
| WWVB | 6-24-00 | 51719 | 2310 | | 60 kHz | | | | | |
| WWVB | 6-25-00 | 51720 | | 0020 | 60 kHz | | | | | |
| WWV | 6-26-00 | 51721 | 2315 | 2340 | 20 MHz | | | | | |
| 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-7 was the U.S. primary standard from 1994 to 1999, when it was replaced by NIST-F1, a cold atom cesium fountain frequency standard. The uncertainty of NIST-F1 is currently 1 part in 1015.

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 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


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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. 453-4 (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) |
|---|---|---|---|---|---|
| Aug 98 | -32 | -179174.0 | -41.0 | 51025 | 51057 |
| Sep 98 | -32 | -180445.0 | -41.0 | 51057 | 51087 |
| Oct 98 | -32 | -181675.0 | -41.5 | 51087 | 51118 |
| Nov 98 | -32 | -182961.5 | -41.5 | 51118 | 51148 |
| Dec 98 | -32 | -184206.5 | -41.5 | 51148 | 51179 |
| Jan 99 | -32 | -185493.0 | -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 | -189183.0 | -40.0 | 51269 | 51299 |
| May 99 | -32 | -190383.0 | -41.0 | 51299 | 51330 |
| Jun 99 | -32 | -191654.0 | -41.0 | 51330 | 51360 |
| Jul 99 | -32 | -192884.0 | -41.0 | 51360 | 51391 |
| Aug 99 | -32 | -194155.0 | -41.0 | 51391 | 51422 |
| Sep 99 | -32 | -195426.0 | -40.5 | 51422 | 51452 |
| Oct 99 | -32 | -196641.0 | -40.5 | 51452 | 51483 |
| Nov 99 | -32 | -197896.5 | -40.0 | 51853 | 51513 |
| Dec 99 | -32 | -199096.5 | -40.0 | 51513 | 51533† |
| Dec 99 | -32 | -199896.5 | -41.0 | 51533 | 51544 |
| Jan 00 | -32 | -200347.5 | -40.5 | 51544 | 51575 |
| Feb 00 | -32 | -201603.0 | -40.5 | 51575 | 51604 |
| Mar 00 | -32 | -202777.5 | -40.5 | 51604 | 51635 |
| Apr 00 | -32 | -204033.0 | -40.5 | 51635 | 51665 |
| May 00 | -32 | -205248.0 | -40.5 | 51665 | 51696 |
| Jun 00 | -32 | -206495.75 | -40.25 | 51696 | 51725†† |
| Jul 00 | -32 | -207663.0 | -40.0 | 51725†† | 51757 |
| Aug 00 | -32 | -208943.0 | -39.5* | 51757 | 51788* |

**† 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

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