**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 | h | - hour |
| VLF | - very low frequency | d | - day |

| DEC 1996 | MJD | UT1 − UTC(NIST) (±5 ms) | UTC − UTC(NIST) (±0.1 μs) | UTC(USNO,MC) − UTC(NIST) (±0.02 μs) |
|---|---|---|---|---|
| 26 | 50443 | −103 ms | 0.0 μs | 24 ns |

**NOTE:** There was an error in UTC(USNO,MC) − UTC(NIST) for 11/28. It should have been +5.

## 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 ±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, 31 December 1972-1979, 30 June 1981-1983, 30 June 1985, 31 December 1987, 1989, 1990, and 1995, 30 June 1992, 1993, and 1994. Advance notice of leap seconds will be provided in the bulletin.

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 =
0.0 s beginning 0000 UTC 03 October 1996
−0.1 s beginning 0000 UTC 05 December 1996
−0.2 s beginning 0000 UTC 06 February 1997

## 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 nanoseconds). 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.**

| DATE | MJD | UTC(NIST)-WWVB(60 kHz) ANTENNA PHASE (μs) | UTC(NIST) - LORAN PHASE (ns) LORAN-C (DANA) (8970) | LORAN-C (FALLON)* (9940) |
|---|---|---|---|---|
| 12/01/96 | 50418 | 5.71 | +733 | +67 |
| 12/02/96 | 50419 | 5.72 | −356 | +10 |
| 12/03/96 | 50420 | 5.73 | −330 | +136 |
| 12/04/96 | 50421 | 5.73 | +50 | −80 |
| 12/05/96 | 50422 | 5.74 | +316 | +109 |
| 12/06/96 | 50423 | 5.76 | −208 | −74 |
| 12/07/96 | 50424 | 5.76 | −228 | +786 |
| 12/08/96 | 50425 | 5.75 | +111 | −493 |
| 12/09/96 | 50426 | 5.74 | +293 | +129 |
| 12/10/96 | 50427 | 5.74 | −403 | +135 |
| 12/11/96 | 50428 | 5.74 | −180 | +30 |
| 12/12/96 | 50429 | 5.76 | +642 | −414 |
| 12/13/96 | 50430 | 5.68 | −573 | +340 |
| 12/14/96 | 50431 | 5.69 | +465 | −63 |
| 12/15/96 | 50432 | 5.70 | −168 | −249 |
| 12/16/96 | 50433 | 5.70 | +246 | −14 |
| 12/17/96 | 50434 | 5.68 | −556 | −210 |
| 12/18/96 | 50435 | 5.69 | −44 | +146 |
| 12/19/96 | 50436 | 5.63 | −108 | −242 |
| 12/20/96 | 50437 | 5.60 | −682 | −272 |
| 12/21/96 | 50438 | 5.65 | +92 | +571 |
| 12/22/96 | 50439 | 5.63 | +414 | +221 |
| 12/23/96 | 50440 | 5.62 | +33 | −316 |
| 12/24/96 | 50441 | 5.70 | +277 | +94 |
| 12/25/96 | 50442 | 5.70 | +215 | −21 |
| 12/26/96 | 50443 | 5.71 | −260 | −194 |
| 12/27/96 | 50444 | 5.70 | −478 | +96 |
| 12/28/96 | 50445 | 5.71 | +335 | +195 |
| 12/29/96 | 50446 | 5.71 | +411 | −98 |
| 12/30/96 | 50447 | 5.72 | +118 | −333 |
| 12/31/96 | 50448 | 5.73 | −77 | +210 |

## 5. GOES TIME CODE INFORMATION

A. TIME CODE PERFORMANCE (1-31 December 1996)

GOES/East:
Currently using the GOES-8 satellite at 75° west longitude. Timing uncertainty is $\pm 100\ \mu s$ with respect to UTC(NIST).

A GOES/East stationkeeping manuever was performed on December 10th at 1800 UTC.

GOES/West:
Currently using the GOES-9 satellite at 135° west longitude. Timing uncertainty is $\pm 100\ \mu s$ with respect to UTC(NIST).

| Station | DEC. 1996 | MJD | Began UTC | Ended UTC | Freq. | | DEC. 1996 | MJD | Began UTC | End UTC |
|---|---|---|---|---|---|---|---|---|---|---|
| WWVB | 12/10 | 50427 | 1820 | 1910 | 60 kHz | | | | | |
| WWV | 12/26 | 50443 | 0100 | 0145 | 2.5,5,10,15 20 MHz | | | | | |
| WWVH | | | | | | | | | | |

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 $\pm 2$ 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.

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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

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

| Month | $x_{ls}$ (s) | x (ns) | y (ns/day) | $T_0$ (MJD) | Valid until 0000 on: (MJD) |
|---|---|---|---|---|---|
| Mar 95 | −29 | −125360 | −45.0 | 49777 | 49808 |
| Apr 95 | −29 | −126755 | −44.0 | 49808 | 49838 |
| May 95 | −29 | −128075 | −43.0 | 49838 | 49869 |
| Jun 95 | −29 | −129408 | −43.0 | 49869 | 49899 |
| Jul 95 | −29 | −130698 | −43.0 | 49899 | 49930 |
| Aug 95 | −29 | −132031 | −43.0 | 49930 | 49961 |
| Sep 95 | −29 | −133364 | −43.0 | 49961 | 49991 |
| Oct 95 | −29 | −134654 | −43.5 | 49991 | 50022 |
| Nov 95 | −29 | −136003 | −44.0 | 50022 | 50052 |
| Dec 95 | −29 | −137323 | −44.0 | 50052 | 50083 |
| Jan 96 | −30 | −138687 | −43.5 | 50083 | 50114 |
| Feb 96 | −30 | −140035 | −43.5 | 50114 | 50143 |
| Mar 96 | −30 | −141297 | −43.5 | 50143 | 50174 |
| Apr 96 | −30 | −142645 | −43.5 | 50174 | 50204 |
| May 96 | −30 | −143950 | −43.5 | 50204 | 50235 |
| Jun 96 | −30 | −145299 | −43.5 | 50235 | 50265 |
| Jul 96 | −30 | −146604 | −44.0 | 50265 | 50296 |
| Aug 96 | −30 | −147968 | −44.5 | 50296 | 50327 |
| Sep 96 | −30 | −149347 | −44.5 | 50327 | 50357 |
| Oct 96 | −30 | −150682 | −44.0 | 50357 | 50388 |
| Nov 96 | −30 | −152046 | −44.0 | 50388 | 50418 |
| Dec 96† | −30<br>−30 | −153366<br>−154066.8 | −43.8<br>−42.6 | 50418<br>50434 | 50434<br>50449 |
| Jan 97 | −30 | −154705.8 | −42.5 | 50449 | 50480 |
| Feb 97 | −30 | −156023.3 | −42.5* | 50480 | 50508 |

†Note rate change in mid-month

## 9. 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.