WUN ARCHIVE
STANDARD FREQUENCY AND TIME SIGNAL STATIONS ON LF AND HF
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Standard frequency and time signal stations on LF and HF, pt.1

Welcome to the first part of a series about Time and Frequency Stations on LF and HF. This month you'll find a frequency list and a general introduction to these stations. During the next few months, we will highlight a bunch of the stations.

Special thanks to Klaus Betke for his research, Stan Skalsky, Kevin Carey, Terry Krey, and Dave Mills. Also thanks to the Institute of Meteorology for Time and Space (Russia), BIPM Bureau International des Poids et Mesures (France) and NIST National Institute of Standards and Technology (USA) for their time, help and the huge amount of info.

Introduction
Exact time intervals are needed for navigation and surveying, in science and engineering. In the past, HF radio signals were often the only way to calibrate a clock onboard a ship or a frequency standard in a laboratory. In the age of GPS satellites and portable atomic clocks, however, time and frequency distribution via HF has become largely obsolete. New applications like network synchronization require an accuracy that cannot be met by HF signals. Moreover, the transmission scheme of most stations and the peculiarity of shortwave propagation make these signals less suitable for automatic, unattended reception. Consequently, many time signal stations have disappeared.

In former times, coastal radio stations also transmitted time signals on their CW frequencies. Although numerous of these services to mariners are still listed in, you will hardly find an active one.

Still of interest to a broader public are the stations with continuous voice announcement of time, as WWV, CHU or YVTO (to our sorrow there is no such station in Europe!). These can be monitored with a common broad- cast receiver, which however should be fitted for the lower shortwave range.

Even an increase of popularity can be stated for time signals on LW. Clocks with built-in receiver for DCF77 or WWVB are very common now. For example, in Germany you can buy a DCF77-controlled alarm clock for less than 20 DM (13 US$). In order to provide a more reliable dissemination of time, WWVB has currently been upgraded from 13 kW to 40 kW transmitting power, and the antenna has been redesigned. A new LF time signal station is currently under construction in Japan. It will replace the "experimental station" JG2AS on 40 kHz in early 1999.

Beside the time information, these LF stations can provide the engineer with an "aging-free" frequency standard 24 hours a day. Although a 10 MHz oscillator locked to WWVB or MSF may be less stable than a GPS-controlled device, it is accurate enough for most calibration purposes. Furthermore, it is inexpensive and fairly easy to build, even for the electronics hobbyist.

Another longwave signal that can be used for timekeeping is the LORAN-C navigation system. The trick of LORAN-C is its special coding scheme, which enables the receiver to separate the ground wave part of the signal from the skywave. Since the ground wave is not affected by ionospheric fluctuations, a LORAN-controlled clock can be 3 orders of magnitude more accurate than a device locked to WWVB or DCF77. Many LORAN-C stations are synchronized to UTC. However, they do not transmit any time code.
UTC can thus be extracted from LORAN-C only with the aid of additional data.

Frequently Asked Questions

Is Coordinated Universal Time (UTC) the same thing as Greenwich Mean Time (GMT)?

Greenwich Mean Time (GMT) is a 24 hour astronomical time system based on the local time at Greenwich, England. GMT can be considered equivalent to Coordinated Universal Time (UTC) when fractions of a second are not important. However, by international agreement, the term UTC is recommended for all general timekeeping applications, and use of the term GMT is discouraged.

Why is the abbreviation for Coordinated Universal Time "UTC"?

In 1970 the Coordinated Universal Time system was devised by an international advisory group of technical experts within the International Telecommunication Union (ITU). The ITU felt it was best to designate a single abbreviation for use in all languages in order to minimize confusion. Since unanimous agreement could not be achieved on using either the English word order, CUT, or the French word order, TUC, a compromise of using neither, UTC, was adopted.

What is a Modified Julian Date (MJD)?

This is a continuous count of the number of days elapsed since 17 Nov. 1858. It is often more useful than conventional calendar dates for record keeping over long periods of time, since the MJD's of two events can easily be subtracted to determine the time difference in days. Usually, the MJD is specified as a number with 5 significant digits. As an example, the MJD for 1 January 1995 is 49718, meaning that this many days have elapsed between 17 Nov. 1858 and 1 Jan.1995.

What is a leap second?

A leap second is a second added to Coordinated Universal Time (UTC) to make it agree with astronomical time to within 0.9 second. UTC is an atomic time scale, based on the performance of atomic clocks. Astronomical time is based on the rate of rotation of the earth. Since atomic clocks are more stable than the rate at which the earth rotates, leap seconds are needed to keep the two time scales in agreement. The first leap second occurred on June 30, 1972. There have been a total of 11 leap seconds at this writing (1996). This means that leap seconds occur at a rate of slightly less than one per year. Although it is possible to have a negative leap second (a second removed from UTC), so far, all leap seconds have been positive (a second has been added to UTC). Based on what we know about the earth's rotation, it is unlikely that we will have a negative leap second in the foreseeable future.

Why do we need leap seconds?

Occasional leap seconds are introduced into the UTC time system by international agreement for keeping the atomic-based time scale in approximate agreement with the astronomical time scale, UT1, which is based on the rotation of the earth. Even though the atomic UTC time scale is much more uniform than the UT1 scale, some users must work with earth-based time. For example, boaters navigating by using celestial navigation, need to know the UT1 time of their observations. Since only UTC time is normally broadcast by time-and-frequency radio stations such as WWV, the broadcasters agreed to occasionally adjust UTC time in steps of exactly 1 second so that the difference between UTC and UT1 would never exceed 0.9 seconds. Thus, celestial navigators could then use the received UTC signals and know that any errors with respect to UT1 would be less than 1 second. Leap seconds have been inserted as needed into the UTC time scale since 1972 at average intervals slightly longer than one year.

Will there ever be a negative leap second?

In order for a "negative" leap second to be required at some point in the future, the rate of the earth-based UT1 time scale will have to increase significantly with respect to the stable UTC atomic time scale. While it is theoretically possible for the speed of rotation of the earth to change in such a manner, it is not considered very likely based on experience.

How often do leap seconds occur?

This depends on the difference in rate between atomic clocks and the earth's rotation and how this difference varies over long periods of time. Since the start of the new UTC system in 1972, about 20 leap seconds have been inserted as of 1995.

Is the year 2000 a leap year?

The year 2000 will be a leap year. Century years (like 1900 and 2000) are leap years only if they are evenly divisible by 400. Therefore, 1700, 1800, and 1900 were not leap years, but the year 2000 will be a leap year. To understand this, you need to know why leap years are necessary in the first place. Leap years are necessary because the actual length of a year is 365.242 days, not 365 days, as commonly stated. Therefore, on years that are evenly divisible by 4 (like 1992, for example) an extra day is added to the calendar on Febr 29th. However, since the year is slightly less than 365.25 days long, adding an extra day every 4 years results in about 3 extra days being added over a period of 400 years. For this reason, only 1 out of every 4 century years is considered as a leap year.

What is an atomic clock?

An atomic clock is a clock that keeps time using natural characteristic frequencies of atoms, such as cesium, hydrogen, or rubidium. Atomic clocks are extremely stable because the frequencies are almost unaffected by factors like temperature, pressure, or humidity.

List of standard frequency and time signal stations

The following list is based on various publications (see below). In addition, we have tried to check as much as possible by own observations, especially on the Russian stations, where most of the available literature turned out to be inaccurate. Up-to-date information on the following stations is still missing: BPM on 2500 kHz, HD2IOA on 5000 and 7600 kHz, ex UQC3 on 25 kHz, VNG on 2500, 5000 and 16000 kHz.

(kHz Callsign: Station. Mode, time of transmission; identification. Remarks)

17.4	NTD: Yoshima, Japan
21.4	NSS: Annapolis, Maryland, USA
22.3	NCW: NW Cape, Australia
23.4	NPM: Lualualei, Hawaii, USA
24	NAA: Cutler, Maine, USA
24.8	NLK: Jim Creek, Washington
25	RJH63: Unid, CIS, Europe. CW + FSK, Winter 0906-0940, 1706-1740, Summer 0806-0840, (2006-2040); Morse id in min. 06. Notes 1 & 2
25	RJH66 (formerly USB2): Bishkek, KGZ. CW, Winter 0406-0447, 1606-1647, Summer 0306-0347, 0906-0947, (1906-1947), no transmission on the 6., 16. and 26. of each month; Morse id in minute 06. Notes 1 & 3
25	RJH69 (formerly UNW3): Molodechno, BLR. CW, Winter 0706-0747, 1306-1347, Summer 0606-0647, (1206-1247), no transmission on the 2., 12. and 22. of each month; Morse id in minute 06. Notes 1 & 3
25	RJH77 (formerly UPD8): Arkhangelsk, RUS. CW, Winter 1106-1147, 2106-2147, Summer 0206-0247, (1006-1047), no transmission on the 4., 14. and 24. of each month; Morse id in minute 06. Notes 1 & 3
25	RJH99 (formerly UTR3): Nizhny Novgorod, RUS. CW, Winter 0506-0547, 1906-1947, Summer 0406-0447, (1806-1847) no transmission on the 8., 18. and 28. of each month; Morse id in minute 06. Notes 1 & 3
25	RJH?? (formerly UQC3): Khabarovsk, RUS. CW. Status unknown. Note 3
28.5	NCA: Aguada, Puerto Rico
40	JG2AS: Sanwa, J. CW, continuous; morse id in minute 15 and 45. Note 4
60	MSF: Rugby, G. CW, continuous. Note 4
60	WWVB: Ft. Collins, Co, USA. CW, continuous. Note 4
66.7	RBU: Moscow, RUS. AM, cont. Exact freq. is 200/3 kHz. Note 4
75	HBG: Prangins, SUI. CW, continuous. Note 4
77.5	DCF77: Mainflingen, D. CW + PSK, continuous. Notes 4 & 6
100	LORAN-C navigation stations
162	Telediffusion Francaise (TDF), F. PSK, continuous. Broadcast station; Note 4.
2500	BPM: Xi'an, CHN. CW, 0900-0100; Morse and voice id in min. 29 and 59
2500	ULA4 (formerly RCH): Tashkent, UZB. CW, 0500-0400 except minute 28 and 58; Morse id in minute 29 and 59
2500	WWV: Ft. Collins, Co, USA. AM, continuous; announcement in minute 00 and 30. Notes 4 & 5
2500	WWVH: Kekaha, HWA. AM, continuous; announcement in minute 29 and 59. Notes 4 & 5
3330	CHU: Ottawa, CAN. AM (USB), continuous; announcement every minute. Notes 4 & 5
3810	HD2IOA: Guayaquil, EQA. AM (LSB), 0000-1200?; announcement in minute 59. Note 5
4996	RWM: Moscow, RUS. CW, continuous except minute 08 and 38; Morse id in minute 09 and 39.
5000	BPM: Xi'an, CHN. CW, continuous; Morse and voice id in min. 29 and 59
5000	BSF: Chung-Li, TWN. AM, continuous except xx35-xx40; Morse & voice id in minute 09, 19, 29, 49, 59 (not at 39)
5000	HD2IOA: Guayaquil, EQA. AM, 1200-1300?; announcement in minute 59
5000	HLA: Taejon, KOR. AM, Monday-Friday 0100-0800; announcement in minute 00 and 30. Note 4

5000 IAM: Rome, I. AM, Monday-Friday Winter 0730-0830, 1030-1130, Summer 0630-0730, 0930-1030; Morse id in minute 05, 20, 35, 50, voice announcement in minute 00, 15, 30, 45
5000 JJY: Sanwa, J. CW, continuous exept xx35-xx39; Morse & voice id in minute 09, 19, 29, 39, 49, 59
5000 ULA4 (formerly RCH): Tashkent, UZB. CW, 0500-0400 except minute 28 and 58; Morse id in minute 29 and 59
5000 VNG: Llandilo (Penrith), AUS. AM, cont.; announcement in minute 00, 15, 30, 45
5000 WWV: Ft. Collins, Co, USA. AM, continuous; announcement in minute 00 and 30. Notes 4 & 5
5000 WWVH: Kekaha, HWA. AM, continuous; announcement in minute 29 and 59. Notes 4 & 5
5000 YVTO: Caracas, VEN. AM (USB), cont.; announcement every minute. Note 5
7335 CHU: Ottawa, CAN. AM (USB), cont.; announcement every minute. Notes 4 & 5
7600 HD2IOA: Guayaquil, EQA. AM, 1300-2400?; announcement in minute 59
8000 JJY: Sanwa, J. CW, continuous exept xx35-xx39; Morse & voice id in minute 09, 19, 29, 39, 49, 59
8638 VNG: Llandilo (Penrith), AUS. AM, continuous; Morse id in minute 14, 29, 44, 59. Note 4
9996 RWM: Moscow, RUS. CW, continuous except minute 08 and 38; Morse id in minute 09 and 39
10000 BPM: Xi'an, CHN. CW, continuous; Morse and voice id in min. 29 and 59
10000 JJY: Sanwa, J. CW, continuous exept xx35-xx39; Morse & voice id in minute 09, 19, 29, 39, 49, 59
10000 ULA4 (formerly RCH): Tashkent, UZB. CW, 0500-0400 except minute 28 and 58; Morse id in minute 29 and 59
10000 WWV: Ft. Collins, Co, USA. AM, cont.; announcement in minute 00 and 30. Notes 4 & 5
10000 WWVH: Kekaha, HWA. AM, cont.; announcement in minute 29 and 59. Notes 4 & 5
12984 VNG: Llandilo (Penrith), AUS. AM, continuous; Morse id in minute 14, 29, 44, 59. Note 4
14670 CHU: Ottawa, CAN. AM (USB), continuous; announcement every minute. Notes 4 & 5
14996 RWM: Moscow, RUS. CW, cont. except minute 08 and 38; Morse id in minute 09 and 39
15000 BPM: Xi'an, CHN. CW, 0100-0900; Morse and voice id in min. 29 and 59
15000 BSF: Chung-Li, TWN. AM, cont. except xx35-xx40; Morse & voice id in minute 09, 19, 29, 49, 59 (not at 39)
15000 WWV: Ft. Collins, Co, USA. AM, cont.; announcement in minute 00 and 30. Notes 4 & 5
15000 WWVH: Kekaha, HWA. AM, cont.; announcement in minute 29 and 59. Notes 4 & 5
16000 VNG: Llandilo (Penrith), AUS. AM, 2200-1000; announcement in minute 00, 15, 30, 45. Notes 4 & 5
20000 WWV: Ft. Collins, Co, USA. AM, cont.; announcement in minute 00 and 30. Notes 4 & 5

Notes:
1. Currently (Summer 1997) no transmission during time slot in brackets.
2. xx06-xx20 time signal on 25.0 kHz, xx21-xx23 unmodulated carrier on 25.1 kHz, xx24-xx26 on 25.5 kHz, xx27-xx31 on 23.0 kHz, xx32-xx36 on 20.5 kHz, xx36-xx40 FSK 50 bd (unknown system) on 20.5 kHz.
3. xx06-xx25 time signal on 25 kHz, xx27-xx30, unmod. carrier on 25.1 kHz, xx32-xx35 on 25.5 kHz, xx38-xx41 on 23.0 kHz, xx44-xx47 on 20.5 kHz.
4. Station transmits binary-coded time and date.
5. Voice announcement of time every minute.
6. The well-known "noisy" sound of the DCF77 signal is caused by the pseudo-random phase-shift keying (PSK).

Some former stations and frequencies

ATA	Delhi, IND	5000, 10000, 15000 kHz
GBR	Rugby, G	16 kHz
FFH	Paris, F	2500 kHz
FTH42	Paris, F	7428 kHz
FTK77	Paris, F	10775 kHz
FTN87	Paris, F	13873 kHz
IBF	Torino, I	5000 kHz
JJY	Sanwa, J	2500, 15000 kHz
LOL	Buenos Aires, ARG	5000, 10000, 15000 kHz
MSF	Rugby, G	2500, 5000, 10000 kHz
OLB5	Prague, CZR	3170 kHz
OMA	Prague, CZR	50, 2500 kHz
RID	Irkutsk, RUS	5004, 10004, 15004 kHz
RTA	Novosibirsk, RUS	10000, 15000 kHz
RTZ	Irkutsk, RUS	50 kHz
WWV	Ft. Collins, CO, USA	25000 kHz
WWVL	Ft. Collins, CO, USA	20 kHz
Y3S	Nauen, DDR	4525 kHz
ZUO	Pretoria, AFS	2500, 5000 kHz

The "Deutsche Hydrographische Institut" DHI, transmitted time signals at various times via Norddeich Radio and Kiel Radio.

Standard frequency and time signal stations on LF and HF, pt.2

This month the second part of a series about Time and Frequency Stations on LF and HF. This month we will focus on the US stations.

The following information is published with kind permission of the U.S. Naval Observatory (USNO) and the National Institute of Standards and Technology (NIST). Thanks for your co-operation gentlemen!

USNO - Timekeeping at the U.S. Naval Observatory
In 1845, at the request of the Secretary of the Navy, the Observatory installed a TIME BALL atop the 9.6-inch telescope dome. The time ball was dropped every day precisely at Noon, enabling the inhabitants of Washington to set their timepieces. Ships in the Potomac River could also set their clocks before putting to sea. The Observatory's Time Service was initiated in 1865. A time signal was transmitted via telegraph lines to the Navy Department, and also activated the Washington fire bells at 0700, 1200, and 1800. This service was later extended via Western Union telegraph lines to provide accurate time to railroads across the nation. The Observatory participated in a program of determining longitude by comparing local time with that telegraphed from a clock at another fixed observatory, and thus exchanged time signals with other observatories and with the Coast Survey field parties.

Beginning in 1934, the Observatory determined time with a PHOTOGRAPHIC ZENITH TUBE (PZT), a specialized instrument that points straight upward toward the zenith and automatically photographs selected stars crossing the zenith. This gave a measure of the Greenwich Mean Time (now called Universal Time), the "time of day" based on the rotation of the Earth. Improvements in clock technology, including the Shortt free-pendulum clock and quartz crystal clocks, soon proved conclusively that the Earth's rotation was not uniform, and a new uniform time scale known as EPHEMERIS TIME came into use in 1956.

Defined by the orbital motion of the Earth about the Sun, in practice Ephemeris time was determined by observations of the Moon, first undertaken with the dual rate moon camera, invented by William Markowitz at the Naval Observatory in 1951. In 1984 the family of time scales known as DYNAMICAL TIME replaced Ephemeris time as the time based on the motion of celestial bodies according to the theory of gravitation, now taking relativistic effects into account. In the meantime, the development of atomic clocks brought about the introduction of a much more accessible time - the Atomic time scale based on the vibration (an energy level transition) of the cesium atom.

In 1958 the Naval Observatory and Britain's NATIONAL PHYSICAL LABORATORY published the results of joint experiments that defined the relation between Atomic time and Ephemeris time. (An interesting scientific and philosophical question is whether the relationship between Atomic time and gravitational time remains constant.) Since 1967 the international definition of the second has been based on these joint experiments. Atomic time is kept synchronized with universal time by the addition or subtraction of a leap second whenever necessary.

Time dissemination has also been continuously improved. In 1904 a naval radio station transmitted the first radio time signals ever; they were derived from a U.S. Naval Observatory clock. This was the beginning of a system of radio time, constantly improved and increasingly automated through the century, that now spans the globe. The function of rating, repairing and disseminating chronometers and other nautical instruments, a major and especially critical effort during World War II, was transferred from the Observatory to the Optical Section of the Norfolk Naval Shipyard in Portsmouth, Virginia in 1950.

The U.S. Naval Observatory continues to be the leading authority in the United States for astronomical and timing data required for such purposes as navigation at sea, on land, and in space, as well as for civil affairs and legal matters. Its current Mission Statement, promulgated in 1984 by the Chief of Naval Operations, reads: "To determine the positions and motions of celestial bodies, the motions of the Earth, and precise time. To provide the astronomical and timing data required by the Navy and other components of the Department of Defense for navigation, precise positioning, and command, control, and communications. To make these data available to other government agencies and to the general public. To conduct relevant research; and to perform such other functions or tasks as may be directed by higher authority."

The U.S. Naval Observatory carries out its primary functions by making regular observations of the Sun, Moon, planets, selected stars, and other celestial bodies to determine their positions and motions; by deriving precise time interval (frequency), both atomic and astronomical, and managing the distribution of precise time by means of timed navigation and communication transmissions and portable clocks; and by deriving, publishing, and distributing the astronomical data required for accurate navigation, operational support, and fundamental positional astronomy. In addition, the U.S. Naval Observatory conducts the research necessary to improve both the accuracy and the methods of determining and providing astronomical and timing data.

By a Department of Defense directive, the U.S. Naval Observatory is charged with maintaining the DOD REFERENCE STANDARD FOR PRECISE TIME AND TIME INTERVAL (PTTI). The Superintendent is designated as the DoD PTTI Manager. The U.S. Naval Observatory has developed the world's most accurate atomic clock system. Increasingly accurate and reliable time information is required in many aspects of military operations. Modern navigation systems depend on the availability and synchronization of highly accurate clocks. This holds for such ground-based systems as LORAN-C as well as for the Department of Defense satellite-based NAVSTAR Global Positioning System (GPS). In the communications and the intelligence fields, time synchronized activities are essential. The U.S. Naval Observatory MASTER CLOCK is the time and frequency standard for all of these systems. Thus, that clock system must be at least one step ahead of the demands made on its accuracy, and developments planned for the years ahead must be anticipated and supported.

The Master Clock system now incorporates hydrogen masers, which in the short term are more stable than cesium beam atomic clocks, and mercury ion frequency standards, which are more stable in the long run. These represent the most advanced technologies available to date. Highly accurate portable atomic clocks have been transported aboard aircraft in order to synchronize the time at Naval Bases and other Department of Defense facilities around the world with the Master Clock. Accurate time synchronization with the Master Clock is now beginning to be carried out through the use of atomic clocks in satellites, such as the GPS satellites, which will provide the primary means of time synchronization and worldwide time distribution in the future.
<text: Dr. Steven Dick, Time Service Dept., U.S. Naval Observatory>

NIST Time and Frequency Services
Precise time and frequency information is needed by electric power companies, radio and television stations, telephone companies, air traffic control systems, participants in space exploration, computer networks, scientists monitoring data of all kinds, and navigators of ships and planes. These users need to compare their own timing equipment to a reliable, internationally recognized standard. The National Institute of Standards and Technology (NIST), formerly the National Bureau of Standards, provides this standard for most users in the United States.

NIST began broadcasting time and frequency information from radio station WWV in 1923. Since then, NIST has expanded its time and frequency services to meet the needs of a growing number of users. NIST time and frequency services are convenient, accurate, and easy to use. They contribute greatly to the nation's space and defense programs, to manufacturers, and to transportation and communications. In addition, NIST services are widely used by the general public.

Broadcast services include radio signals from NIST radio stations WWV, WWVH, and WWVB; the GOES satellites, and Loran-C. Services are also available using telephone voice and data lines.

NIST operates two high-frequency (shortwave) radio stations, WWV and WWVH. WWV is in Ft. Collins, Colorado, and WWVH is in Kauai, Hawaii. Both stations broadcast continuous time and frequency signals on 2.5, 5, 10, and 15 MHz. WWV also broadcasts on 20 MHz. All frequencies provide the same information. Although radio reception conditions in the high-frequency band vary greatly with factors such as location, time of year, time of day, the particular frequency being used, atmospheric and ionospheric propagation conditions, and the type of receiving equipment used, at least one frequency should be usable at all times. As a general rule, frequencies above 10 MHz work best in the daytime, and the lower freqs work best at night.

WWV, Fort Collins, Colorado, USA
2.5 MHz, 2.5 kW / 5.0 MHz, 10 kW / 10.0 MHz, 10 kW / 15.0 MHz, 10 kW / 20.0 MHz, 2.5 kW

WWVH, Kauai, Hawaii
2.5 MHz, 5 kW / 5.0 MHz, 10 kW / 10.0 MHz, 10 kW / 15.0 MHz, 10 kW

WWVB, Fort Collins, Colorado, USA
60 kHz, 13 kW

Services provided by WWV and WWVH include:

- Time announcements
- Standard time intervals
- Standard frequencies
- UT1 time corrections
- BCD time code
- Geophysical alerts
- Marine storm warnings
- OMEGA Navigation System status reports (now deleted -Ary-)
- Global Positioning System (GPS) status reports

Notes on Audio Tones
Beginning of each hour is identified by 0.8-second-long, 1500-Hz tone. Beginning of each minute is identified by 0.8-second-long tone, WWV: 1000-Hz, WWVH: 1200-Hz. The 29th and 59th second pulses of each minute are omitted. 440-Hz tone is omitted during first hour of each day.

WWV & WWVH
Accuracy and stability
WWV and WWVH are referred to the primary NIST Frequency Standard and related NIST atomic time scales in Boulder, Colorado. The frequencies is transmitted are accurate to about 1 part in 100 billion (1 x 10^-11) for frequency and about 0.01 ms for timing. The day-to-day deviations are normally less than 1 part in 1,000 billion (1 x 10^-12). However, the received accuracy is far less due to various propagation effects. The usable received accuracy is about 1 part in 10 million for freq. (1 x 10^-7) and about 1 ms for timing.

Radiated power, antennas, and modulation
WWV and WWVH radiate 10,000 W on 5, 10, and 15 MHz. The radiated power is lower on the other frequencies: WWV radiates 2500 W on 2.5 and 20 MHz while WWVH radiates 5000 W on 2.5 MHz and does not broadcast on 20 MHz.

The WWV antennas are half-wave dipoles that radiate omnidirectional patterns. The 2.5-MHz antenna at WWVH is also of this type. The other antennas at WWVH are phased vertical half-wave dipole arrays. They radiate a cardioid pattern with maximum gain pointed toward the west.

Both stations use double sideband amplitude modulation. The modulation level is 50 percent for the steady tones, 25 percent for the BCD time code, 100 percent for the seconds pulses and the minute and hour markers, and 75 percent for the voice announcements.

WWVB

Radio station WWVB is located on the WWV site near Ft. Collins, Colorado. WWVB continuously broadcasts time and freq signals at 60 kHz, primarily for the continental United States. WWVB does not broadcast voice announcements, but provides standard time information, including the year; time intervals; Daylight Saving Time, leap second, and leap-year indicators; and UT1 corrections by means of a BCD time code. In addition, the 60-kHz carrier freq provides an accurate freq standard which is referenced to the NIST Frequency Standard.

Accuracy and stability

The transmitted accuracy of WWVB is normally better than 1 part in 100 billion (1 x E-11). Day-to-day deviations are less than 5 parts in 1000 billion (5 x E-12). The BCD time code can be received and used with an accuracy of approximately 0.1 ms. Propagation effects are minor compared to those of WWV and WWVH. When proper receiving and averaging techniques are used, the received accuracy of WWVB should be nearly as good as the transmitted accuracy.

Station identification

WWVB identifies itself by advancing its carrier phase 45ø at 10 minutes after the hour and returning to normal phase at 15 minutes after the hour. WWVB is also identified by its unique time code.

Radiated power and antenna

The effective radiated power from WWVB is 13,000 watts. The antenna is a 122-m, top-loaded vertical, installed over a radial ground screen.

WWVB time code

The WWVB time code is synchronized with the 60 kHz carrier and is broadcast continuously at a rate of 1 pulse per second using pulse-width modulation. Each pulse is generated by reducing the carrier power 10 dB at the start of the second, so that the leading edge of every negative going pulse is on time. Full power is restored either 0.2, 0.5, or 0.8 s later to convey either a binary "0", "1", or a position marker, respectively. Details of the time code are in appendix C.

Time Announcements

Voice announcements are made from WWV and WWVH once every minute. Since both stations can be heard in some locations, a man's voice is used on WWV, and a woman's voice is used on WWVH to reduce confusion. The WWVH announcement occurs first, at about 15 s before the minute. The WWV announcement follows at about 7.5 s before the minute. Though the announcements occur at different times, the tone markers are transmitted at the exact same time from both stations. However, they may not be received at exactly the same instant due to differences in the propagation delays from the two station sites.

The announced time is "Coordinated Universal Time" (UTC). UTC was established by international agreement in 1972, and is governed by the International Bureau of Weights and Measures (BIPM) in Paris, France. Coordination with the international UTC time scale keeps NIST time signals in close agreement with signals from other time and frequency stations throughout the world.

UTC differs from your local time by a specific number of hours. The number of hours depends on the number of time zones between your location and the location of the zero meridian (which passes through Greenwich, England). When local time changes from Daylight Saving to Standard Time, or vice versa, UTC does not change. However, the difference between UTC and local time does change-by 1 hour.

UTC is a 24-hour clock system. The hours are numbered beginning with 00 hours at midnight through 12 hours at noon to 23 hours and 59 minutes just before the next midnight.

The international agreement that established UTC in 1972 also specified that occasional adjustments of exactly 1 s will be made to UTC so that UTC should never differ from a particular astronomical time scale, UT1, by more than 0.9 s. This was done as a convenience for some time-broadcast users, such as boaters using celestial navigation, who need to know time that is based on the rotation of the Earth. These occasional 1-s adjustments are known as "leap seconds." When deemed necessary by the International Earth Rotation Service in Paris, France, the leap seconds are inserted into UTC, usually at the end of June or at the end of December, making that month 1 s longer than usual. Typically, a leap second has been inserted at intervals of 1 to 2 years. (See also: "UT1 Time Corrections," and appendix A).

Standard Time Intervals

The most frequent sounds heard on WWV and WWVH are the seconds pulses. These pulses are heard every second except on the 29th and 59th seconds of each minute. The first pulse of each hour is an 800-ms pulse of 1500 Hz. The first pulse of each minute is an 800-ms pulse of 1000 Hz at WWV and 1200 Hz at WWVH. The remaining seconds pulses are short audio bursts (5-ms pulses of 1000 Hz at WWV and 1200 Hz at WWVH) that sound like the ticking of a clock.

Each seconds pulse is preceded by 10 ms of silence and followed by 25 ms of silence. The silence makes it easier to pick out the pulse.

Standard Audio Frequencies

In alternate minutes during most of each hour, 500Hz or 600-Hz audio tones are broadcast. A 440-Hz tone (the musical note A above middle C) is broadcast once each hour. In addition to being a musical standard, the 440-Hz tone provides an hourly marker for chart recorders and other automated devices. The 440-Hz tone is omitted, however, during the first hour of each UTC day.

Silent Periods

The silent periods are without tone modulation. However, the carrier freq, seconds pulses, time announcements, and the 100-Hz BCD time code continue during the silent periods. In general, one station will not broadcast an audio tone while the other station is broadcasting a voice message.

On WWV, the silent period extends from 43 to 46 and from 47 to 52 mins after the hour. WWVH has two silent periods; from 8 to 11 mins after the hour, and from 14 to 20 mins after the hour. Mins 29 and 59 on WWV and mins 00 and 30 on WWVH are also silent.

BCD Time Code

WWV and WWVH continuously broadcast a binary coded decimal (BCD) time code on a 100-Hz subcarrier. The time code presents UTC information in serial fashion at a rate of 1 pulse per second. The information carried by the time code includes the current minute, hour, and day of year. The time code also contains the 100-Hz frequency from the subcarrier. The 100-Hz frequency may be used as a standard with the same accuracy as the audio frequencies. More information about the time code format is given in appendix B.

Official Announcements

Announcement segments 45 s long are available by subscription to other Federal agencies. These segments are used for public service messages. The accuracy and content of these messages is the responsibility of the originating agency.

Geophysical Alerts

Current geophysical alerts (Geoalerts) are broadcast in voice from WWV at 18 minutes after the hour and from WWVH at 45 minutes after the hour. The messages are less than 45 s in length and are updated every 3 hours (typically at 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 UTC). Hourly updates are made when necessary.

PART A of the message gives the solar-terrestrial indices for the day: specifically the 1700 UTC solar flux from Ottawa, Canada, at 2800 MHz, the estimated A-index for Boulder. Colo., and the current Boulder K-index.

PART B gives the solar-terrestrial conditions for the previous 24 hours.

PART C gives optional information on current conditions that may exist (that is, major flares, proton or polar cap absorption [PCA] events, or stratwarm conditions).

PART D gives the expected conditions for the next 24 hours. For example:

A. "Solar-terrestrial indices for 26 October follow: Solar flux 173 and estimated Boulder A-index 20; repeat: Solar flux one-seven-three and estimated Boulder A-index two-zero. The Boulder K-index at 1800 UTC on 26 October was four; Repeat: four."
B. "Solar-terrestrial conditions for the last 24 hours follow: Solar activity was high. Geomagnetic field was unsettled to active.
C. "A major flare occurred at 1648 UTC on 26 October. A satellite proton event and PCA are in progress."
D. "The forecast for the next 24 hours follows: Solar activity will be moderate to high. The geomagnetic field will be active."

Marine Storm Warnings

Marine storm warnings are broadcast for the marine areas that the United States has warning responsibility for under international agreement. The storm warning information is provided by the National Weather Service. Storm warnings for the Atlantic and eastern North Pacific are broadcast by voice on WWV at 8, 9, and 10 minutes after the hour. Storm warnings for the western, eastern, southern, and north Pacific are broadcast by WWVH at 48, 49, 50, and 51 minutes after the hour. An additional segment (at 11 minutes after the hour on WWV and at 52 minutes after the hour on WWVH) is used occasionally if there are unusually widespread storm conditions. The brief voice messages warn mariners of storm threats present in their areas.

The storm warnings are based on the most recent forecasts. Updated forecasts are issued by the National Weather Service at 0500, 1100, 1700, and 2300 UTC for WWV; and at 0000, 0600, 1200, and 1800 UTC for WWVH.

A typical storm warning announcement text is as follows: "North Atlantic weather West of 35 West at 1700 UTC; Hurricane Donna, intensifying, 24 North, 60 West, moving northwest, 20 knots, winds 75 knots; storm, 65 North, 35 West, moving east, 10 knots; winds 50 knots, seas 15 ft."

Global Positioning System (Gps) Status Announcement

Since March 1990 the U.S. Coast Guard has sponsored two voice announcements per hour on WWV and WWVH, giving current status information about the GPS satellites and related operations. The 45-s announcements begin at 14 and 15 minutes after each hour on WWV and at 43 and 44 minutes after each hour on WWVH.

Appendix A: Dating Of Events In The Vicinity Of Leap Seconds
Leap seconds are sometimes needed to keep UTC within +0.9 s of UT1. The addition or deletion of a leap second always occurs at the end of a month. By international agreement, first preference is given to December 31 or June 30. Second preference is given to March 31 or September 30, and third preference is given to any other month.

When UDT1 is slow relative to UTC, a positive leap second is needed. The second is inserted beginning at 23h 59m 60s of the last day of the month and ending at 0h 0m 0s of the first day of the following month. The minute containing the leap second is 61 s long.

Since UTC has historically run faster than UT1, only positive leap seconds have been needed thus far. However, if the speed of the Earth's rotation were to increase to the point where UTl runs faster than UTC, a negative leap second would be needed. In that case, exactly 1 s would be deleted at the end of some UTC month. The minute containing the negative leap second would be only 59 s long.

Appendix B.: WWV/WWVH Time Code
The WWV/WWVH time code is a modified version of the IRIG-H code. The code is transmitted on a 100-Hz subcarrier at a rate of 1 pulse per second. The code is in binary coded decimal (BCD) format. Groups of binary digits (bits) are used to represent decimal numbers. The binary-to-decimal weighting scheme is 1-2-4-8. The least significant bit is always sent first. Table 2 shows the BCD groups and the equivalent decimal number.

The decimal number is obtained by multiplying each bit in the binary group by the weight of its respective column and then adding the four products together. For example, the table shows that the binary group 1010 is equal to 5. This is derived by: (1x1) + (0x2) + (1x4) + (0x8) = 1 + 0 + 4 + 0 = 5

In the standard IRIG-H code, a "0" bit consists of exactly 20 cycles of 100-Hz amplitude modulation (20 -ms duration), and a "1" bit consists of 50 cycles of 100-Hz (500-ms duration). The WWV/ WWVH code differs from IRIG-H because all tones are suppressed briefly while the seconds pulses are transmitted.

Tone suppression also deletes the first 30 ms of each binary pulse in the time code. This makes the WWV/WWVH bits 30 ms shorter than the IRIG-H bits. Therefore, 170-ms pulses are recognized as "0" bits, and 470 ms pulses are recognized as "1" bits. The leading edge of each pulse coincides with the positive-going crossing of the 100-Hz sub-carrier, but due to the tone suppression, it occurs 30 ms after thestart of the second.

Within 1 minute, enough bits are sent to express the minute, hour, and day of year; two digits of the current year (to be implemented during the first half of 1991); a leap-second warning indicator (to be implemented during the first half of 1991); the UT1 correction, and a Daylight Saving Time (DST) indicator. The coded time information refers to the time at the start of the one-minute frame. Seconds are determined by counting pulses within the frame. Two BCD groups are needed to express the hour (00 to 23), minute (00 to 59), and year (00-99); and three groups are needed to express the day of year (001 to 366). Some bits in the BCD groups are unused, but may provide additional information in the future. To represent units, tens, or hundreds, the basic 1-2-4-8 weights are multiplied by 1, 10, or 100 as appropriate.

Each frame begins with a unique spacing of pulses that mark the start of a new minute. During the first second of the minute, no pulse is transmitted. This creates a 1-s (1000-ms) hole. Since the pulses are already delayed 30 ms by the tone suppression, the UTC minute actually begins 1030 ms (1.03 s) earlier than the first pulse in the frame.

For synchronization purposes, a position identifier pulse is transmitted every 10 s. The position identifier pulse lasts for 770 ms (77 cycles of 100 Hz).

UT1 corrections are sent during the final 10 s of each frame. These corrections are to the nearest 0.1 s. The UT1 correction is expressed with bits called control functions. Control function #1 occurs at 50 s, and tells whether the UT1 correction is negative or positive. If a "0" bit is sent the correction is negative, and if a "1" bit is sent the correction is positive. Control functions #7, #8, and #9, tell the amount of the UT1 correction. They occur at 56, 57, and 58 s, respectively. Since the UT1 corrections are in tenths of seconds, the binary-to-decimal weights are multiplied by 0.1.

Currently (late 1990), DST information is sent only by control function #6, at 55 s. If DST is in effect, a "1" bit is sent. If Standard Time is in effect, a "0" is sent. The setting of this bit is changed a few hours prior to 0000 UTC on the date of change. This schedule notifies users in the continental United States of the time change several hours before it occurs locally (usually at 2:00 a.m.). Receivers that display local time can read control function #6 and make the one-hour adjustment automatically when time changes occur.

Appendix C: WWVB Time Code

The WWVB time code is also sent in BCD format, but the weighting is different from the WWV/WWVH weighting. Bits are sent by shifting the power of the 60 kHz carrier. The carrier power is reduced 10 dB at the start of each second. If full power is restored 200 ms later, it represents a "0" bit. If full power is restored 500 ms later, it represents a "1" bit. Reference markers and position identifiers are sent by restoring full power 800 ms later.

The decimal number is obtained by multiplying each bit in the binary group by the weight of its respective column and then adding the four products together. For example, the table shows that the binary group 0101 is equal to 5. This is derived by: (0x8) + (1x4) + (0x2) + (1x1) = 0 + 4 + 0 + 1 = 5

Every minute, the WWVB time code sends the current minute, hour, day of year, 2 digits of the current year, a UT1 correction, a leap-second warning bit, and Daylight Saving Time (DST) and leap year indicators. Two BCD groups are needed to express the hour (00 to 23), minute (00 to 59), and year (00-99); and three groups are needed to express the day of year (001 to 366). Some bits in the BCD groups are unused, but may provide additional information in the future. To represent units, tens, or hundreds, the basic 8-4-2-1 weights are simply multiplied by 1, 10, or 100 as appropriate. The coded information refers to the time at the start of the one-minute frame. Seconds are determined by counting pulses within the frame.

Each minute begins with a frame reference pulse lasting for 0.8 s. A position identifier pulse lasting for 0.8 s is transmitted every ten s.

UT1 corrections are broadcast at seconds 36 through 43 of each frame. These corrections are to the nearest 0.1 s. The bits transmitted at seconds 36, 37, and 38 show if UT1 is positive or negative with respect to UTC. If "1" bits are sent at seconds 36 and 38, the UT1 correction is positive. If a "1" bit is sent at second 37, the UT1 correction is negative. The amount of the UT1 correction is sent in a four-bit BCD group at seconds 40, 41, 42, and 43. The binary-to-decimal weights are multiplied by 0.1, because the UT1 corrections are expressed in tenths of seconds.

The WWVB time code also contains information about leap years, DST, and leap seconds. The leap year bit is transmitted at second 55. If it is set to "1", the current year is a leap year. The bit is set to "1" during each leap year sometime after January 1 but before February 29. It is set back to "0" shortly after January 1 of the year following the leap year. Receivers that read this bit can automatically adjust them-selves during leap years. The two DST bits are sent at 57 and 58 s after each minute. If "Standard" time is in effect, both bits (#57 and #58) are set to 0. If DST is in effect, both bits are set to 1. On the day of change from "Standard" to DST bit #57 is changed from "0" to "1" at 0000 UTC. Exactly 24 hours later, bit #58 also changes from "0" to "1" at 0000 UTC. On the day of change from DST back to "Standard" time bit #57 goes from "1" to "0" at 0000 UTC, followed 24 hours later by bit #58. Receivers displaying local time can read the DST bits and make the one-hour adjustment automatically when time changes occur locally.

Bit #56 is used to warn users that a leap second will be inserted into the UTC(NIST) time scale at the end of the current month. The bit is set to "1" near the beginning of the month in which a leap second is added. It is reset to "0" immediately following the leap second insertion.

Appendix D: Goes Satellite Time Code

The GOES time code is interlaced with interrogation messages used for other purposes. The interrogation messages are broadcast at a rate of 100 bits per second. They are one-half second, or 50 bits in length. The first 4 bits of the message form a BCD time-code word. The remaining 46 bits do not contain timing information.

A time-code frame consists of 60 BCD time-code words. It takes 60 interrogation messages, or 30 s, to complete a time-code frame. The completed time-code frame contains a synchronization word, the last two digits of the current year, the time-of-year (day of year, hour, and minute), time-code accuracy indicators, Daylight Saving Time (DST) and leap second indicators, system status information, the UT1 correction, and the satellite's position. The position info is updated every minute. It includes the satellite's latitude, longitude, and height above the Earth's surface.

Appendix E: Time-Code Format For Automated Computer Time Service (Acts)

The time code for ACTS is sent in ASCII at either 300 or 1200 Baud. Both Baud rates require 8 data bits, 1 stop bit, and no parity.

The first part of the time code contains the Modified Julian Date (MJD), the date (year, month, day), and the time (UTC hours. minutes. and seconds). This information is followed by the Daylight Saving Time (DST) information. The DST code is always a two-digit number (00 to 99). This code is normally a 00 when Standard Time (ST) is in effect, or a 50 when DST is in effect. About 48 days prior to a time change, however, this code starts counting the days until the change. When ST is in effect, the DST code counts down from 99 to 51 in the 48 days prior to the time change. When DST is in effect, the DST code counts down from 49 to 01 in the 48 days prior to the time change. In both cases, the code is updated at 0000 UTC.

The leap second (LS) flag is always a "0", a "1", or a "2". If no leap second is scheduled at the end of the current month, it is a "0". It is a "1" if a (positive) leap second is scheduled to be added on the last day of the current month. The LS flag remains on for the entire month before the leap second is added. Once the leap second is added, the LS flag is reset to "0". The leap second flag is a "2" only if a (negative) leap second is to be deleted on the last day of the current month. So far, a negative leap second has never been needed.

The UT1 correction is shown as either a positive or negative number in steps of 0.1 s.

The remainder of the time code shows the ms advance (msADV) and the on-time marker (OTM). The displayed time is valid at the OTM. The OTM is either a "*" or a "#" character. When the connection is established, the "*" OTM is displayed. This marker is transmitted 45 ms early with respect to UTC(NIST). The 45 ms accounts for the 8 ms required to send 1 character at 1200 Baud, an additional 7 ms to compensate for delay from NIST to the user, plus a 30-ms "scrambler" delay. The "scrambler" delay approximately compensates for the internal delay found in 1200-Baud modems.

If the user's equipment is set to echo all characters, or at least the OTM, NIST measures the round-trip delay and advances the OTM so that the midpoint of the stop bit arrives at the user's computer on time. When this happens, the msADV shows the actual required advance in ms and the OTM becomes a "#". Four consecutive stable measurements are needed before the OTM switches from "*" to "#". If the user's

1200-Baud modem has the same internal delay used by MST (30 ms), then the "#" OTM should arrive at the user's location within +/- 2 ms of the correct time. Different brands of 1200 Baud modems have different internal delays, and the actual offset of the "#" OTM may be as large as +/- 10 ms. This should still be more than adequate, however, since many computer clocks can only be set within 20-50 ms.

The 300-Baud time code includes less information than the 1200-Baud code, but is more accurate. At 300 Baud, the MJD and DUT1 values are deleted and the time is sent every 2 s with the OTM referring to the even-numbered second. Due to a simpler modulation scheme, the OTM should arrive at the user's computer within 1 ms of the correct time.

Users are allowed 56 s on ACTS unless all lines are busy. In that case, the first call that reaches 28 s is terminated.

Frequently Asked Questions

When I listen to WWV, how accurate is the time?
The WWV time signal as transmitted from the Ft. Collins, CO, station site is accurate within a few millionths of a second with respect to the UTC (NIST) time scale. However, as the signal travels from the station to your location, it may be reflected from the earth's ionosphere and suffer other degrading propagation effects. As a result, the usable accuracy of the signal at your location may not be better than a few thousandths of a second at best. If you listen to the WWV time signal by telephone, the accuracy may also be affected by the time it takes for the signal to travel from Boulder, CO, to your location. Generally, the accuracy over the telephone should not be worse than about 40 thousandths of a second.

What other kinds of information are available on WWV in addition to the voice time announcements?
WWV (and WWVH) also broadcasts precise 1 second time intervals (the interval between the "ticking sounds" you hear), complete time info in coded form; standard audio frequencies of 440, 500, and 600 Hz; info on the current difference between the UT1 and UTC time scales; standard RF carrier frequencies; and public service announcements in co-operation with other government agencies relating to marine storm warnings for selected areas of the Atlantic and Pacific Ocean areas, geophysical alert information, and status information about the Global Positioning System. In addition there are station-identification announcements twice each hour.

Why are the time announcements on WWV done by a male voice and on WWVH by a female voice?
The antenna system of WWVH in Hawaii is especially designed to minimize radiation back toward the U.S. mainland in order to prevent mutual interference with WWV on the same frequencies. However, interference sometimes occurs under favorable propagation conditions. Often in the nighttime hours, it is possible to hear both stations simultaneously. To aid users in differentiating between the two stations, male and female voices are used.

Standard frequency and time signal stations on LF and HF, pt.3

Time and Standard Frequency Station DCF77
Physikalisch-Technische Bundesanstalt (PTB) Braunschweig, Febuar 1984 Lab 1.21, Bundesalle 100, D-3300 Braunschweig Translated from German by Peter Lamb, Swiss Fed. Inst. of Technology.

The 1978 law on time standards defines legal time in Germany on the basis of Coordinated World Time (UTC) and gives the PTB responsibility for the keeping and broadcasting of legal time. As well as this, the time standards law empowers the Federal government to issue regulations for the introduction of Summer Time.

Legal time in Germany is either Middle European Time (MEZ in German) or, in case of its introduction Middle European Summer Time (MESZ). The following relationships hold between UTC and MEZ and MESZ.

MEZ(D) = UTC(PTB) + 1h
MESZ(D) = UTC(PTB) + 2h

Legal time is generated in the PTB Atomic Clock Building in Braunschweig and it is broadcast mainly through the LF transmitter DCF77 which the PTB rents from the German Post Office (DBP). The PTB has sole responsibility for the control of DCF77, while the DBP has responsibility for the transmitter and antennas.

DCF77 Specifications

Location:	Mainflingen transmitter complex, (50:01N, 09:00E), ca. 25km south-east of Frankfurt am Main.
Carrier Frequency:	Standard frequency 77.5kHZ, derived from the PTB atomic clocks. Relative deviation of the carrier from specifications: averaged over 1d: <1e-12 and averaged over 100d: <2e-13. The carrier phase is controlled so that deviations relative to UTC(PTB) are never greater than +-0.3us. Larger phase and frequency variation observed at the receiver are due to summation of ground and space waves.
Power output:	Transmitter power 50kw, estimated emitted power approx. 25kW.
Antenna:	150m high (backup antenna 200m high) vertical omnidirectional antenna with top capacitance.

Transmissions: 24-hour continuous service. Short interruptions (of a few minutes) are possible if, because of technical problems or servicing, the service must be switched to a backup transmitter or antenna. Thunderstorms can cause longer interruptions to the service. Time signal: The carrier is amplitude-modulated with second marks. At the beginning of each second (with the exception of the 59th second of each minute), the carrier amplitude is reduced to 25% for the duration of either 0.1 or 0.2 seconds. The start of the carrier reduction marks the precise beginning of the second. The minute is marked by the absence of the previous second mark.

The second marks are phase-synchronous with the carrier. There is a relatively large uncertainty possible in the time of the second mark which depends on the receiver position. The causes are the relatively low bandwidth of the antenna, space wave and other interference sources. Despite this, it is possible to achieve accuracy better than 1ms at distances of several hundred kilometers.

Time code:
The transmission of the numerical values for minute, hour, day, weekday, month and year are BCD-encoded through the pulse duration modulation of the second marks. A second mark with duration 0.1s encodes a binary 0 and a duration of 0.2s encodes 1. The order of encoding is shown in the following diagram [replaced by a table in this translation]. The three test bits P1, P2 and P3 extend the 3 major sections of the time code (7 bits for minutes, 6 bits for the hour and 22 bits for the date, including the week day number) to maintain an even count of 1's.

The second marks No. 17 and 18 indicate the time system for the transmitted time codes. In the case of transmission of MEZ, mark 18 has a duration of 0.2s and mark 17 a duration of 0.1s. If MESZ is being transmitted, this is reversed. Furthermore, an approaching transition from MEZ to MESZ or back is announced by extending mark 16 from 0.1 to 0.2s for one hour prior to the changeover.

Encoding Scheme

Mark number(s)	Encodes (01.s=0, 0.2s=1)
0	Minute, always 0 (0.1s)
1-14	Reserved
15	0=Normal antenna, 1=backup antenna
16	1=Approaching change from MEZ to MESZ or back
17,18	Time zone 0,1=MEZ; 1,0=MESZ
19	The leap second is encoded in this bit one hour prior to occurrence.
20	Start bit for encoded time, always 1
21-27	1, 2, 4, 8, 10, 20, 40 Minutes (mark 21=1 minute)
28	P1 maintains even parity for marks 21-28
29-34	1,2,4,8,10,20 Hours (mark 29=1 hour)
35	P2 maintains even parity for marks 29-35
36-41	Day in month (1, 2, 4, 8, 10, 20)
42-44	Day in week (1,2,4)
45-49	Month number (1, 2, 4, 8, 10)
50-57	Year (1, 2, 4, 8, 10, 20, 40, 80)
58	P3 maintains even parity for marks 36-58 There is no mark transmitted for the 59th second.

Additional information: DCF77

Since July 1983, the DCF77 carrier has been phase modulated in a test configuration. The phase modulation is a pseudorandom binary sequence sent twice each second. The clock frequency of the binary sequence is 645.833...Hz and the phase shift \Delta\tau about 3% of the period (\^{=} 10\deg). Equal numbers of shifts of +\Delta\tau and -\Delta\tau are always sent, so that the mean frequency remains unchanged, and the use of DCF77 as a frequency standard is unaffected. The timecode is encoded in the sequence by inverting the sequence or not. Not inverted sequence corresponds to a 0 bit. The sequence is alleged to be generated by a 9 bit shift register which is coupled back on positions 5 and 9. The polynomial might be: x^9 + x^4 + 1.

Because the pseudo-random bitstring has a strictly deterministic nature, the correlation analysis at the receiver end leads to a correlation function with triangular form, and thereby to timing information. Early test results show that the time information received with the help of pseudo-random phase modulation is more resistant to interference and more accurate (standard deviation \approx 10\mu s during the day and \approx 25\mu s at night) than the conventional method using amplitude modulated second marks. Since this new modulation method is compatible with previous usage of DCF77, and that the users have made no difficulties known to us, the tests have been extended. The transmission of the pseudo-random phase distortion still has experimental status, and should not be seen as a permanent commitment. Further information will be made available in the future.

Announcement bit for a leap second

The DCF77 control unit is currently being modified so that in future an announcement bit for a leap second can be sent. It is expected that for the first time on 1st July 1985 the second mark Nr. 19 will be extended to a length of 0.2s for one hour prior to the introduction of a leap second. Intelligent receivers will then be able to recognise the discontinuity and maintain correct indicated time in spite of a 61s minute.

Canada's Time Service

Introduction

The demands of science have pushed the capabilities for accurate time and frequency determination to very high levels that can meet almost all requirements. Accuracy levels are available in Canada that might appear excessively high for everyday applications, yet provide an economical basis for many modern systems of navigation and communication; for international acceptance of Canadian quality control measurements; and for measurements in diverse fields such as radio astronomy, spectroscopy, geodesy, length measurement, voltage measurement, broadcasting and much electronics manufacturing and testing.

There are also the more obvious requirements for time coordination: in radio and television networks, in automated data recording systems and in computer-controlled systems and networks. Quite apart from technical interests, part of the general public now demands time-of-day service accurate to the second for their quartz watches and clocks.

In Canada, the National Research Council (NRC) is the federal agency responsible for official time. Through the Time Standards group of its Institute for National Measurement Standards, NRC tries to satisfy requirements for time at all levels of precision, down to milliseconds and even to nanoseconds. It endeavours to make this service available throughout Canada, in some cases as a free public service, and in other cases on a fee-for-service basis.

Irrespective of the precision of the time obtained, NRC time is referred to its primary cesium atomic clocks, designed, built, and maintained at the NRC time standards laboratory in Ottawa. These clocks are used in conjunction with atomic clocks in the time laboratories of other countries to construct the internationally accepted scale of time, UTC (Coordinated Universal Time), which is now the reference for the official time used by all countries. UTC is the modern implementation of Greenwich mean time, incorporating the unequalled stability of atomic clocks. UTC is kept within a second of the time kept by the vastly more irregular rotation of the Earth by the use of a leap second, if required, at 00:00 UTC January 1 or July 1.

As a major contributor in the development of atomic clocks, NRC has played a significant role in the regulation of UTC through international organizations since well before the present implementation of UTC in 1972.

Time Of Day Announcements

Both the English and French radio networks of the Canadian Broadcasting Corporation carry the NRC time signal once per day, the former at 13:00 and the latter at 12:00 noon Eastern Standard or Daylight Time.

Short Wave Radio Time Signals

Time accuracy superior to telephone time accuracy is available throughout Canada and in many other parts of the world by means of NRC's radio time signals broadcast continuously from short wave radio station CHU. If corrections are made for the propagation delay from CHU to the user, and for delays in the user's receiver, an accuracy of better than 1 ms can be obtained. Signal availability at a user's location depends on ionospheric conditions. CHU also broadcasts a time code which can be decoded with common computers and modems.

Three frequencies are used: 3330, 7335, and 14670 kHz. The transmission mode, upper single sideband with carrier re-inserted, provides time signal service without requiring a special SSB radio, and also provides three standard frequencies. The frequencies are derived from one of a trio of closely synchronized atomic clocks located at the transmitter site. Three clocks are employed to permit majority logic checking. CHU time signals are also derived from these clocks. The clocks at the CHU transmitter site, about 20 km from NRC's time laboratory, are compared daily with the NRC primary cesium clocks.

The CHU station is located 15 km southwest of Ottawa at 45o 17' 47" N, 75o 45' 22" W. Main transmitter powers are 3 kW at 3330 and 14670 kHz, and 10 kW at 7335 kHz. Individual vertical antennas are used for each frequency. The electronics systems feeding the transmitters are duplicated for reliability, and have both battery and generator protection. The generator can also supply the transmitters. The announcements are made by a talking clock using digitally recorded voices.

Normally CHU's emission times are accurate to 10-4 s, with carrier frequency accuracy of 5x10-12, compared to NRC's primary clocks, which are usually within 10 microseconds and 1x10-13 compared to UTC. UTC is the international official time reference. It is constructed by the Bureau International des Poids et Mesures, based on the average of laboratory and commercial atomic clocks located in laboratories around the world. It is steered in frequency using the primary cesium standards (such as those at NRC) located at some of the major time laboratories. UTC loosely follows the irregularities of the astronomical time scale UT1, which is needed in astronomical observations and in celestial navigation. Since 1972, leap seconds have been used to keep UTC within 0.9 s of UT1. The difference [UT1-UTC] is called DUT1, and this fraction of a second [-0.8 s to +0.8 s] is broadcast by means of an internationally accepted code. To decode the size of DUT1, in tenths of a second, a user counts the number of emphasized seconds markers in one minute. For CHU, the emphasized seconds pulses are split, so that a double tone is heard. When the emphasis is on seconds 1 through 8, DUT1 is positive; and when DUT1 is negative, seconds 9 through 16 are used.

The complete sequence of the CHU time signals, is as follows. The first minute of each hour commences with a full 1 s pulse of 1000 Hz tone, followed by 9 s of silence, and then the normal pattern of 0.3 s pulses of 1000 Hz at one-second intervals. The normal pattern for each of the next 59 minutes starts with a 0.5 s 1000 Hz pulse, followed by the DUT1 code employing split 0.3 s pulses where required, and normal 0.3 s pulses up to and including that at 28 seconds. The pulse at 29 seconds is omitted. Following the normal pulse at 30 seconds, for a 9 s period, 1000 Hz pulses of 0.01 s occur, each followed by the CHU FSK digital time code described in CHU Broadcast Codes. The pulses between 40 and 50 seconds are of normal length. In the final 10s period of each minute a bilingual station identification and time announcement is made, with the 1000 Hz seconds pulses shortened to "ticks". Each minute's - announced time refers to the beginning of the pulse which follows. Since April 1 '90, the announced time is always UTC.

The data is in the form of an FSK data stream. The frequencies are compatible with the Bell 103 standard: 2225 Hz mark and 2025 Hz space. The carrier is active between 10 and 510 msec past the second. Each byte of data is encoded as one start bit, 8 data bits and two stop bits. there are ten bytes in each packet, and the last stop bit ends at precisely 500 msec past the second. (1 start bit + 8 data bits + 2 stop bits) x 10 characters = 110 bits. Each bit takes 1/300 of a second (300 bps). So the whole code takes 366.66... msec. 500 - 366.66... = 133.33...msec.

The data stream itself consists of ten bytes. There are two formats: format "B" for second 31 and format "A" for seconds 32 through 39. Each format has 5 bytes of data, then 5 bytes of redundancy. The "A" format redundancy bytes are exactly the same as the data bytes. The "B" format redundancy bytes are exactly inverted (one's complement, NOT, XOR 0xff, etc) from the data bytes. This is how one can tell what sort of frame was received.

Once the data is received and the redundancy bytes are checked, the next thing to do is to swap the least and most significant nibbles in each byte. After doing all of this, the frames look like this:

A frame: 6D DD HH MM SS
DDD is the day of the year. HH:MM:SS is the time UTC. 6 is a constant. Each nibble is a BCD digit.

B frame: XZ YY YY TT AA
Z is the absolute value of DUT1 in tenths of a second. YYYY is the Gregorian year, TT is the difference between TAI and UTC, AA is a byte for a code number for the daylight saving time pattern in effect at this time across all time zones of Canada. The x is coded as follows:

```
8 4 2 1
| | | |
| | | +--- The sign of DUT1 (0=+).
| | +------ Leap second warning. One second will be added.
| +--------- Leap second warning. One second will be subtracted.
+------------ Even parity bit for this nibble.
```

A sample A frame as received from the modem might look like this:

    36 95 21 51 53 36 95 21 51 53

Note that these numbers are in hex. This translates to the 359th day of the year (Dec 25, or Dec 24 in a leap year), 12:15:35 UTC.

A sample B frame as received from the modem might look like this:

    19 91 39 72 00 E6 6E C6 8D FF

This translates to a DUT1 of -0.1, year 1993, TAI-UTC=27, serial number 00 for Canada's daylight saving pattern.

Daylight Saving Time In Canada:
Clocks are turned forward by one hour on the first Sunday in April and turned back on the last Sunday of October. Most of Saskatchewan does not change their clocks. The daylight saving time code pattern #00 has been in effect since 1988 and will be in effect until further notice. If policies change the hour or date of daylight saving time in any zone, this will be documented and a new number will be assigned.

Remote Calibrations
Some Canadian calibration laboratories have received formal NRC recognition of their capabilities for time or frequency measurement under the auspices of the Calibration Laboratory Assessment Service (CLAS). Current information about these laboratories' recognized measurement capabilities may be obtained from the NRC Institute for National Measurement Standards. Accurate time comparisons between the NRC time laboratory and other locations in Canada can be arranged if a suitable common-mode signal exists. TV line 10, Loran C, and GPS signals can be used to obtain time comparisons with NRC accurate to a few tens of nanoseconds, in the most favorable cases.

Standard frequency and time signal stations on LF and HF, pt.4

Welcome to the fourth part of a series about Time and Frequency Stations on LF and HF. This month the Russian stations. Many thanks to Klaus Betke and the Institute of Meteorology for Time and Space in Moscow.

RAB99: Khabarovsk, RUS
Frequency 25.0 kHz. Former call sign UQC3. Never heard here.
Probably too weak and too far away. Not sure if it still exists.
Schedule: Winter 0206-0247, 0806-0847, 1406-1447, Summer 0106-0147, 0706-0747, 1306-1347. No transmission on the 10., 20., 30. of each month

RBU: Moscow, RUS
Frequency 66.67 kHz. Operates 24h a day, except for the 3rd Tuesday of the month between 08.00 and 16.00 UTC and the 1st Sunday in June between 08.00 and 16.00 UTC.

RJH63: Krasnodar, RUS
Frequency: 25.0 kHz.
Schedule: Winter 0906-0940, (1706-1740), Summer 0806-0840, (2006-2040). No transmission on the 3., 13., 23. of each month

RJH66: Bishkek, KGZ
Frequency 25.0 kHz, Former call sign USB2, former town name "Frunze".
According to the ITMS, the callsign is RJH86, although they transmit
RJH66. ALRS lists RJH66 as well.
Schedule: Winter 0406-0447, 1606-1607. Summer 0306-0347, 0906-0947, (1906-1947) *) No transmission on the 6., 16., 26. of each month

RJH69: Molodecno, BLR
Frequency 25.0 kHz. Former call sign UNW3.
Schedule: Winter 0706-0747, (1306-1307) *) Summer 0606-0647, (1206-1247) *) No transmission on the 2., 12., 22. of each month

RJH77: Arkhangelsk, RUS
Frequency 25.0 kHz. Former call sign UPD8.
Schedule: Winter (1106-1147), 2106-2147. Summer 0206-0247, (1006-1047) *) No transmission on the 4., 14., 24. of each month

RJH99: Nizhniy Novgorod, RUS
Frequency 25.0 kHz, Former call sign UTR3, former town name "Gorki".
According to the ITMS, the callsign is RJH90, although they transmit RJH99. ALRS lists RJH99 as well.
Schedule: Winter 0506-0547, 2106-2147, Summer 0406-0447, (1006-1047), *) No transmission on the 8., 18., 28. of each month

*) Listed by the IMTS, but obviously no transmission at that time, as of spring 1997. In case of RAB99, of course, it is unknown whether they have reduced their schedule as well. On certain days the stations do not transmit, even if it is not one of the 3 "quiet days" per month.

RID: Irkutsk, RUS
Frequencies 5004, 10004, 15004 kHz. Inoperative since the end of 1996. At times there is a signal on 5004 or 10004, but this is a spurious emission of RWM Moscow. Note: If it sounds like RWM on 4996 or 9996, it IS RWM! The schedules of RWM, RID and ULA4 are similar, but shifted against each other in time. They never transmit the same pattern at the same time.

RTZ: Irkutsk, RUS
Frequency 50 kHz. Never heard. According to the ITMS it operates 23h a day (01.00-24.00), except on the 3rd and 4th Monday of the month between 03.00 and 11.00 UTC. Not sure if it's still on the air.

RW166: Irkutsk, RUS
Frequency 198 kHz. Of course never heard here. Looks as if this is a broadcast station that an be used as a frequency standard, like Droitwich (BBC) or France Inter. It operates 24h a day, except on the 1st, 2bd and 4th Thursday of the month between 03.00-12.00 UTC.

RWM: Moscow, RUS
Frequencies 4996, 9996, 14996 kHz. Operational. 24h a day, except for the 1st Wednesday of the quarter (4996), the 2nd Wednesday (9996) and the 3rd Wednesday (14996), between 08.00 and 16.00 UTC. Easy to identify as it transmits its callsign in CW on the 8th and 38th minute.

ULA4: Tashkent, UZB
Frequencies 2500, 5000, 10000 kHz. Operational.
Times: 2500 kHz; 00.00-07.00, 08.00-24.00 UTC
5000 kHz; 00.00-07.00, 17.00-24.00 UTC
10000 kHz; 08.00-16.30 UTC
Maintenance on the 3rd Monday of the month between 04.00-14.00 UTC

Standard frequency and time signal stations on LF and HF, pt.5

Welcome to the 5th part of the TSS series. This month we focus on: VNG, HBG, HD2IOA, YVTO, HLA, JJY, JG2AS and IAM. Next month the final part.

VNG - Australia's Standard Frequency and Time Signal Service
VNG is Australia's standard frequency and time signal service. For many years people and organisations throughout Australia have made use of the timing signals broadcast by VNG. For approximately 23 years, VNG was broadcast from Lyndhurst, Victoria. It was funded by Telstra (formerly Telecom Australia) and the monitoring and research were conducted by their research laboratories at Clayton, Victoria.

In late 1986 the Precise Time Working Group (now the National Time Committee), under the auspices of the Commission, learned of the impending closure of VNG and conducted a survey to ascertain the usage of the service and the scientific and economic impact of its closure. The survey results showed that there was extensive and diverse usage of the service throughout the community; usage which, by the very nature of its application, was difficult to quantify economically.

Following the closure of VNG in October 1987, the Commission convened a seminar to investigate what provisions needed to be made for an intermediate accuracy time service and to consider the extent to which the provisions for high accuracy time comparisons were meeting Australia's needs.

Several alternatives to VNG were discussed but each was found to have significant disadvantages in terms of accessibility and cost compared with VNG's time service. It was recommended by the many participants at the meeting that VNG be reinstated; that the service be recognised as part of Australia's technological infrastructure and be funded by the Federal Government. At this time no single department or authority was identified to fund the operation of VNG.

The VNG Users Consortium was formed to re-establish VNG and to collect donations from former users to dismantle, pack and transfer the transmitting equipment to a new location. More than $10 000 was raised and the equipment was relocated to Air Services Australia's (formerly the Civil Aviation Authority) International Transmitting Station in Llandilo, NSW. The Australian Surveying and Land Information Group (AUSLIG), agreed to finance the operation of VNG on a partial cost recovery basis from users. Initially, there were both technical and licensing problems, all of which have since been resolved.

As part of its responsibility of coordinating the national measurement system, the Commission took over the funding of VNG from AUSLIG in November 1992 and on 12 January 1993 became the owner of the transmitting license. The Commission also administers the National Measurement Act 1960 and the Regulations empowered under it. These Regulations define the units of measurement used for legal purposes in Australia, including the units of measurement for time interval.

VNG Technical Details
Location
VNG is broadcast from the AirServices Australia, International Transmitting Station, located at Llandilo, NSW, position 33.42.52S, 150.47.33E.

Transmitters
The service employs STC double sideband, full carrier AM, HF broadcast transmitters. The 2.5 MHz service uses a STC 4SU55A/S transmitter whilst the 5 MHz, 8.638 MHz, 12.984 MHz and 16 MHz services employ STC 4SU48B transmitters.

Frequencies, Power and Emission Mode
The transmitter frequencies, powers and transmission modes are:
2.5 MHz 1 kW, emission mode to be advised 5 MHz 10 kW, emission mode 6K00B9W
8.638 MHz 10 kW, emission mode 3K00A1A
12.984 MHz 10 kW, emission mode 3K00A1A
16 MHz: 5 kW, emission mode 6K00B9W
Note: 8.638 MHz and 12.984 MHz are frequencies on loan from the Royal Australian Navy.

Antennae
2.5 MHz monopole (vertical antenna).
5 MHz Wells quadrant antenna.
8.638 MHz delta-matched quadrant antenna with a single wire per arm.
12.984 MHz delta-matched quadrant antenna with a single wire per arm.
16 MHz: delta-matched quadrant antenna with a single wire per arm.

Transmission Schedule
2.5 MHz, 5 MHz, 8.638 MHz, 12.984 MHz continuous. 16 MHz: 2200-1000 UTC

Voice Station Identification Announcement
This is provided on the 2.5 MHz, 5 MHz and 16 MHz services only using an AWA digital voice recorder. It is given during the 15th, 30th, 45th and 60th minutes without interruption to the time signal. The speech is "notched" to allow seconds markers to continue and has spectral components around 1000 Hz removed to avoid erroneous operation of tuned relay time circuits.

Morse Station Identification
This is provided on the 8.638 MHz and 12.984 MHz frequencies only. It is given during the 15th, 30th, 45th and 60th minutes without interruption to the time signals. VNG is transmitted in slow morse at a frequency of approximately 400 Hz up to six times per minute. Broken idents may occur at the beginning and end of the minute.

Reception Reports
All correspondence including reception report and requests for reception reports (QSLs) should be addressed to: VNG, National Standards Commission, PO Box 282, NORTH RYDE NSW 2113, Australia.
The reports should be sufficiently detailed to permit verification. Return postage, preferably in the form of an International Reply Coupon (or US$1) would be appreciated from other than VNG Users Consortium members.

Talking Clock
This gives Coordinated Universal Time as UTC(ATC) each minute, immediately after the minute marker. It operates on 2.5 MHz, 5 MHz and 16 MHz services only.

Time Delay Through Transmitters
The timing of VNG time signal pips is done prior to transmission. Users who wish to obtain the greatest accuracy could benefit by taking into account the delays introduced by the transmitters. The time delay for the 5 MHz, 8.638 MHz, 12.984 MHz and 16 MHz services is 190 æs. The delay associated with the 2.5 MHz is to be advised.

Accuracy and Traceability
The time and frequency information broadcast by VNG is traceable to the standards maintained by the Telstra Research Laboratories at Clayton, Victoria. The carrier frequencies and 1 kHz tone broadcast by VNG are within 1 part in 1011 of Telstra's frequency standard (24 hour average value).

The time interval information has the same accuracy as the carrier frequencies except for intervals which are subject to routine step adjustments.

The time of day information is maintained within 100 æs of UTC(ATC) and is typically within 10 æs of UTC(ATC). In turn UTC(ATC) is within approximately 50 æs of UTC.

Unfortunately due to effects such as ionospheric jitter the accuracy of the frequency information received from the VNG broadcasts may be degraded to around 1 part in 107. The time signal accuracy is typically of the order of 1 millisecond.

Japan: JJY and JG2AS
The CRL (Communications Research Laboratory) is responsible for determining and disseminating frequency and time standards including Japan standard time (JST).

The Japanese standard time service is transimittted on 5, 8 and 10 MHz with the callsign JJY. There is also an experimental service on 40 kHz longwave with call sign JG2AS.

A recent e-mail from CRL Japan revealed that CRL is constructing a new LF station that will start transmitting early 1999. This station will replace experimental station JG2AS in Nazaki. The new station will also have a center freq of 40 kHz and a power of 10 kW.

The Japanese Ministry of Posts and Telecommunication announced last year its decision to close down the standard time and frequency station JJY and replace it with the new longwave station in 1999. It is however still uncertain whether all HF transmissions will be silenced or just the 5 and 10 kHz transmissions. JJY is on 5 and 10 kHz often inaudible in western Japan due to severe interference from WWV, WWVH, and other time stations in Russia, South Korea, China, and Taiwan.

Italy: IAM Roma and IBF Turin
IAM Rome has been silent for a while, but now the new optical fibre landline is ready, they are back on 5000 kHz. The transmission times are 0730-0830 and 1030-1130 UTC (one hour later during summer time) on weekdays. Their address is: Ministero delle Comunicazioni, Istituto Superiore CTI, Laboratorio Frequenze Campioni, Ufficio 8 Reparto 2, viale America 201, IT-00144 Rome, Italy.

IBF Turin ceased its transmissions several years ago.

South Korea: HLA Taejon
HLA transmits on 5000 kHz, on Monday-Friday, 0100-0800 UTC. There is a voice announcement each minute between 53-58s . A binary time code is transmitted continuously on a 100 kHz subcarrier.

Switzerland: HBG Prangins
HBG tranmits continuously on 75 kHz. System: second pulses 100ms duration; minute marker: two 100ms interruptions at 00s; hour marker: three 100ms interruptions at 00m 00s; 12h marker: four 100ms interruptions at 00h 00m 00s and 12h 00m 00s. HBG transmits no id.

Ecuador: HD2IOA Guayaquil

HD2IOA transmits on 3810, 5000 and 7600 kHz. The latter two frequencies haven't been logged since late 1996. Not sure if they still exist.

Schedule: 3810 kHz, 0000-1200 UTC
5000 kHz, 1200-1300 UTC
7600 kHz, 1300-2400 UTC

There is a voice time announcement in Spanish between 52s-58s and a station id at 59m, on 3810 and 7600 kHz only.

Venezuela: YVTO Caracas

The time signals from the Observatorio Naval Caracas (YVTO) can be heard on 5000 kHz, 24h. There is station id in Spanish at 40s, each minute, and a time announcement at 52s.

Standard frequency and time signal stations on LF and HF, pt.6

This is the 6th and final part of the TSS series. I hope that you liked it. Once again I'd like to thank all members and organizations who cooperated in this project.

This month the last stations: BPM, BSF, MSF, and TDF.

China: BPM Xian
BPM transmits on 2500, 5000, 10000 and 15000 kHz in CW/AM.
Schedule: 2500 kHz, 0730-0100 UTC
5000 kHz, 24h
10000 kHz, 24h
15000 kHz, 0100-0900 UTC

Each minute, between 29-30m and 59-60m, callsign BPM is transmitted in CW, followed by a station id in Chinese (female voice).

Taiwan: BSF Chung-Li
BSF transmits continuously on 5000 and 15000 kHz. Voice and CW id in minutes 9, 19, 29, 49, 59. There is a 5 min. silence between 35-40m.

UK: MSF 60
The MSF transmission from Rugby (latitude 52ø 22' N, longitude 1ø 11' W) is the principal means of disseminating the UK national standards of time and frequency which are maintained by the National Physical Laboratory. The estimated radiated power of the MSF transmission is 27 kW and the antenna is substantially omnidirectional. The signal provides adequate field strength throughout the UK, and it can be received widely in northern and western Europe. The carrier frequency is maintained at 60 kHz to within 2 parts in 1012.

The MSF time and date code format is summarized in the diagrams above. Simple on-off carrier modulation is used, the rise and fall times of the carrier are determined by the combination of antenna and transmitter. The timing of these edges is governed by the seconds and minutes of Coordinated Universal Time (UTC), which is always within a second of Greenwich Mean Time (GMT). Every UTC second is marked by an 'off' preceded by at least 500 ms of carrier, and this second marker is transmitted with an accuracy better than ñ1 ms.

The first second of the minute nominally contains a period of 500 ms with the carrier off, to serve as a minute marker. However, for a transitional period, there may be on/off carrier modulation between 25 ms and 330 ms during second 00.

The other 59 (or, exceptionally, 60 or 58) seconds of the minute always begin with at least 100 ms 'off' and end with at least 700 ms of carrier. Seconds 01-16 carry information for the current minute about the difference between atomic and astronomical time (DUT), and the remaining seconds convey the time and date code. The time and date code information is always given in terms of UK clock time and date, and it relates to the minute following that in which it is transmitted.

The allocation of the signaling bits is detailed below and on the continuation sheet. Bits 17B-*51B inclusive, and bits 01A-*16A inclusive, are currently set to '0', but may be used in the future. Bits *52B and *59B are currently set at '0' but they may be used in the future.

Minute Identifier

Bits *53A, *54A, *55A, *56A, *57A and *58A are all set permanently at '1', and are always preceded by bit *52A at '0', and followed by bit *59A at '0'. This sequence 01111110 never appears elsewhere in bit A, so it uniquely identifies the following second 00 minute marker.

*In minutes lengthened or shortened by a positive or negative leap second all these numbers are correspondingly increased or decreased by one (i.e. during these 61- or 59-second minutes the position of the time and date code is shifted by one second relative to the start of the minute).

DUT Code

The difference between UTC and UT1 (which is closely equivalent to GMT), is known as DUT1 and is signaled to the nearest 100 ms in the range ñ800 ms. A positive figure means that GMT is at a higher count than UTC. Bits 01B-16B are used to signal the DUT code in the following way.

DUT1	**positive**	**DUT1**	**negative**
0 ms	no bits set to '1'	- 0 ms	no bits set to '1'
+100 ms	bit 01B '1'	-100 ms	bit 09B '1'
+200 ms	bits 01B and 02b '1'	-200 ms	bits 09B and 10B '1'
+300 ms	bits 01B-03B incl.'1'	-300 ms	bits 09B-11B incl.'1'
+400 ms	bits 01B-04B incl.'1'	-400 ms	bits 09B-12B incl.'1'
+500 ms	bits 01B-05B incl.'1'	-500 ms	bits 09B-13B incl.'1'
+600 ms	bits 01B-06B incl.'1'	-600 ms	bits 09B-14B incl.'1'
+700 ms	bits 01B-07B incl.'1'	-700 ms	bits 09B-15B incl.'1'
+800 ms	bits 01B-08B incl.'1'	-800 ms	bits 09B-16B incl.'1'

Time and Date Code

Binary-Coded-Decimal Year (00 - 99)

80	40	20	10	8	4	2	1
*17A	*18A	*19A	*20A	*21A	*22A	*23A	*24A

BCD Month (01-12)

10	8	4	2	1
*25A	*26A	*27A	*28A	*29A

BCD Day-of-Month (01-31)

20	10	8	4	2	1
*30A	*31A	*32A	*33A	*34A	*35A

Day-of-Week (0-6)

4	2	1
*36A	*37A	*38A

Note: for Day-of-Week, 0=Sunday to 6=Saturday

BCD Hour (00-23) BCD Minute (00-59)

20 10 8 4 2 1 40 20 10 8 4 2 1

*39A *40A *41A *42A *43A *44A *45A *46A *47A $48A *49A *50A *51A

Parity Bits
Bit *54B, taken with bits *17A-*24A incl., provides and odd number of 1's
Bit *55B, taken with bits *25A-*35A incl., provides and odd number of 1's
Bit *56B, taken with bits *36A-*38A incl., provides and odd number of 1's
Bit *57B, taken with bits *39A-*51A incl., provides and odd number of 1's

Summer Time
When UK civil time is subject to a one-hour positive offset during part of the year, this period is indicated by setting bit *58B to '1'. Bit *53B is set to '1' during the 61 consecutive minutes immediately before a change, the last being minute 59, when bit *58B changes.

In the event of UK civil time undergoing an additional permanent offset, bit *58B will need to be changed once without any corresponding change in UK clock time.

France: TDF
Information provided by Richard B. Langley, University of New Brunswick

Station:	TDF, Allouis, France
Address:	Centre National d'Etudes des Telecommunications PAB - STC - Etalons de frequence et de temps 196 avenue Henri Ravera, F - 92220 Bagneux, France
Coordinates:	47d 10' N, 2d 12' E
Frequency:	162 kHz
Power:	2,000 kW
Schedule:	continuous except every Tuesday from 01:00 to 05:00 UTC

Form of Time Signals:
TDF is an amplitude modulated longwave broadcasting station, transmitting the programs of the France-Inter Network of Telediffusion de France (TDF). Time signals are transmitted by phase modulation of the carrier by + and -1 radian in 0.1 s every second except the 59th second of each minute. This modulation is doubled to indicate binary 1. The numbers of the minute, hour, day of the month, day of the week, month and year are transmitted each minute from the 21st to the 58th second, in accordance with the French legal time scale. In addition, a binary 1 at the 17th second indicates that the local time is 2 hours ahead of UTC (i.e., summer time), a binary 1 at the 18th second indicates when the local time is 1 hour ahead of UTC (i.e., winter time). A binary 1 at the 14^{th} second indicates that the current day is a public holiday (14 July, Christmas, etc.) and a binary 1 at the 13th second indicates that the current day is the day before a public holiday.

The phase modulation pattern.
One signal element consists of the following: the phase of the carrier is advanced linearly up to +1 radian in 0.025 second, then retarded linearly up to -1 rad in 0.050 second, then advanced again to reach 0 after another 0.025 second. One signal element is always sent at each second between 0 and 58. The epoch is when the down ramp crosses zero. If a '1' bit is to be transmitted, two signal elements are sent in sequence. Since the phase is the integral of the frequency, to this triangular phase modulation corresponds a square frequency modulation with an amplitude of about + and - 6Hz.

```
                         binary '0'                      binary '1'
                          / \                       / \         / \
          phase      ___ /   \       ___       ___ /   \       /   \       ___
                               \   /                     \   /       \   /
                                \ /                       \ /         \ /

           (0.025 s     |  |  |  |  |             |  |  |  |  |  |  |  |  |
            ticks)            |                         |
                            epoch                     epoch
                         __       __               __       _____       __
                        |  |     |  |             |  |     |     |     |  |
          frequency  ___|  |     |  |___       ___|  |     |     |     |  |___
                           |     |                   |     |     |     |
                           |_____|                   |_____|     |_____|
```

Both the average phase and the average freq. deviation are thus zero. More data is sent by phase modulation during the rest of each second. But the second marker (and data bit) is always preceded by 0.1 second without modulation. There is no marker at the beginning of the 59th second, nor any data sent during the entire duration of that second.

The binary encoding of date and time data.
Seconds 20 to 58 carry exactly the same information as the signal of the German transmitter DCF77.

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