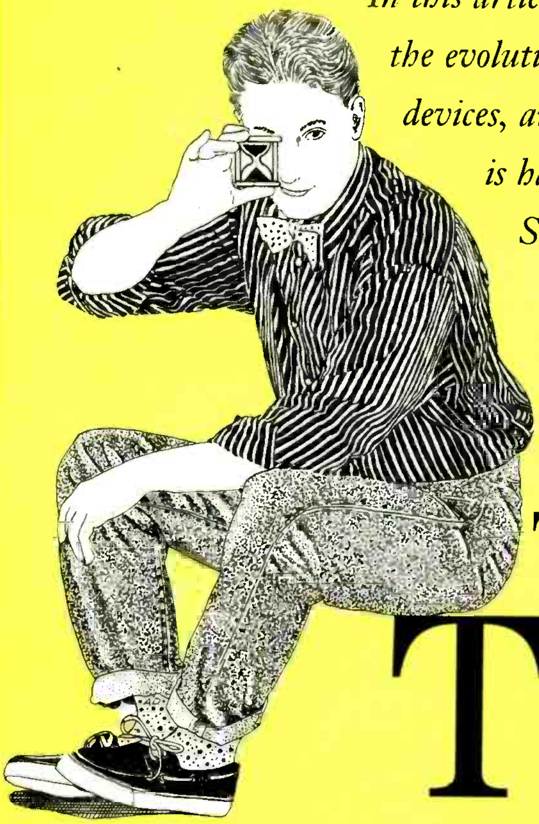
KARL THURBER

A day by any other name would still have only 24 hours. In this article we'll take a look at the evolution of timekeeping devices, and see how that task is handled in the United States and Canada



ALL THE TIME IN THE WORLD

We all know that time is a highly valuable commodity. Each and every one of us observes and uses time, especially those of us with a technical interest—scientists, engineers, air traffic controllers, military personnel, shortwave listeners (SWLs), amateur radio operators, and others. In this article, we'll look at time, see what it is, and describe how to best use it in our day-to-day hobby activities. We'll also discuss ways of accurately keeping and recording time, and how time and frequency are controlled in this country. In addition, we'll describe the current National Institute of Science and Technology (NIST) methods of disseminating time information through a variety of technical services, including HF and LF radio, and several high-tech methods; and present some details of precision timekeeping by our northern neighbor, Canada.

Time Calendars of Yore. We don't know much about prehistoric timekeeping, but we do know that in practically every culture some people in the society were preoccupied with measuring and recording time—whether they were ice age hunters, Sumerians, or Stonehenge dwellers. And they all used celestial bodies as references for time frames—ancient civilizations relied heavily upon them to determine the seasons, months, and years.

Over 20,000 years ago, ice age hunters scratched lines in sticks and bones, possibly counting days between phases of the moon. Some 5000 years ago, the Sumerians, in the Tigris-Euphrates valley (an area that is today called Iraq) used a calendar that divided the year into 30-day months. The Sumerians further divided the day into 12 periods (each corresponding to 2 of our hours) and again into 30 parts (each like 4 of our minutes). Today, Muslims use a Babylonian-based 354-day calendar, while most of the world uses a 365-day solar calendar with a leap year every fourth year.

Segmenting the Day Using Sun Clocks. About 5000 years ago people found that they had a need to know the time of day. The advanced civilizations of the Middle East and North Africa stressed making clocks rather than calendars. The Egyptians took an early step in segmenting the day into usable parts something like our hours. As early as 3500 BC, they developed the *obelisk*, a slender, four-sided tapering monument. The obelisk's moving shadow formed a sort of sundial that was capable of determining each day's midday, as well as the year's longest and shortest days. You may be surprised to learn that the Egyptians developed what likely was the world's first portable timepiece—a shadow clock first used in 1500 BC to determine hours. The small device divided the sunlit day into 10 increments, plus two twilight hours, and it also indicated noontime.

The Basic Elements of a Clock. Having described various ancient ways to mark the passage of time, let's define just what a clock is. In essence, a clock is a mechanism that counts and records a series of periodic events. There are two essential components of a clock. The first is a regular, constant, or repetitive process or action to mark off equal time increments. The second is a means of keeping track of the time increments and displaying the result. Timekeeping history is really the continuing search for ever more consistent and precise actions or processes to regulate clock rate.

Early Water Clocks. Water clocks were some of the world's earliest timekeepers. Water clocks differed from previous timekeeping methods in that they didn't depend on celestial bodies. One of the earliest water clocks was developed by the Egyptians as early as 1500 BC; one such device was found in the tomb of Pharaoh Amenhotep I.

Mechanical Clocks and Pendulums. Despite known deficiencies, fairly simple time-telling systems prevailed during the Middle Ages. In Europe, sundials, hourglasses, marked candles, and oil-burning lamps and wicks were popular. In the Far East, the Chinese even had an incense clock. Large mechanical clocks were first seen in Europe in the 14th century, and they became more prominent in the 16th and 17th centuries. Such clocks were regulated by a so-called *verge and foliot escapement* mechanism, a design advancement that characterized modern clocks and watches for some 300 years. Early mechanical clocks were difficult to regulate, and most did not work well aboard ships in rough seas. It wasn't until the 17th century that the first windup clocks were introduced—the British navy was among the first to use these clocks.

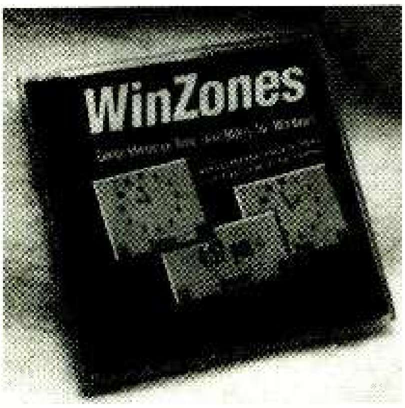
During the early 20th century, the clock (and watch) still were high-priced commodities, which soon became associated with the accuracy of the railroad industry, and later with the radio and TV industries. It took the advent of quartz clocks to make real changes in timekeeping for the public. Today, the clock is a low-cost commodity that's available to practically everyone.

Modern Quartz Clocks. Quartz clocks are based on the piezoelectric (electricity produced by pressure) property of quartz crystals. They are much better than mechanical clocks because they have no gears or escapements to disturb their frequency.

Quartz-based clocks still rely on a mechanical vibration whose frequency depends upon the crystal's size and shape; unfortunately, no two crystals are precisely alike. Therefore, for very precise timekeeping, the quartz clock, in turn, yielded to the *cesium beam* atomic clock in the 1960s as primary laboratory timekeeping devices. The atomic clocks generated very precise frequencies, with time interval accuracies (beyond the reach of mechanical- and quartz-based timepieces) in nano- and picosecond ranges.

Atomic Time and Atomic Clocks. Atomic clock accuracy stems from the very constant resonant frequency of atoms. In 1949, the first atomic clock was based on measurement of a resonant frequency caused by the microwave absorption of the ammonia gas module. But actual performance wasn't much better than existing standards, and so in 1957 National Bureau of Standards or NBS built its first cesium beam atomic clock. In 1960, after the natural resonance frequency of the cesium-133 atom was determined precisely, the cesium atomic clock became the frequency standard maintained by NBS.

However, it wasn't until 1967 that the cesium standard was adopted as the international unit of time, and the second was defined as the microwave resonance frequency (9,192,631,770 cycles per second) of the cesium atom. That made the natural resonance of this element the world standard for atomic time.



WinZones is a Windows utility that displays up to nine active clocks simultaneously on your PC's screen, each showing the correct time for cities in other time zones. It's especially useful for amateur radio enthusiasts; executives; sales people; workers in communications, the media, and transportation; and others who have business across multiple time zones. The program often eliminates the need for multiple desk or wall clocks.

Greenwich and World Time Zones. In the 1840s, the Greenwich time standard was established. Because Great Britain was the major world power at the time, the center of the first time zone was set at the Royal Greenwich Observatory, which was located on the 0-degree longitude meridian. The line was determined by the Astronomer Royal using a transit telescope. The international date line was set to generally follow the 180-degree longitude meridian in the Pacific.

On November 1, 1884, the International Meridian Conference met in Washington DC with delegates from 25 countries. They officially referenced mean solar time to the 24 standard meridians, based 15 degrees east and west of Greenwich, the point from which reckoning for each day should begin. Each time zone represents one hour's time difference between adjacent zones. (See Fig. 1).

Time Zones in the U.S. In this country, time zones didn't become necessary until trains traversed the country. Previously, cities relied on their own local "sun time." The problems associated with tracking hundreds of local times and publishing timetables were overcome only partially by the establishment of some 100 different, but consistent, railroad time zones. In 1883, the government sought to improve the situation by dividing the country into four time zones. At noon on November 18, 1883, the master clock at the United States Naval Observatory (USNO) transmitted the time by telegraph lines to major cities, each of which adjusted their clocks to their time zone's correct time.

Zulu Time. You're probably familiar with the standardized times such as Coordinated Universal Time (UTC). Often, UTC (or Greenwich Mean Time (GMT), as it used to be called) is written with the 24-hour time suffixed with a "Z," for "Zulu" time, using the internationally recognized phonetic for Z, which originated with the military. In that Greenwich is at the "zero meridian," the military began calling GMT "Zero Time," or "Z-Time" for short. The old phonetic alphabet for "Z" was Zebra, but when the international phonetic alphabet changed, the new phonetic became *Zulu*.

Various Time Considerations. In dealing with GMT, UTC, or Zulu time, you must be careful about several points. One of the points is the date. In converting times, you must account for the correct date if the time "crosses" midnight or the International Date Line. Having a time chart or world map available helps you picture needed International Date Line time conversions. Daylight Savings Time (DST) also can foul you up, since local standard time is advanced one hour for DST.

UTC doesn't change seasonally, but we have to adjust local timepieces accordingly. In the spring, we set our clocks ahead one hour (spring ahead, as they say) in most places, and in the fall we set them back (fall back). To avoid confusion, international times usually are stated in UTC, and to avoid further confusion between AM and PM, the 24-hour military-style clock usually is used. A very useful software program, WinZones, helps to keep track of the correct times and dates for cities in other time zones.

Time Scales for Everyone. Major users of highly precise time include civilian and military aircraft and ships, commercial radio and TV stations, spacecraft tracking stations, seismographers, astronomers, geologists, electronic power distribution companies, and scientific laboratories. Until 1972, several different time scale families existed. Each time scale was offset from the others for special purposes and users, such as navigators and satellite trackers. That glut of time scales posed a problem because the earth's rotational fluctuations affected UT, but didn't affect atomic time. A compromise time scale, UTC was developed and became effective internationally on January 1, 1972.

Today UTC is considered the modern implementation of GMT, but one that incorporates the accuracy and stability of atomic clocks. Of course, old habits die hard, and people today still refer to UTC as GMT. The UTC time scale, as it's called, that's broadcast by NIST stations WWV and WWVH meets most needs. It runs at a rate that's almost perfectly constant because it's based on atomic standards.

The BIPM. The World's Official

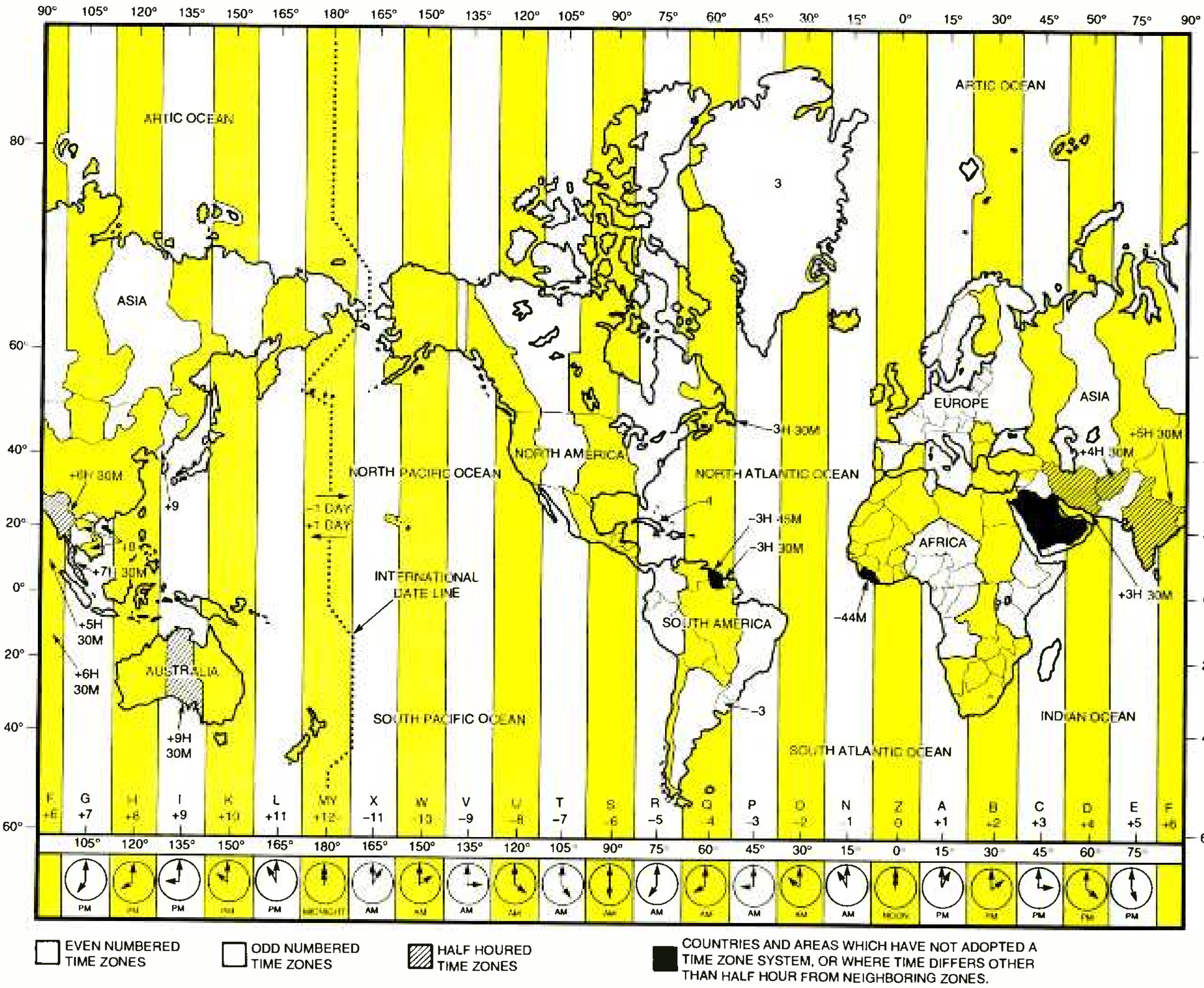


Fig. 1. Shown here are the world's 24 standard time zones and their relationship to the UTC reference zone. Some zones vary in width or are bent, because some countries want to deal with only one standard time. A few countries and areas have not adopted the zone system, and some even have oddball times that differ by only a half-hour or an hour from neighboring zones.

Timekeeper, the Paris-based *Bureau International Des Poids et Mesures* (BIPM), the International Bureau of Weights and Measures, helps to maintain a single, uniform time system. It's the official custodian of the UTC scale, and it also determines when leap seconds are needed. The BIPM's jobs are many. They involve supervising the International Atomic Time Scale, or TAI; determining and publishing the current values of Universal Time, the angular velocity of the earth's rotation, and the operational coordinates of the poles (which do change); promoting dissemination of the correct UTC by time-signal stations; and refining and improving the time measurement.

Time and Frequency Management in the U.S. The measurement of time and frequency is closely connected. In the U.S., the United States Naval Observatory (USNO) maintains the national time standard and coordinates civil and Department of Defense (DOD) time scales. Thus, USNO serves as the official time reference for timed systems in the United States, such as the OMEGA Navigation system, the Global Positioning Service (GPS), and various Department of Defense communications systems. NIST, while also heavily involved in time determination and dissemination, has primary responsibility for the maintenance of the national standard of frequency. UTC is the basis for the standard frequency and time signals broadcast by the NIST radio stations. Both USNO and NIST maintain practical time scales that are steered to remain within less than one microsecond of UTC.

NIST's Role. As we've seen, accurate time and frequency information is needed by many users. They all need to compare their equipment with a reliable and internationally recognized standard. NIST provides the benchmark for doing this: the primary NIST frequency standard offers a frequency and time interval reference based on the international definition of the second. NIST maintains time and frequency generation and measurement equipment at its Boulder,

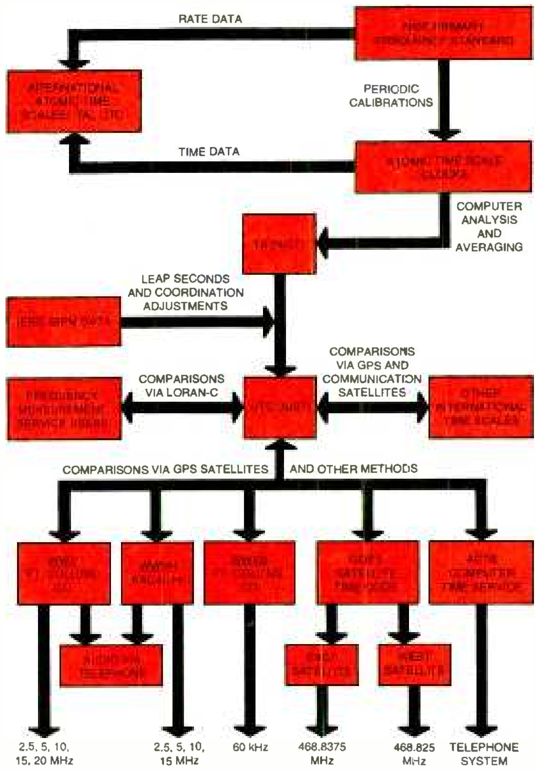


Fig.2. Here's how NIST ties together and controls the various time clocks and frequency standards to ensure accuracy and conformance to international standards. Also depicted is how information is disseminated by radio, satellite, and telephone. Note how atomic-based time and frequency standards are compared, calibrated, and adjusted to ultimately produce UTC, the time scale that's disseminated to users.

CO laboratories. The labs contain the primary NIST frequency standard, the cesium beam atomic clocks, and related equipment. The labs also contain commercial cesium standards, hydrogen maser frequency standards, and other equipment in controlled environments as working standards.

The NIST atomic clock system comprises three main elements. In the first element, there are two primary frequency/time standards, several secondary atomic clocks, and associated computing and measuring equipment (see Fig. 2). A group of smaller commercial atomic clocks forms the second part of the system—the secondary standards—which serve as insurance for continuous timekeeping and adds statistical reliability to the timekeeping process. The use of multiple clocks also permits repairs and modifications without interrupting the time scales.

The third element, computers and measurement equipment, monitors the frequencies or rates of all the clocks against each other, and measures the time differences between the individual clocks. Each clock's performance is evaluated and a weighted average of the inferred atomic time from each is computed. The result provides NIST with a continuous measure of atomic time. The whole system keeps time so precisely that it gains or loses only about one-billionth of a second per day.

USNO's Role. Established in 1830 to cooperate with the Royal Greenwich Observatory and other world observatories, the USNO coordinates with other observatories in determining sidereal (star-related) and universal time (UT), and other important astronomical data. That's done especially for the use of ships (which navigate using celestial bodies) as stellar maps and as references for determining local earth time and position.

Navigators historically have been the largest group of users of precise time information. They must know the time accurately to determine their position from the observation

Summary of Radio Broadcast Services

Characteristics & Services:	WWV		WWVH		WWVB
Standard Carrier Frequencies	2.5 & 20 MHz	5, 10, & 15 MHz	2.5 MHz	5, 10, & 15 MHz	60 kHz
Power	2500 W	10,000 W	5000 W	10,000 W	13,000 W
Standard Audio Frequencies	440 (A above middle C), 500, & 600 Hz				—
Time Intervals	1 pulse/s; minute mark; hour mark				s; min.
Time Signals: Voice	Once per minute				—
Time Signals: Code	BCD code on 100-Hz subcarrier, 1 pulse/s				BCD code
UT1 Corrections	UT1 corrections are broadcast with an accuracy of ±0.1 s				
Special Announcements	Omega Reports, Geoalerts, Marine Storm Warnings, Global Positioning System Status Reports				—

Fig. 3. Here's a concise summary of the radio broadcast characteristics and services offered by the three NIST standard time and frequency stations—WWV, WWVH, and WWVB. Note the variety of special announcements carried by WWV and WWVH. Telephone service, both voice and modem, also is offered.

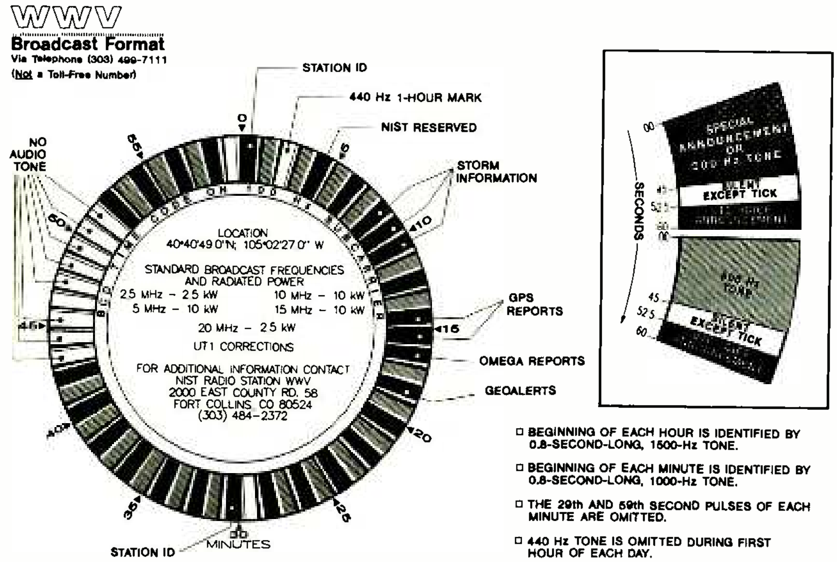


Fig. 4. Here is the hourly broadcast format and schedule of NIST Radio Station WWV, located in Ft. Collins, CO. Note the variety of detailed time and other specialized information presented in the broadcasts. Sister station WWVH in Hawaii broadcasts using a similar, but slightly different, format as well as a female voice for voice IDs to help avoid confusion when both stations may be audible to the user.

of celestial objects or satellites. And today's navigational needs extend from the traditional sea and land uses to air and into space. The USNO determines the positions and motions of the earth, sun, moon, planets, stars, and other celestial objects; provides astronomical data; determines precise time; measures the earth's rotation; and maintains the official master clock for the nation.

As keeper of the master clock, USNO is the source of official time in the United States. The USNO's accurate timekeeping is performed by cesium and hydrogen maser clocks, kept constant to within one nanosecond per day.

The data, which help determine UT based on the rotation of the earth on its axis, are sent to the USNO by magnetic tape. At the USNO, the data are analyzed in a high-speed computing system know as a Very Long Baseline Interferometry (VLBI) correlator. An increasing amount of Observatory data is disseminated over the Internet, which you can find at the USNO home page at *http://www.usno.navy.mil/*. The time also is available by calling 202-762-1401 or 900-410-TIME. You can obtain automated time information at 202-653-0351. For information on USNO tours call 202-762-1467.

Current NIST HF and LF Radio Broadcast Services. Some users bring their own clocks and frequency standards to Boulder for calibration and tests. But most of us simply receive needed signals via the NIST radio stations. NIST uses radio broadcasts to distribute the time and frequency signals because it's not economical to maintain NIST-type standards in laboratories across the country and on every ship and plane. The broadcasts offer practical accuracy of better than one one-hundredth of a second.

Historical Background. The NIST radio stations offer a variety of time, frequency, and other vital technical services. You can "zero in" on the correct time by several means, including telephone company recordings and radio/TV station announcements. But for most of us the most satisfactory and flexible method is to tune our radios to a primary standard provided by the NIST. NIST's predecessor, the NBS, initially set up shop in March, 1923 with radio station WWV, then in Beltsville, MD and, since 1943, in Greenbelt, MD.

In 1966, WWV moved to Fort Collins, CO to increase the accuracy and control of transmissions and to more uniformly cover the U.S. But, in fairness, the Navy gets the honors for transmitting the first time signals. In 1904, a U.S. Navy station broadcast the first worldwide radio time signals, based on a clock provided and controlled by the USNO. NIST's current broadcast services focus on the radio signals from stations WWV, WWVB, and WWVH. You'll find that the time and frequency information sent out by the stations, since it's based on the NIST's atomic clocks, is almost perfectly accurate.

WWV and WWVH. NIST operates two HF radio stations, WWV and WWVH, in Ft. Collins, CO and Kauai, Hawaii, respectively. Both stations continuously broadcast time and frequency signals on 2.5, 5, 10, and 15 MHz, and WWV also broadcasts on 20 MHz.

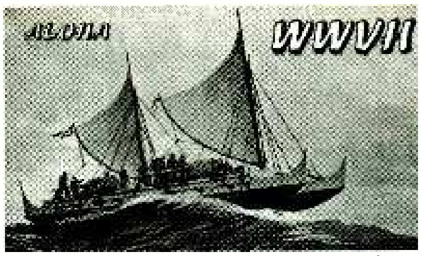
You should be able to hear at least one frequency at any time, depending on the time of day and year, radio conditions, and equipment. Frequencies above 10 MHz work best in the daytime, while lower frequencies are best at night. WWV and WWVH offer voice time announcements, standard frequencies and time intervals, digital time code, astronomical time corrections, geophysical alerts, radio propagation information, marine storm warnings, and OMEGA Navigation System and GPS status reports (see Fig. 3 and Fig. 4). The transmitted frequencies are accurate to about 1 part in 100 billion for frequency and 0.01 milliseconds for time. However, received accuracy for WWV and WWVH is less due to propagation effects.

You can hear the WWV and WWVH audio by telephone, with an accuracy of 30 ms or better. To hear the broadcasts, dial 303-499-7111 for WWV or 808-335-4363 for WWVH.

WWVB. The longwaves (LW) are a potential source of standard time and frequency information for serious users. Several stations worldwide broadcast highly accurate LF signals, mostly on frequencies below 100 kHz. As long ago as 1956, the old NBS tested 60 kHz LF transmissions using the experimental callsign KK2XEI. Across the big pond, one of the first broadcast time services, the British station GBR, aired in 1926 on 16 kHz. NIST's WWVB, near the WWV site, broadcasts on 60 kHz with 13 kW to cover the continental U. S.

WWVB uses a highly stable crystal oscillator as its frequency generator, referenced to the primary NIST frequency standard. The station is so accurate that it's used by many international standard time-and-frequency stations as a cross-check on their own signals. The station doesn't use voice announcements, but provides continuous digital-based standard time information; time intervals; DST, leap second, and leap year notices; and astronomical time corrections.

A 60-kHz, LF receiver is required to decode the binary coded data sent by WWVB. Why are such low frequencies used for standard time and frequency stations? The low frequencies are favored because of the improvement in received signal accuracy that's possible. At low frequencies, reception doesn't suffer the slight time delays and unpredictable atmospheric variations that distort regular reception of the HF stations WWV and WWVH.



WWVH "aloha" QSL (reception verification) card from the earlier, pre-NIST NBS era indicates that WWVH is located on the island of Kauai. The station commenced broadcasting in November, 1948 from Maui, but it moved to Kauai in July, 1971. The station broadcasts in a format fairly similar to that used by sister station WWV, but it doesn't use the 20 MHz frequency.

You should be able to hear WWVB well anywhere in the country as a result of its central location. To receive WWVB, you can use a surplus VLF/LF receiver, a communications receiver covering the low frequencies, or a converter hooked to your receiver's antenna connection (Palomar Engineers offers a reasonably priced converter for this purpose—call 800-883-7020 for details).

The NIST Automated Computer Time Service (ACTS). Many users require time-of-day to a precision higher than a human operator can achieve, and computer systems of many kinds (including your own PC) can benefit from direct, automated access to a source of official time. In 1988, NIST began the Automated Computer Time Service (ACTS). Using commercial dial-up telephone lines to deliver a digital time code, it lets your PC access the NIST clocks with an accuracy approaching a few milliseconds. Features of the service include compensation for telephone-line delay, advance alert for changes to and from DST, and advance notice of leap second insertion. Since the time code used by ACTS uses the standard ASCII character set, the system works with nearly all computer systems and 300 or 1200 baud modems.


The Palomar Engineers VLF Converter lets you receive the low bands for about $80; all you need to receive WWVB and other low-frequency stations, along with the so-called 1750-meter experimenters' band, is a communications receiver and an antenna. Covering 10–500 kHz, the Model VLF-A converts VLF signals to the 80-meter amateur band, while the Model VLF-S converts signals to 4010–4500 kHz for general coverage SW receivers.

The NIST GOES Satellite Time Code Service. For higher accuracy than that attainable with the radio broadcast services and ACTS, NIST offers the Geostationary Operational Environmental Satellites (GOES) Time Code Service. It's a digital satellite broadcast of time signals from the NOAA GOES weather satellites, orbiting 22,300 miles above the earth's surface. Because they are geostationary, the time code path delay remains relatively constant. NIST uses two GOES satellites to handle the Western Hemisphere and portions of the Atlantic and Pacific, covering at least 40 percent of the earth's surface. Its accuracy, though superb, is limited primarily by knowledge of the exact satellite positions. The broadcast GOES time code includes the current year; day, hour, and minute; astronomical corrections; satellite position information; accuracy indicators; Daylight Savings Time and leap second notices; and system status information.

The NIST Frequency Measurement Service. The NIST Frequency Measurement Service (FMS) lets you make accurate frequency calibrations on-site for a small fee. That's less expensive than sending your equipment to NIST or to a commercial lab for calibration. You can subscribe to FMS by paying a one-time subscription fee and a small monthly fee. NIST loans subscribers a computer-controlled

There's little to distinguish the nondescript "radio shack" of the NIST Radio Station WWV (located on East County Road 58 in Ft. Collins, CO), except for the station's familiar callsign, which is displayed prominently in the building's entranceway.

"measurement system" centered on a special LORAN-C LF radio-navigation receiver. You can connect up to four oscillators to the system; FMS, under computer software control, measures their output constantly and feeds the information back to NIST by modem. NIST compares the measurements with its own standards to certify calibrations as being accurate and traceable to NIST. However, Loran-C doesn't have a time code and is not usually used to obtain time.

NIST Publications. If you're a serious user of time and frequency information, you can obtain a free subscription to the *NIST Time and Frequency Bulletin*. Published monthly, it contains detailed current technical data on WWV, WWVH, WWVB, GOES, and GPS, as well as NIST time scales. Also, NIST Special Publication 432, NIST Time and Frequency Services, tells the whole story of NIST radio broadcast and other services. For additional information, write the NIST Time and Frequency Division at 325 Broadway, Boulder, CO 80303-3328.

Precision Timekeeping in Canada. If you live overseas, you may want to use standard time and frequency stations located in Buenos Aires, Tokyo, London, Moscow, and several other major cities. The stations are prominently listed in the *World Radio TV Handbook*. Canadians, in particular, find the signals broadcast by the National Research Council's (NRC) Canada time station, CHU, to be very useful since the station provides a service similar to WWV and WWVH.

NRC Canada is the Canadian federal agency responsible for official time, which is handled by its Time Standards Group. NRC time is referenced to its primary cesium beam atomic clocks, located at the NRC time standards laboratory in Ottawa. The clocks are used in conjunction with atomic clocks in the time laboratories of other countries such as the U.S., and, like NIST's clocks, they're coordinated with BIPM.

Among the time services offered by the NRC are Telephone and Radio. Voice announcements of Eastern Time are made over the phone at ten-second intervals, followed by a tone that indicates the exact time. You can get the time announcement in English by dialing 613-745-1576, or in French by calling 613-745-9426. The time signal also ticks each second.

Both the English and French radio networks of the Canadian Broadcasting Corporation (CBC) carry the NRC time signal once per day, at 1300 (on the English network) and at 1200 (on the French), Eastern Time. Note that both the telephone and radio time signals may be routed by one or two communications satellite hops, each hop delaying the signals by 0.25 seconds.

NRC also offers precision telephone digital code time signals for computers and automatic systems. NRC offers two kinds of telephone digital time code. The so-called "old code" system can be used with 300 bps modems; the system offers an accuracy of about .001 seconds. But the precision is degraded by variations in the signal propagation delay through the

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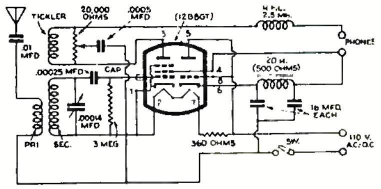
Located on the island of Kauai, Hawaii, NIST Radio Station WWVH's continuous broadcast services supplement those of WWV to provide high-quality signal coverage to the Pacific Basin on all except the 20-MHz frequency. Often you'll hear both WWV and WWVH mixing together. One way to distinguish them quickly is by the voice—WWV's voice is male, while WWVH's voice is female.

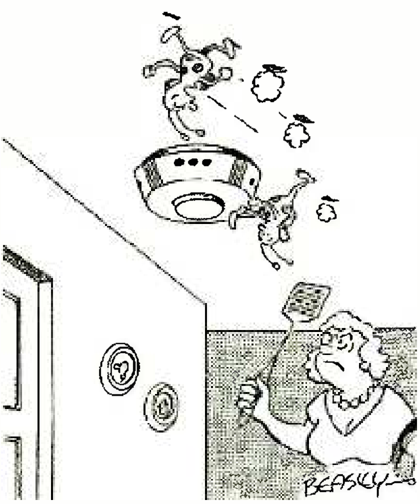


Schematic of One Tube radio

Europe on One Tube

Saving perhaps the most romantic for last, we have *Europe on One Tube.* Also a simple regenerative, the shortwave set is AC-DC powered, using the triode section of a dual-purpose 12B8GT (grid and plate tied together) as the rectifier. Note that the designer prudently used a ground bus, so there is no dangerous grounding of the AC/DC line to the chassis.

I hope you had fun with this little tour through *Radio for the Millions.* We'll do it again sometime, and I might even tell you about my long-ago adventures with *Four Dollars Builds This Loudspeaker Set!* ■



That's not our ship you idiot - that's a smoke detector!

ALL THE TIME

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THE WORLDRADIO "CONTACT ALL TIME ZONES" AWARD

The structure of the world's time zones is important to radio amateurs. Worldradio, a major monthly amateur radio news publication, recently set up a new award—Contact All Time Zones (CATZ)—for amateurs to achieve. The award is based on the division of the world into 24 time zones, each 15 degrees wide. For the sake of the award, half-hour and other artificial time zones are ignored.

If you're applying for the award, you must have a two-way contact on amateur radio frequencies with a station in each of the 24 time zones; contacts with one's own nation don't count. You must have made all contacts from a location within the same country, and you must have QSL (verification) cards from each of the time zones. To obtain the award (an attractive 8- x 10-inch certificate), you must submit a list showing each contact's details along with a nominal fee to the award's sponsor. For more information, contact Worldradio. Worldradio CATZ Award Manager, 2120 8th St., Sacramento, CA 95818; Tel: 916-457-3655.

telephone lines, including the delay of up to 0.25 seconds per communications satellite hop. An improved code system using an interactive ASCII-based protocol supports correction for signal propagation through the telephone link; an overall accuracy of a few milliseconds is possible.

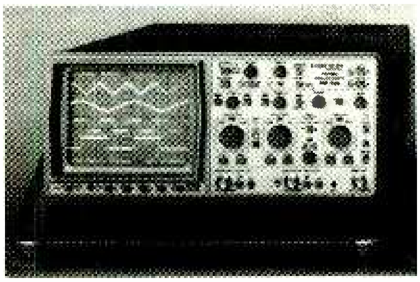
You can obtain time accuracy superior to telephone time accuracy by means of NRC's radio time signals, broadcast continuously from shortwave radio station CHU. If you make corrections for the propagation delay from CHU to you, and for delays in your receiver, you can attain an accuracy of better than 1 millisecond. CHU also broadcasts a time code that can be decoded with common computers and modems. While the NIST stations operate on round frequencies such as 2.5, 5, 10, 15, and 20 MHz, CHU transmits on oddball frequencies—3330, 7335, and 14,670 kHz—using up to 10 kW of power. The CHU frequencies are derived from one of a trio of closely synchronized atomic clocks located at the transmitter site, three clocks being used to allow majority logic checking.

Summary. The measurement of time has become more sophisticated with each year. And time measurements will become more complex in the future, as new techniques in several scientific fields afford even more progress in defining just what time is and how best to measure and disseminate it. ■

NEW PRODUCTS

(continued from page 22)

The HM1505 features two vertical input channels and a second time base. The second time base—with the ability to magnify, over 1000 times, extremely small portions of the input signal—has its own triggering controls, including level and slope selection, to allow a stable and precisely referenced display of asynchronous or jittery signal segments. The trigger circuit is designed to provide reliable triggering to over 250-MHz at signal levels as low as 0.5 division. An active TV Sync Separator for TV-signal tracing ensures accurate triggering even with noisy signals.



To ensure accuracy, a built-in switchable calibrator checks the instrument's transient response characteristics—from probe tip to CRT screen. The essential high-frequency compensation of wide-band probes can be performed with the calibrator, which features a rise time of less than 4 ns.

The HM1505 oscilloscope costs $1480. For information, contact Hameg Instruments, 266 East Meadow Avenue, East Meadow, NY 11554; Tel: 800-247-1241 or 516-794-4080; Fax: 516-794-1855; e-mail: *hameg @aol.com.*

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