A UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NBS SPECIAL PUBLICATION 236

1973 EDITION

NBS FREQUENCY AND TIME BROADCAST SERVICES

RADIO STATIONS
WWV, WWVH, WWVB, WWVL

ANNIVERSARY

WWVH & ATOMIC CLOCK

WWV

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.
[4] Part of the Center for Building Technology.

NBS FREQUENCY AND TIME BROADCAST SERVICES

RADIO STATIONS WWV, WWVH, WWVB, and WWVL

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Issued May 1973

National Bureau of Standards Special Publication 236

(Supersedes NBS Special Publication 236, 1972 and previous editions)

Nat. Bur. Stand. (U.S.), Spec. Publ. 236, 19 pages (May 1973)

CODEN: XNBSAV

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

(Order by SD Catalog No. C13.11:236).

Price $0.45 domestic postpaid or $0.35 G.P.O. Bookstore.

Contents

Services Provided by NBS Standard Frequency and Time Stations

Peter P. Viezbicke

Detailed descriptions are given of the technical services provided by the National Bureau of Standards (NBS) radio stations WWV, WWVH, WWVB, and WWVL. These services are: 1. Standard radio frequencies; 2. Standard audio frequencies; 3. Standard musical pitch; 4. Standard time intervals; 5. Time signals; 6. UT1 corrections; and 7. Official announcements. In order to provide users with the best possible services, occasional changes in broadcasting schedules are required. This publication shows the schedules in effect on January 1, 1973. Annual revisions will be made. Current data relating to standard frequencies and time signals are available monthly in the Time and Frequency Services Bulletin. Advance notice of changes occurring between revisions will be sent to users of NBS broadcast services who request such notice on the basis of need.[1]

Key words: Broadcast of standard frequencies; high frequency; low frequency; standard frequencies; time signals; very low frequency.

Introduction

In March 1923 NBS started transmitting standard radio frequencies on a regularly announced schedule from radio station WWV. The WWV transmitter, originally located at NBS, Washington, D.C., has moved several times. Between 1931 and 1967 the station was moved successively to College Park, to Beltsville, to Greenbelt, Maryland, and finally to Fort Collins, Colorado, where it went on the air at 0000 hours Universal Time on December 1, 1966.

The move to Fort Collins was prompted by several considerations: the need for wider and more uniform coverage in the continental U.S. from a more central location; the advantage of more precise control from the NBS Time and Frequency Division at Boulder, Colorado; and improvement in radiation patterns obtained by location in a less congested area.

Original broadcast frequencies were accurate to within a few parts in a thousand. Their transmitted accuracy today is on the order of a part in 10^{12} — approaching the accuracy of the NBS frequency standard itself.

To supplement the coverage of WWV, broadcasts from WWVH, Hawaii, were instituted in 1948. These play an increasingly important role in various types of operations, both military and civilian, in the Pacific and Far East. In 1971, WWVH was moved from its former site on Maui to its present location near Kekaha, Kauai.

WWVB began broadcasting from Boulder, Colorado in 1956, and WWVL, an experimental station, from Sunset, Colorado in 1960. Both of these stations have been located at Fort Collins, Colorado, since July, 1963. Operations from WWVL were curtailed on July 1, 1972, and WWVL now broadcasts very low frequency (VLF) experimental programs only on an intermittent basis contingent upon need and funds. WWVB, transmitting on low frequency (LF), provides widespread distribution of the NBS frequency and time scale. The WWVB broadcasts are used to coordinate operations of continental networks of missile and satellite stations and to provide a highly accurate standard of frequency that is readily available to many users for electronic research and development. WWVB serves as a national time and frequency reference for many U.S. electric utilities and as a timing reference by government contractor groups for a large number of sensing stations which monitor seismological events.

Thus in the 50 years since the beginning of its radio broadcasts, NBS has expanded these services so that they are making major contributions today to the nation's space and defense programs, to world-wide transportation and communications, and to a multitude of industrial operations, as well as providing convenient time services to thousands of listeners.

Visiting hours are observed at WWV, WWVB, and WWVL every Wednesday, except holidays, from 1:00 p.m. to 4:00 p.m. Special tours may be scheduled at other times only by prior arrangement with the Engineer-in-Charge.

Correspondence pertaining directly to station operations may be addressed to:

John Stanley, Engineer-in-Charge
NBS Radio Stations WWV/WWVB/WWVL
2000 East County Road 58
Fort Collins, CO 80521
Telephone (303) 484-2372

Charles Trembath, Engineer-in-Charge
NBS Radio Station WWVH
P.O. Box 417
Kekaha, Kauai, HI 96752
Telephone (808) 335-4217

[1] Inquiries concerning the Time and Frequency Services Bulletin or the NBS broadcast service policies may be addressed to Frequency-Time Broadcast Services Section, Time and Frequency Division, NBS, Boulder, CO 80302.

1. WWV and WWVH Broadcast Services

1.1. Standard Radio Frequencies

(a) Program

Both WWV and WWVH transmit frequencies and time coordinated through the Bureau International de l'Heure (BIH), Paris, France, in accord with international agreements. Transmissions are based upon the international time scale, Universal Coordinated Time (UTC).

WWV broadcasts on radio carrier frequencies of 2.5, 5, 10, 15, 20, and 25 MHz. WWVH broadcasts on radio carrier frequencies of 2.5, 5, 10, 15, and 20 MHz. The broadcasts of both stations are continuous, day and night.

The broadcasts of WWV may also be heard via telephone by dialing (303) 499-7111, Boulder, Colorado. The telephone user will hear the live broadcasts as transmitted from the station. Considering the instabilities and variable delays of propagation by telephone, the listener should not expect accuracy of the telephone time signals to be better than 30 milliseconds. This service is automatically limited to 3 minutes per call.

TABLE 1. Services and coordinates of the NBS broadcast stations

Station	Date in Service	Radio Frequencies	Audio Frequencies	Musical Pitch	Time Intervals	Time Signals	UT1 Corrections	Official Announcements
WWV	1923	✓	✓	✓	✓	✓	✓	✓
WWVH	1948	✓	✓	✓	✓	✓	✓	✓
WWVB	1956	✓			✓	✓	✓	
WWVL	1960	✓						

The coordinates of these NBS radio stations are as follows:

WWV	40° 40′ 49.0″ N	105° 02′ 27.0″ W
WWVB	40° 40′ 28.3″ N	105° 02′ 39.5″ W
WWVL	40° 40′ 51.3″ N	105° 03′ 00.0″ W
WWVH	21° 59′ 26.0″ N	159° 46′ 00.0″ W

(b) Accuracy and Stability

Since December 1, 1957, the standard radio transmissions from WWV and WWVH have been held as nearly constant as possible with respect to the atomic frequency standards maintained and operated by NBS. Relative to the primary frequency standard of NBS, there are very small intentional offsets which may be of the order of one part in 10^{12}. Up-to-date information on these small offsets can be obtained from the monthly Time and Frequency Services Bulletin.

Atomic frequency standards have been shown to realize the ideal cesium resonance frequency, f_{Cs}, to within a few parts in 10^{13}. The present NBS frequency standard and time scale system realizes this resonance frequency to an uncertainty of about 5 parts in 10^{13} [1][2].

The definitions for time and frequency are based on the same physical process: "The second is the duration of 9, 192, 631, 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom" as was decided in October 1967 by the XIIIth General Conference of Weights and Measures. For frequency, the hertz is one cycle per second.

On January 1, 1960, the NBS standard was brought into agreement with this definition as quoted above by increasing its assigned value by 74.5 parts in 10^{10}. Frequency measurements in terms of the NBS standard between December 1, 1957 and January 1, 1960 need to take the above correction into account [2].

All carrier and modulation frequencies at WWV and WWVH are derived from cesium-controlled oscillators and are held stable to better than ± 2 parts in 10^{11} at all times. Deviations are normally less than 1 part in 10^{12} from day to day.

Changes in the propagation medium (causing Doppler shifts, diurnal shifts, etc.) result in fluctuations in the carrier frequencies as received which may be very much greater than the uncertainties quoted above.

(c) Corrections

Incremental frequency adjustments not exceeding 1 part in 10^{11} are made at WWV as necessary. Frequency adjustments at WWVH do not exceed 2 parts in 10^{11}. Corrections to the transmitted frequency or phase are determined regularly with respect to the NBS time standard and are published monthly (since March 1966) in the NBS Time and Frequency Services Bulletin.

In conformity with the UTC scale, the carrier and modulation frequencies of WWV and WWVH are no longer offset significantly from nominal values. At the recommendation of the International Radio Con-

[2]Figures in brackets indicate the literature references at the end of this publication.

sultative Committee (CCIR), the frequency offset of UTC was made permanently zero relative to International Atomic Time (TAI) effective 0000 hours UTC January 1, 1972. Previously, the fractional frequency offset was -150 parts in 10^{10} during 1960 and 1961; -130 parts in 10^{10} during 1962 and 1963; -150 parts in 10^{10} during 1964 and 1965; and -300 parts in 10^{10} from 1966 through 1971.

1.2. Standard Audio Frequencies

(a) Program

The hourly broadcast format of WWV and WWVH is presented in figure 1. Standard audio frequencies of 440 Hz, 500 Hz, and 600 Hz are broadcast on each radio carrier frequency by the two stations. The duration of each transmitted standard tone is approximately 45 seconds. A 600-Hz tone is broadcast during odd minutes by WWV and during even minutes by WWVH. A 500-Hz tone is broadcast during alternate minutes unless voice announcements or silent periods are scheduled. The 440-Hz tone is broadcast beginning one minute after the hour at WWVH and two minutes after the hour at WWV. The 440-Hz tone period is omitted during the first hour of the UTC day.

No audio tones or special announcements are broadcast during a semi-silent period from either station. The periods are from 45 minutes to 50 minutes after the hour at WWV, and from 15 minutes to 20 minutes after the hour at WWVH.

(b) Accuracy

The audio frequencies are derived from the carrier and have the same basic accuracy as transmitted. Changes in the propagation medium sometimes result in fluctuations in the audio frequencies as received.

While the 100-Hz subcarrier (sec. 1.7) is not considered one of the standard audio frequencies, the modified IRIG-H time code transmitted continuously from WWV and WWVH does contain this frequency and may be used as a standard with the same accuracy as the audio and radio frequencies.

1.3. Standard Musical Pitch

The frequency 440 Hz, for the note A above middle C, is the standard of the music industry in many countries and has been in the United States since 1925. The radio broadcast of this standard was commenced by the National Bureau of Standards in 1937. The 440-Hz tone is broadcast for approximately 45 seconds beginning 1 minute after the hour at WWVH and 2 minutes after the hour at WWV. The tone is omitted during the zero hour of each UTC day. In addition to its application as a musical standard, the 440-Hz tone may be used to provide an hourly marker for chart recorders or other automated devices.

1.4. Standard Time Intervals

Seconds pulses at precise intervals are derived from the same frequency standard that controls the radio carrier frequencies; i.e., they commence at intervals of 5,000,000 cycles of the 5-MHz carrier. They are given by means of double-sideband amplitude modulation on each radio carrier frequency. Every minute, except the first of the hour, begins with an 800-millisecond tone of 1000 Hz at WWV and 1200 Hz at WWVH. The first minute of every hour begins with an 800-millisecond tone of 1500 Hz at both stations.

The 1-second markers are transmitted throughout all programs of WWV and WWVH except that the 29th and 59th markers of each minute are omitted. As noted above, the seconds marker which begins the minute is lengthened to 800 milliseconds. All other markers consist of a 5-millisecond pulse of 1000 Hz at WWV and 1200 Hz at WWVH, commencing at the beginning of the second (fig. 2).

The seconds pulse spectrum is composed of Fourier frequency components as shown in figure 2. Each pulse is preceded by 10 milliseconds of silence and followed by 25 milliseconds of silence. These 40-millisecond interruptions do not appreciably degrade the intelligibility of voice announcements.

1.5. Time Signals

(a) Program

Because of common usage of the name Greenwich Mean Time, the time announcements of WWV and WWVH are referred to by this name.[3] More precisely, the actual reference time scale is the Coordinated Universal Time Scale maintained by the National Bureau of Standards, UTC(NBS). The UTC(NBS) scale is affected by very small frequency offsets relative to the NBS primary frequency standard as mentioned in section 1.1.(b).

The 0 to 24 hour system is used starting with 0000 for midnight at the Greenwich Meridian (longitude zero). The first two figures give the hour, and the last two figures give the number of minutes past the hour when the tone returns. The time announcement refers to the end of an announcement interval, i.e., to the time when the next 800-millisecond tone begins after the announcement.

At WWV a voice announcement of Greenwich Mean Time is given during the 7.5 seconds immediately preceding the minute. Just before 1035 GMT, for instance, the voice announcement (given in English) is: "At the tone—ten hours, thirty-five minutes Greenwich Mean Time."

At WWVH a voice announcement of Greenwich Mean Time occurs during the period 15 seconds to 7.5 seconds preceding the minute. It should be noted that the voice announcement for WWVH precedes

[3] As noted in a resolution of Commission 31 of the International Astronomical Union, August 1970: "The terms of 'GMT' and 'Z' are accepted as the general equivalents of UTC in navigation and communication." Standard time zones are established at intervals of 15° longitude east and west of the zero meridian. Local standard time differs from GMT by an integral number of hours.

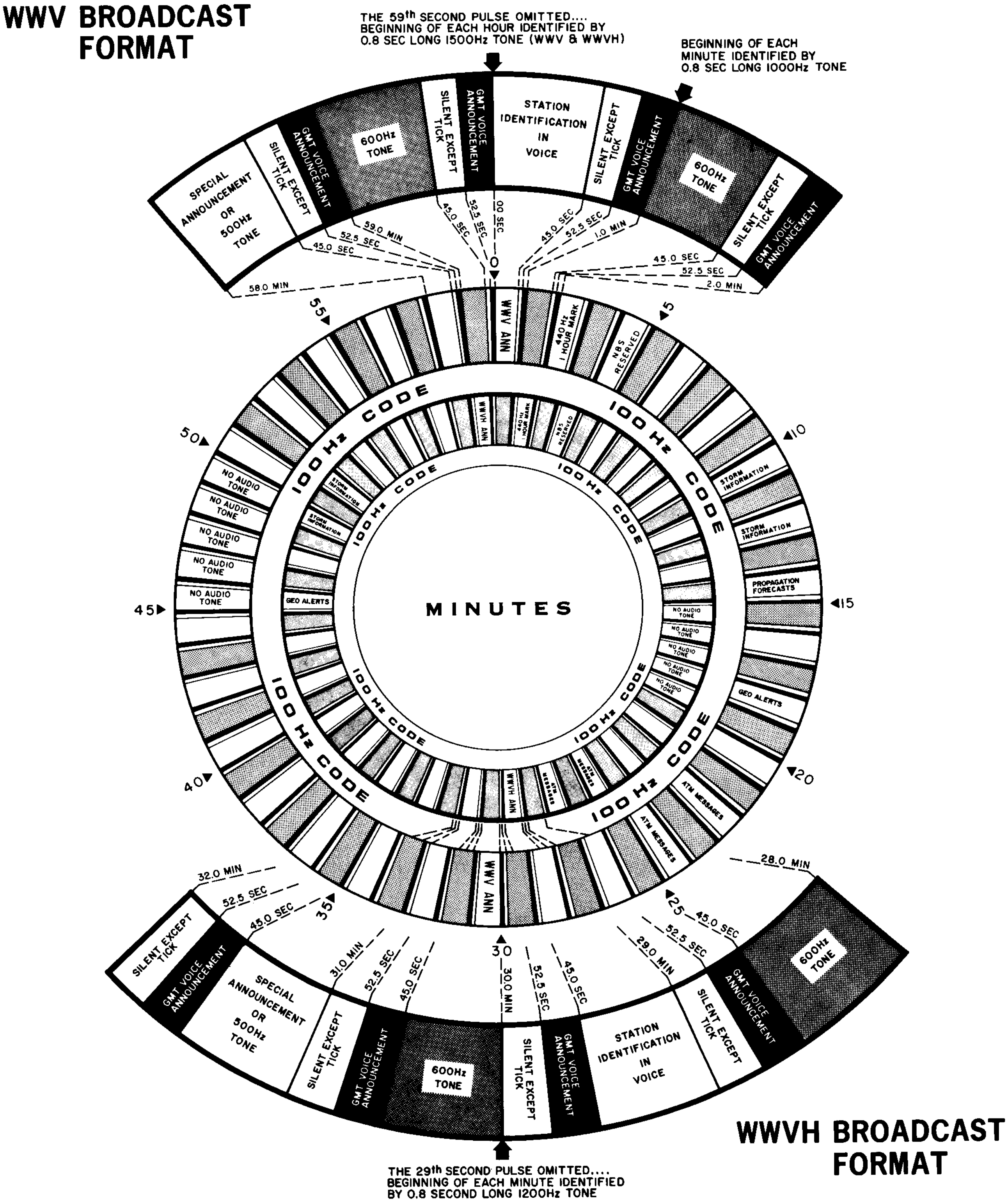


FIGURE 1. *The hourly broadcast schedules of WWV and WWVH.*

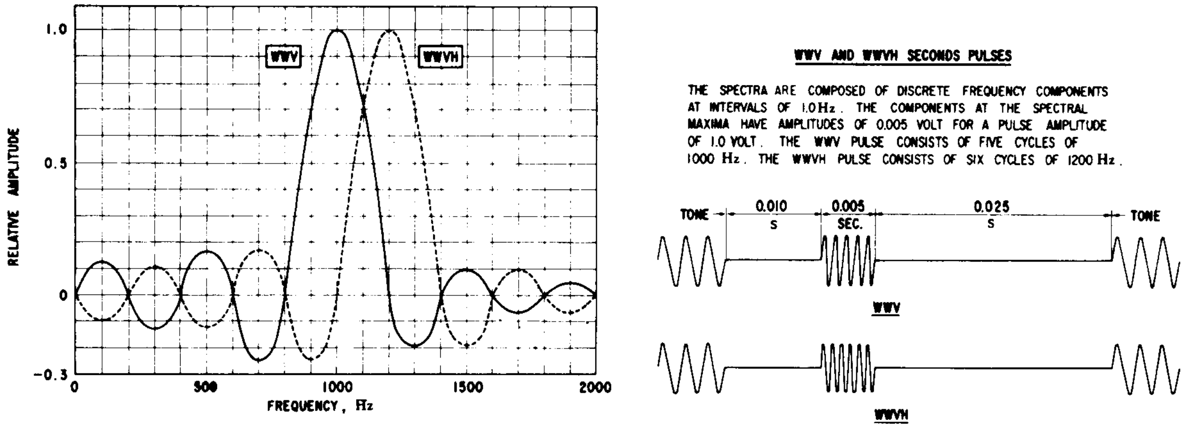


FIGURE 2. *Sample characteristics of time pulse broadcast from NBS radio stations WWV and WWVH.*

that of WWV by 7.5 seconds. However, the tone markers referred to in both announcements occur simultaneously, though they may not be so received due to propagation effects.

(b) Corrections

Prior to January 1, 1972, time signals broadcast from WWV and WWVH were kept in close agreement with UT2 (astronomical time) by making step adjustments of 100 milliseconds as necessary. On December 31, 1971 at 23h 59m 60.107600s UTC, the UTC(NBS) scale was retarded 0.107600 second to give it an initial difference of 10 seconds late with respect to the TAI scale as maintained by BIH. As of January 1, 1973, the UTC scale was 12 seconds late with respect to TAI.

Since the new UTC rate (effective January 1, 1972) is no longer adjusted periodically to agree with the earth's rotation rate, UTC departs more rapidly than before from earth rotation time (known as UT1), gaining about 1 second per year. Corrections to UTC are now made in step adjustments of exactly 1 second (called a leap second) as directed by BIH. The leap second adjustments ensure that UTC signals as broadcast will never differ from UT1 by more than about ± 0.7 second. (Note: the corrections no longer relate to UT2). BIH announces the occurrence of a leap second two months in advance.

The leap second adjustments are made as necessary at the end of the UTC month, preferably on 31 December or 30 June. Thus, when required, a leap second is inserted between the end of the 60th second of the last minute of the last day of a month and the beginning of the next minute.[4] This is analogous to adding an extra day (which could be called a leap day) during a leap year. Figure 3 illustrates how events are dated in the vicinity of a leap second.

A positive leap second was inserted in the transmissions of all NBS broadcast stations at the end of June 1972 and December 1972 as announced by BIH.

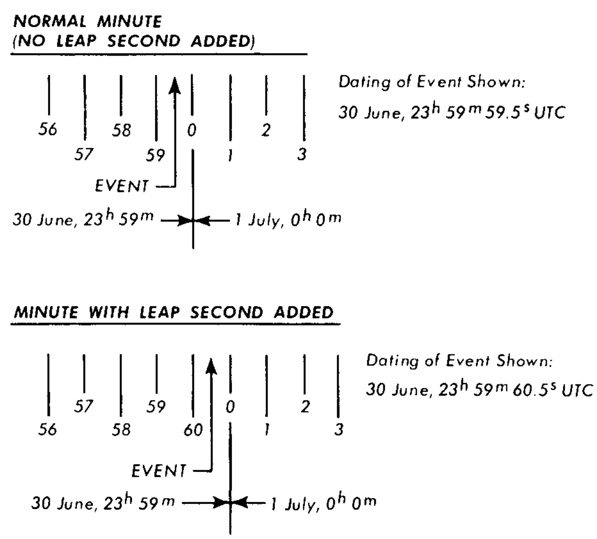


FIGURE 3. *Illustration of how events will be dated in the vicinity of a leap second.*

[4]Effective January 1, 1972: During the minute in which a one-second step correction occurs, that minute will contain either 59 or 61 seconds depending on whether the correction is negative or positive.

(c) Coding of UT1 Corrections

The method of coding UT1 corrections uses a system of double seconds pulses. The first through the seventh seconds pulses, when doubled, indicate a "plus" correction, and from the ninth through the fifteenth a "minus" correction. The eighth seconds pulse is not used. The amount of correction in units of 0.1 second is determined by counting the number of seconds pulses that are doubled. For example, if the first, second, and third seconds pulses are doubled, the UT1 correction is "plus 0.3 second." Or if the ninth, tenth, eleventh, twelfth, thirteenth, and fourteenth seconds pulses are doubled, the UT1 correction is "minus 0.6 second." To obtain UT1, use the algebraic relationship,

$$UT1 = Broadcast + Correction$$

That is, add the correction to the time broadcast if "plus" is transmitted; subtract if "minus" is transmitted. Thus, a clock keeping step with the time signals broadcast will be early with respect to UT1 if a "minus" is broadcast. These corrections will be revised as needed, the new value appearing for the first time during the hour after 0000 UTC.

UT1 corrections are also encoded in the time code (sec. 1.7) transmitted continuously on a 100-Hz subcarrier from WWV and WWVH. The value of the correction is indicated by the weight of the control functions that occur at the end of the code frame. The "plus or minus" indication is encoded in the first control function. If control function #1 is a binary one, the correction is positive; if it is a binary zero, the correction is negative. The correction is expressed to the nearest 0.1 second.

1.6. Official Announcements

The 45-second announcement segments available every other minute from WWV and WWVH are offered on a subscription basis to other agencies of the Federal Government to disseminate official and public service information. The accuracy and content of these announcements is the responsibility of the originating agency—not necessarily NBS.

All segments except those reserved for NBS use and the semi-silent periods are available. Arrangements for use of segments at the two stations may be made through the Frequency-Time Broadcast Services Section, 273.02, National Bureau of Standards, Boulder, CO 80302.

(a) Propagation Forecasts

A forecast of radio propagation conditions is broadcast in voice from WWV at 14 minutes after every hour. The announcements are short-term forecasts and refer to propagation along paths in the North Atlantic area, such as Washington, D.C. to London or New York to Berlin. These forecasts are also applicable to high latitudes provided the appropriate time correction is made for other latitudes. The forecasts are prepared by the Telecommunications Service Center, OT, Boulder, Colorado.[5]

The broadcast consists of the statement, "The radio propagation quality forecast at. . . (one of the following times: 0100, 0700, 1300, or 1900 GMT) is. . . (one of the following adjectives: excellent, very good, good, fair-to-good, fair, poor-to-fair, poor, very poor, or useless). Current geomagnetic activity is. . . (one of the following characteristics: quiet, unsettled, or disturbed)."

The propagation forecast announcements are repeated in synoptic form comprised of a phonetic and a numeral. The phonetic (Whiskey, Uniform, or November) identifies the radio quality at the time the forecast is made. The numeral indicates on a scale of 1 to 9 the radio propagation quality expected during the six-hour period after the forecast is issued. The meaning of the phonetics and numerals are:

Phonetic	Meaning
Whiskey	disturbed
Uniform	unsettled
November	normal

Numeral	Meaning
One	useless
Two	very poor
Three	poor
Four	poor-to-fair
Five	fair
Six	fair-to-good
Seven	good
Eight	very good
Nine	excellent

If, for example, propagation conditions are normal and expected to be good during the next six hours, the coded forecast announcement would be "November Seven."

(b) Geophysical Alerts

Current geophysical alerts (Geoalerts) as declared by the World Warning Agency of the International Ursigram and World Days Service (IUWDS) are broadcast in voice from WWV at 18 minutes after each hour and from WWVH at 45 minutes after each hour. The messages are changed daily at 0400 UTC with provisions to provide real-time data alerts of outstanding occurring events. These are followed by a summary of selected solar and geophysical events during the previous 24 hours. Messages concerning these forecasts are prepared by the Space Environment Laboratory, NOAA, Boulder, Colorado.[6]

[5] For details regarding these forecasts, write Kent D. Boggs, Telecommunications Services Center, OT, Boulder, CO 80302.

[6] For details of these announcements, write Miss J. Virginia Lincoln, Deputy Secretary IUWDS, NOAA, Boulder, CO 80302.

(c) Weather Information

Weather information about major storms in the Atlantic and Pacific areas is broadcast from WWV and WWVH respectively.[7] The brief messages are designed to tell mariners of storm threats in their areas. If there are no warnings in the designated areas, the broadcasts will so indicate. The ocean areas involved are those for which the U.S. has warning responsibility under international agreement. The regular times of issue by the National Weather Service are 0500, 1100, 1700 and 2300 UTC for WWV and 0000, 0600, 1200, and 1800 UTC for WWVH. These broadcasts are updated effective with the next scheduled announcement following the time of issue.

WWV broadcasts information about storms in the western North Atlantic, and WWVH lists storms in the eastern and central part of the North Pacific. These broadcasts are given in voice from WWV at 10 and 12 minutes after each hour and from WWVH at 49 and 51 minutes after each hour.

Sample broadcasts that exemplify the type of information mariners might expect to receive from WWV, for instance, are as follows:

"North Atlantic weather, West of 35 West at 1700 GMT: 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 feet."

(d) ATM Skylab Messages

In January 1973, WWV and WWVH began transmitting information messages regarding the Apollo Telescope Mount (ATM) observation missions which are scheduled during the Skylab Program.[8] These announcements, designed to coordinate efforts of participating ground stations throughout the world, include actual ATM observation program accomplishments and planned programs to be executed throughout the mission. The regular times of issue by the Space Environment Laboratory, NOAA, are at 0222, 0622, 1022, 1422, 1822 and 2222 from WWV and at 0225, 0625, 1025, 1425, 1825 and 2225 from WWVH. These broadcasts are updated effective with the next scheduled announcement with provisions to provide real time alert messages in the event of unusual solar activity. The messages are given in voice from WWV at 22 and 24 minutes after the hour and repeated from WWVH at 25 and 27 minutes after the hour.

[7]For information regarding these broadcasts, contact George P. Cressman, Director, National Weather Service, Silver Spring, MD 20910.

[8]For further information regarding these messages, write Robert B. Doeker, Chief, Space Environment Services Center, NOAA, Boulder, CO 80302.

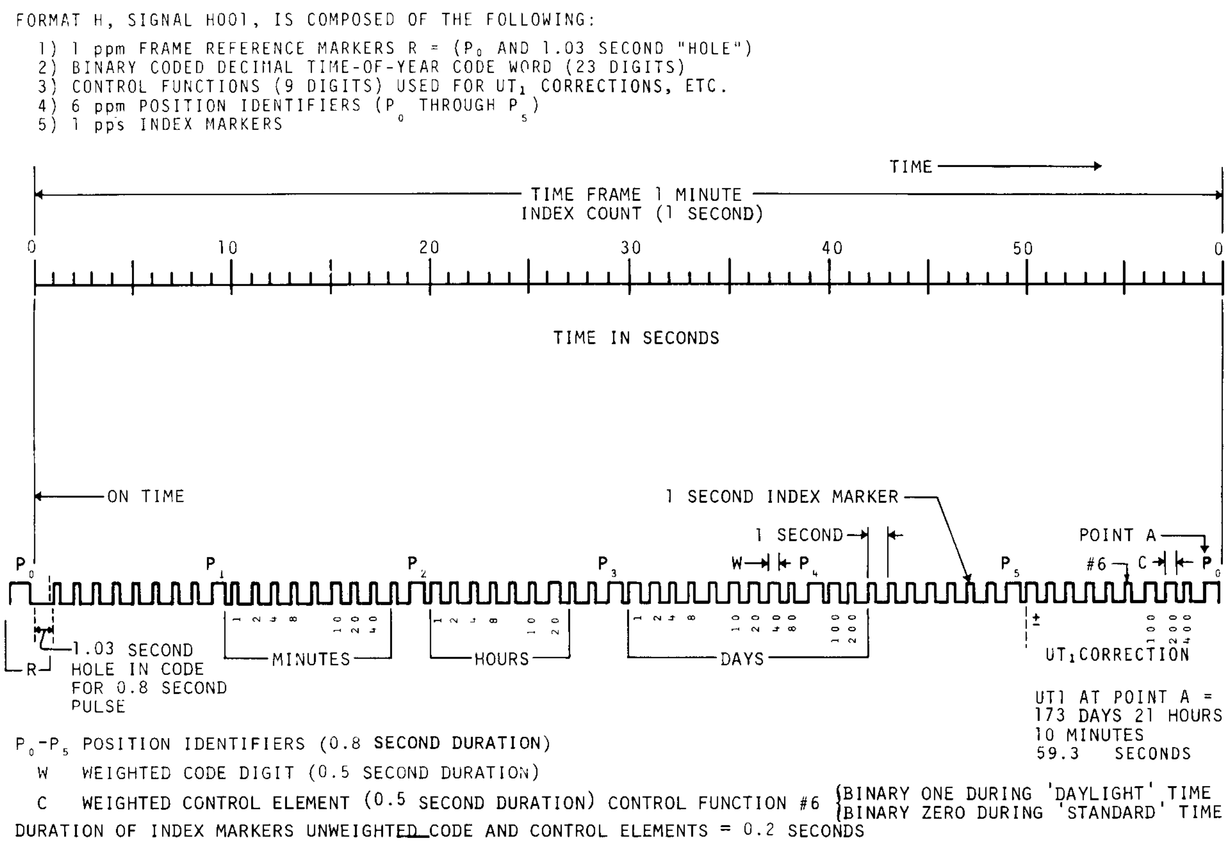


FIGURE 4. *Chart of time code transmissions from NBS radio stations WWV and WWVH.*

1.7. WWV/WWVH Time Code

On July 1, 1971, WWV commenced broadcasting the time code shown in figure 4. The time code is now transmitted continuously by both WWV and WWVH on a 100-Hz subcarrier. This time code provides a standardized timing base for use when scientific observations are made simultaneously at widely separated locations. It may be used, for instance, where signals telemetered from a satellite are recorded along with the time code; subsequent analysis of the data is then aided by having unambiguous time markers accurate to about 10 milliseconds.

The code format being broadcast is a modified IRIG-H time code. The code is produced at a 1-pps rate and is carried on 100-Hz modulation. The 100-Hz subcarrier is synchronous with the code pulses so that 10-millisecond resolution is readily obtained.

The code contains UTC time-of-year information in minutes, hours, and day of year. Seconds information may be obtained by counting pulses.

The binary coded decimal (BCD) system is used. Each minute contains seven BCD groups in this order: two groups for minutes, two groups for hours, and three groups for day of year. The code digit weighting is 1-2-4-8 for each BCD group multiplied by 1, 10, or 100 as the case may be. A complete time frame is 1 minute. The binary groups follow the 1-minute reference marker.

In the standard IRIG-H format, "on-time" occurs at the leading edge of all pulses. A binary zero pulse comprises 20 cycles of 100-Hz amplitude modulation; a binary one pulse comprises 50 cycles of 100-Hz amplitude modulation. Because of the 40-millisecond hole that accompanies each seconds marker in the WWV/WWVH format, however, the leading 30-millisecond portion in the WWV/WWVH time code is deleted. The leading edge of each pulse coincides with a positive-going zero-axis crossing of the 100-Hz modulating frequency.

Based upon a clocking rate of 60 markers per minute, the code contains six position identification markers per minute and a minute reference marker. Each 6-per-minute position identification marker consists of a 0.8-second pulse preceding a code group. The 1-per-minute reference marker consists of a 0.8-second pulse followed by a 1.03-second hole in the code and eight binary zero pulses in succession. The minute begins with the 1.03-second hole preceding the first binary zero.

UT1 corrections to the nearest 0.1 second are encoded via control function pulses during the final ten seconds of the frame. Control function #1, which occurs as the 50th second pulse, discloses the sense of the correction. Control function #1 is a binary zero when the UT1 correction is negative and a binary one when the correction is positive. Control function #7, #8, and #9, which occur as the 56th, 57th, and 58th second pulses, identify the magnitude of the UT1 correction.

Control function #6, which occurs as the 55th second pulse, is programmed as a binary one throughout those weeks when Daylight Saving Time is in effect and as a binary zero when Standard Time is in effect. The setting of this function is changed at 0000 GMT on the last Sunday of April and October respectively. Throughout the U.S. mainland this schedule allows several hours for the function to be received before the change becomes effective locally, i.e., at 2:00 AM. Thus, control function #6 provides a feature through which clocks or digital recorders operating on local time can be programmed to make an automatic one-hour adjustment in changing from Daylight Saving Time to Standard Time and vice versa.

1.8. Station Identification

WWV and WWVH identify by voice every 30 minutes. The station identification voice announcements are automatically synchronized recordings, not live broadcasts. The regular announcer for WWV is Mr. Don Elliott of Atlanta, Georgia; the regular announcer for WWVH is Mrs. Jane Barbe, also of Atlanta.

1.9. Radiated Power, Antennas and Modulation

(a) Radiated Power

Frequency	Radiated Power, kW	
MHz	WWV	WWVH
2.5	2.5	5
5	10	10
10	10	10
15	10	10
20	2.5	2.5
25	2.5	---

(b) Transmitting Antennas

The broadcasts on 5, 10, 15, and 20 MHz from WWVH are from phased vertical half-wave dipole arrays. They are designed and oriented to radiate a cardioid pattern directing maximum gain in a westerly direction. The 2.5-MHz antenna at WWVH and all antennas at WWV are half-wave vertical dipoles which radiate omnidirectional patterns.

(c) Modulation

At WWV and WWVH, double sideband amplitude modulation is employed with 50 percent modulation on the steady tones, 25 percent for the IRIG-H code, 100 percent for seconds pulses, and 75 percent for voice.

2. WWVB Broadcast Services

WWVB transmits a standard radio frequency, standard time signals, time intervals, and UT1 corrections. The station is located near WWV on the same site. The coordinates of WWVB are

40° 40′28.3″ N   105° 02′39.5″ W.

Alternating its scheduled maintenance periods with those of experimental and intermittently operated station WWVL, it suspends operation for several hours between 1300 UTC and 2400 UTC every other Tuesday. Otherwise the service is continuous.

(a) Program

WWVB broadcasts a standard radio carrier frequency of 60 kHz with no offset. It also broadcasts a time code consistent with the internationally coordinated time scale UTC(NBS).

(b) Accuracy and Stability

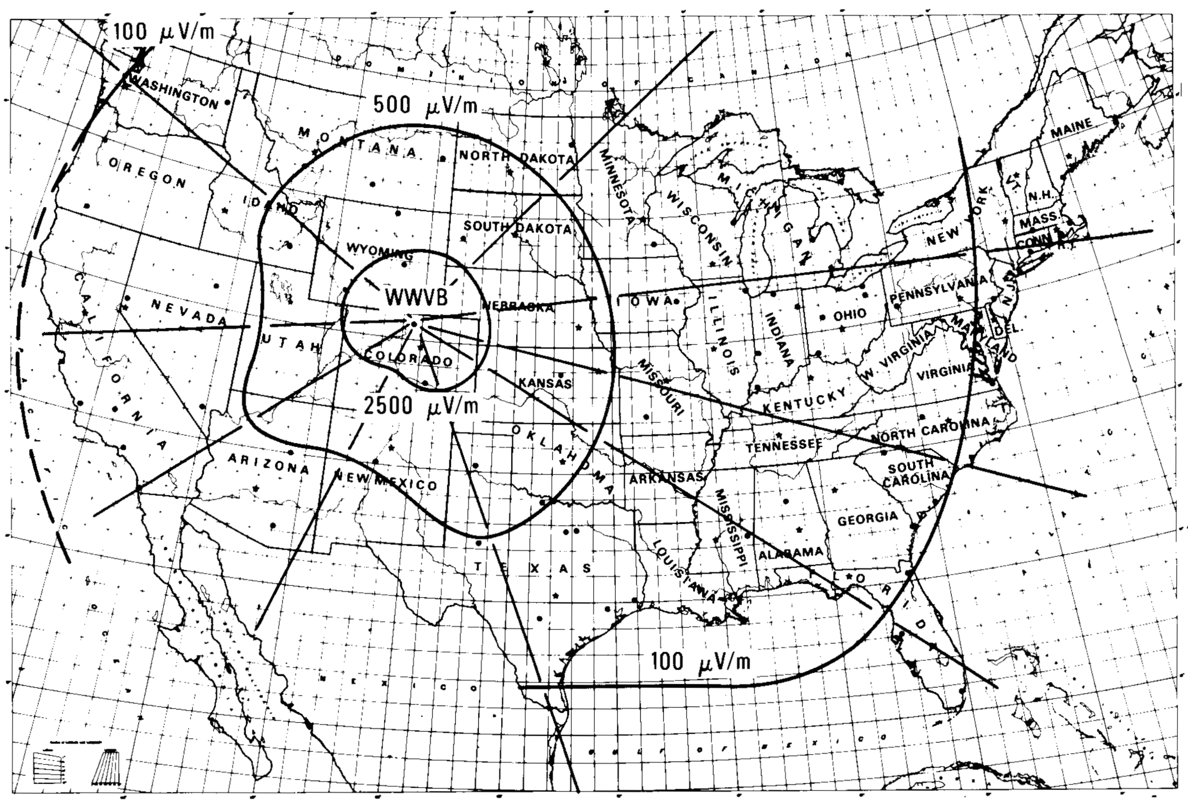
The frequency of WWVB is normally within its prescribed value to better than 2 parts in 10^{11}. Deviations from day to day are less than 1 part in 10^{12}. Effects of the propagation medium on received signals are relatively minor at low frequencies (LF); therefore, the accuracy of the transmitted signals may be fully utilized by employing appropriate receiving and averaging techniques [3, 4].

(c) Station Identification

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

(d) Radiated Power, Antenna, and Coverage

The effective radiated power from WWVB is 13 kW. The antenna is a 122-meter, top-loaded vertical installed over a radial ground screen. Some measured field intensity contours are shown in figure 5.



MEASURED FIELD INTENSITY CONTOURS: WWVB @13 kW ERP

FIGURE 5. *Measured field intensity contours: WWVB @ 13 kW ERP*

2.1. WWVB Time Code

(a) Code and Carrier

On July 1, 1965, WWVB began broadcasting time information using a carrier-level-shift time code. The code, which is binary coded decimal (BCD), is broadcast continuously and is synchronized with the 60-kHz carrier signal. Features of the WWVB time code are shown in figure 6.

(b) Marker Generation

The signal consists of 60 markers each minute, with one marker occurring during each second. (Time progresses from left to right.) Each marker is generated by reducing the power of the carrier by 10 dB at the beginning of the corresponding second and restoring it 0.2 second later for an uncoded marker or a binary zero, 0.5 second later for a binary one, and 0.8 second later for a 10-second position marker or for a minute reference marker. The leading edge of every negative-going pulse is on time.

(c) Marker Order and Groups

The 10-second position markers, labeled P0 through P5 in figure 6, occur respectively as the 59th, 9th, 19th, 29th, 39th, and 49th second pulses of each minute.[9] The minute reference marker begins at zero seconds. Uncoded markers occur periodically as the 4th, 14th, 24th, 34th, 44th, and 54th seconds pulses and also as the 10th, 11th, 20th, 21st, 35th, 55th, 56th, 57th, and 58th seconds pulses of each minute. Thus every minute contains twelve groups of five markers, each group ending either with a position marker or an uncoded marker.

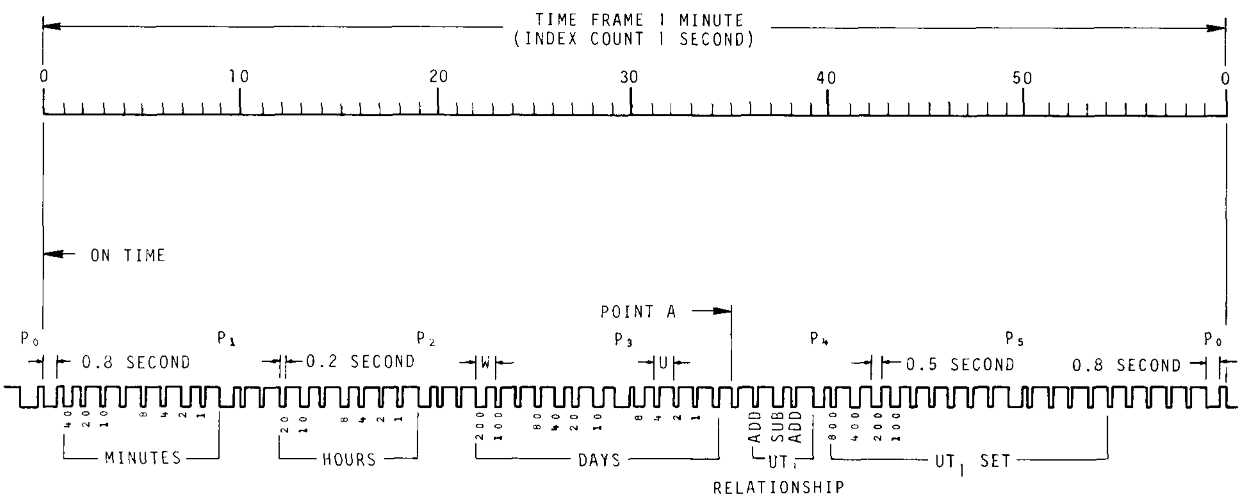
[9]Effective January 1, 1972: During the minute in which a one-second step correction occurs, that minute will contain either 59 or 61 seconds.

(d) Information Sets

Once every minute the code presents complete UTC(NBS) time-of-year information in minutes, hours, and day of the year as well as the estimated difference between UTC and UT1. Seconds information can be obtained by counting pulses.

The first two groups in the frame specify the minute of the hour. The third and fourth groups comprise a set which specifies the hour of the day. The fifth, sixth, and seventh groups form a set which specifies the day of the year. A set made up of the ninth, tenth, and eleventh groups specifies the number of milliseconds that must be added to or subtracted from the time as broadcast in order to obtain UT1. The twelfth group is not used.

The positive or negative relationship of the UT1 scale with respect to UTC is indicated by the eighth group. If UT1 is late with respect to UTC, a binary one (labeled SUB in figure 6) will be broadcast in the eighth group as the 37th second pulse of the minute. If UT1 is early with respect to the code time, binary ones (labeled ADD) will be broadcast in the eighth group as the 36th and 38th second pulses of the minute.



1 PPM FRAME REFERENCE MARKERS
BINARY CODED DECIMAL TIME-OF-YEAR CODE WORD (23 DIGITS)
CONTROL FUNCTIONS (15 DIGITS) USED FOR UT1 CORRECTIONS
6 PPM POSITION IDENTIFIER MARKERS AND PULSES (P_0 THRU P_5)
(REDUCED CARRIER 0.8 SECOND DURATION PLUS 0.2 SECOND DURATION PULSE)
W - WEIGHTED CODE DIGIT (CARRIER RESTORED IN 0.5 SECOND - BINARY ONE)
U - UNWEIGHTED CODE DIGIT (CARRIER RESTORED IN 0.2 SECOND - BINARY ZERO)

TIME AT POINT A
258 DAYS
18 HOURS
42 MINUTES
34.3 SECONDS

FIGURE 6. *Chart of time code transmissions from NBS radio station WWVB.*

(e) Digital Information

When used to convey numerical information, the four coded markers used as digits in a BCD group are indexed 8-4-2-1 in that order. Sometimes only the last two or three of the coded markers in a group are needed, as in the first groups of the minutes, hours, and days sets. In these cases, the markers are indexed 2-1, or 4-2-1, accordingly. The indices of the first group in each set which contains two groups are multiplied by 10, those of the second group of such a set are multiplied by 1. The indices of the first group in each set which contains three groups are multiplied by 100, those of the second group by 10, and those of the third group by 1.

Example

A specific example is indicated in figure 6. The occurrence of two binary ones in the "minutes set" indicates that the minute contemplated is the 40 + 2 = 42nd minute. Similarly, the two binary ones in the "hours set" indicate the 10 + 8 = 18th hour of the day, while the four binary ones in the "day set" indicate the 200 + 40 + 10 + 8 = 258th day of the year. It is seen from the "UT1 Relationship" group and the "UT1 Set" that one should *subtract*, from any second in this minute, 400 + 200 + 100 = 700 milliseconds to get an estimate of UT1. For example, the 35th UT1 interval would end 700 milliseconds (or 0.7 second) *later* than the end of the 35th second. In other words, the UT1 scale reading for the end of the 35th second would be 18h 42m 34.3s, since 35.0s - 0.7s = 34.3s.

3. WWVL Experimental Broadcasts

WWVL broadcasts experimental programs, usually involving multiple frequencies. The station is located in the same building with WWVB and on the same site with WWV. The coordinates of WWVL are:

40°40′51.3″ N   105°03′00.0″ W.

Effective 0h UTC, 1 July 1972, regularly scheduled transmissions from WWVL were discontinued. Contingent upon need and availability of funds this station now broadcasts experimental programs on an intermittent basis only. Transmissions can be made available on a subscription basis to civil organizations as well as agencies of the Federal government. Arrangements for use of WWVL should be made through the Frequency-Time Broadcast Services Section, 273.02, National Bureau of Standards, Boulder, CO 80302.

(a) Program Format

WWVL transmits only carrier frequencies with no modulation. In accordance with the new UTC system the frequency offset used prior to January 1, 1972, was reduced to zero on that date. The format and frequencies used by WWVL are subject to change to meet the requirements of the particular experiment being conducted.

(b) Accuracy and Stability

The transmitted frequencies from WWVL are normally within their prescribed values to better than 2 parts in 10^{11}. Deviations from day to day are less than 1 part in 10^{12}. Because of the excellent coverage and phase stability in the very low frequency (VLF) region, this mode of transmission permits the frequencies to be received with an accuracy approaching that of signals at the transmitter itself.

(c) Station Identification

WWVL is identified only by its unique program format.

(d) Radiated Power, Antenna

The effective radiated power from WWVL is 2 kW. The antenna is a 122-meter, top-loaded vertical installed over a radial ground screen.

4. How NBS Controls the Transmitted Frequencies

A simplified diagram of the NBS frequency control system [5] is shown in figure 7. The entire system depends upon the basic frequency reference shown in this diagram as the Cesium (Cs) Atomic Beam. This standard is used to calibrate the oscillators, dividers and clocks which generate the controlled frequency and the NBS time scales.

Utilizing the line-10 horizontal synchronizing pulses from a local television station, the Fort Collins master clock is compared on a daily basis with the NBS master clock [6]. All other clocks and time-code generators at the Fort Collins site are then compared with the Fort Collins master clock. Frequency corrections of the WWVB and WWVL quartz crystal oscillators are based on their phase relative to the NBS master clock.

The transmissions from WWV and WWVH are controlled by three cesium standards located at each site. To ensure accurate time transmissions from each station, the time-code generators are compared with the station's master clock several times each day.

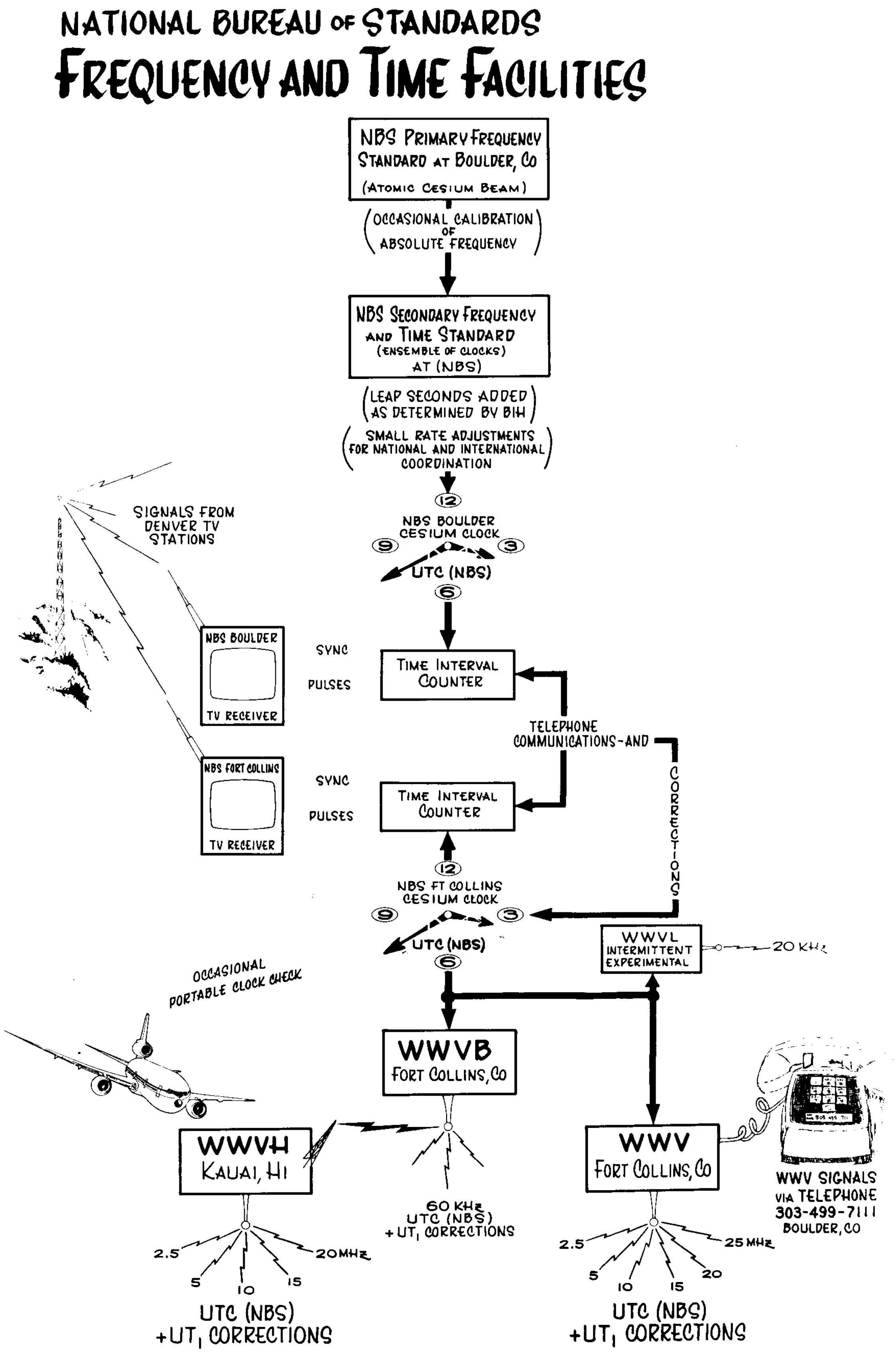


FIGURE 7. *NBS frequency control system.*

Control of the signals transmitted from WWVH is based not only upon the cesium standards, but upon signals from WWVB as received by phase-lock receivers. The cesium standards controlling the transmitted frequencies and time signals are continuously compared with the received signals.

To ensure that systematic errors do not enter into the system, the NBS time scale is often compared with the transmitting station clocks by the use of a very precise portable clock.

5. References

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[2] National Standards of Time and Frequency in the United States, Proc. IRE, **IRE-48**, No. 105 (1960).

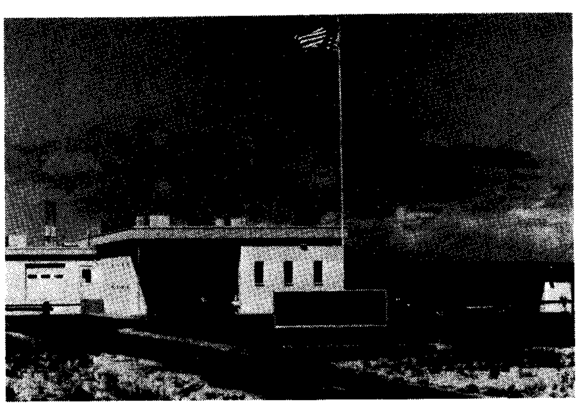
[3.] Allan, D.W., and Barnes, J.A., Some Statistical Properties of LF and VLF Propagation, AGARD Conf. Proc. No. 33, Phase and Frequency Instabilities in Electromagnetic Wave Propagation (Proc. AGARD/EPC 13th Symp., Ankara, Turkey, Oct. 9-12, 1967). K. Davies, Ed., Chapter 15 (Technivision Services, Slough, England, in press).

[4.] Guetrot, A., Higbie, L.S., Lavanceau, J., and Allan, D.W., An Application of Statistical Smoothing Techniques on VLF Signals for Comparison of Time Between USNO and NBS, (Summary) Proc. 23rd Annual Symp. on Frequency Control, Fort Monmouth, NJ, (May 6-8, 1969), p. 248.

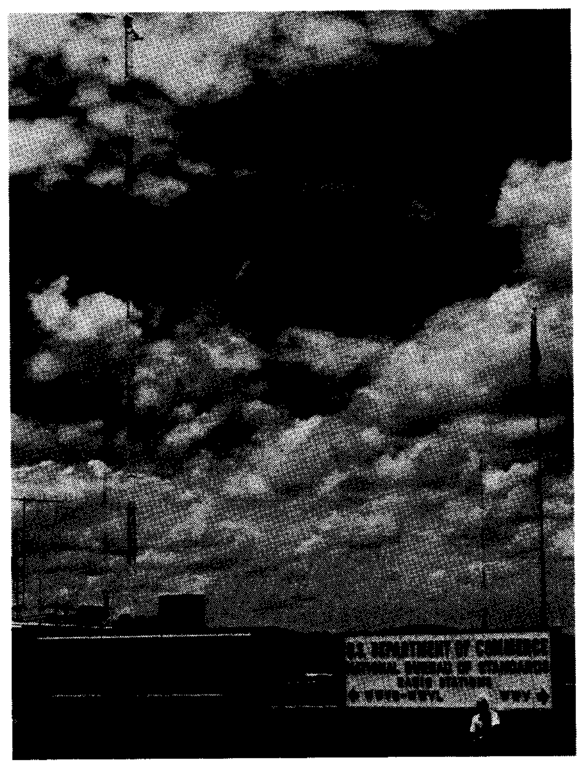
[5.] Milton, J.B., Standard Time and Frequency: Its Generation, Control, and Dissemination from the National Bureau of Standards Time and Frequency Division, NBS Technical Note 379 (Aug. 1969).

[6.] Tolman, J., Ptacek, V., Soucek, A., and Stecher, R., Microsecond clock comparisons by means of TV synchronizing pulses, IEEE Trans.—Instr. and Meas. **IM-16**, No. 3, (Sept. 1967). pp. 247-254.

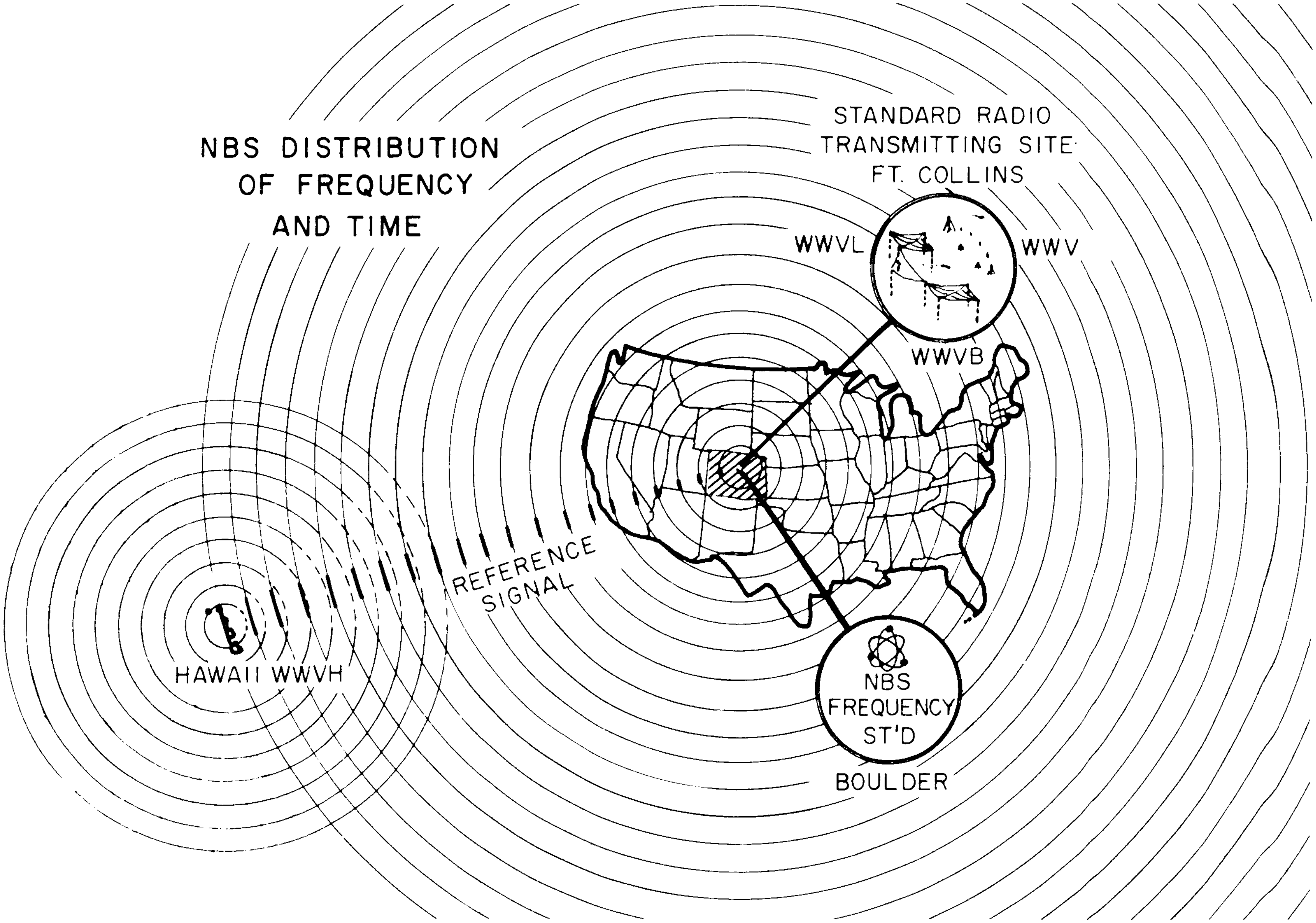
NBS Fort Collins facility showing WWV transmitter building.



WWVH transmitter building, Kekaha, Kauai, Hawaii.



WWVB/WWVL transmitter building and antennas.


NBS DISTRIBUTION
OF FREQUENCY
AND TIME
STANDARD RADIO
TRANSMITTING SITE
FT. COLLINS
WWVL
WWV
WWVB
REFERENCE
SIGNAL
HAWAII WWVH
NBS
FREQUENCY
ST'D
BOULDER