6

Standard Frequency Transmissions

NATIONAL BUREAU OF STANDARDS

There are seven technical services provided by the National Bureau of Standards radio station WWV, WWVH, WWVB, and WWVL. These services are: (1) standard radio frequency; (2) standard audio frequencies; (3) standard musical pitch; (4) standard time intervals; (5) time signals; (6) UT1 corrections; and (7) official announcements.

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

John Stanley, Engineer-in-Charge
NBS Radio Stations WWV/WWVB/WWVL
Route 2, Box 83-E
Fort Collins, Colorado 80521
Telephone (303) 484-2372

Charles Trembath, Engineer-in-Charge
NBS Radio Station WWVH
P.O. Box 417
Kekaha, Kauai, Hawaii 96752
Telephone (808) 337-5217

1.1. STANDARD RADIO FREQUENCIES

Program

WWV and WWVH broadcast nominal frequencies and time consistent with the internationally agreed upon time scale, Universal Coordinated Time[1] (UTC). Changes in UTC effective January 1, 1972, are discussed in section 1.5(b).

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 on both stations are continuous, night and day.

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.

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 the National Bureau of Standards. Atomic frequency standards have been shown to realize the ideal cesium resonance frequency, f_{Cs}, to within a few parts in 10^{11}. The present NBS frequency standard and time scale system realizes this resonance frequency to an uncertainty of ± 9 parts in 10^{13} [1].

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

[1]As noted in a resolution of Commission 31 of the International Astronomical Union, August 1970: "The terms 'GMT' and 'Z' are accepted as the general equivalents of UTC in navigation and communication."

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}. Frequencies measured in terms of the NBS standard between December 1, 1957 and January 1, 1960 need to take the above correction into account [2].

The frequencies transmitted by WWV and WWVH are held stable to better than ± 2 parts in 10^{11} at all times. Deviations at WWV are normally less than 1 part in 10^{12} from day to day. Incremental frequency adjustments not exceeding 1 part in 10^{11} are made at WWV as necessary. Frequency adjustments made at WWVH do not exceed 2 parts in 10^{11}.

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

Corrections

All carrier and modulation frequencies at WWV and WWVH are derived from cesium-controlled oscillators. These frequencies, in conformity with the UTC scale, are broadcast with no intentional offset from the nominal frequency. Previously, the fractional frequency offset for 1960 and 1961 was —150 parts in 10^{10}; in 1962 and 1963, —130 parts in 10^{10}; in 1964 and 1965, —150 parts in 10^{10}; and in 1966 through 1971, —300 parts in 10^{10}.

At the recommendation of the International Radio Consultative Committee (CCIR), the frequency offset of UTC was made permanently zero effective 0000 hours UTC January 1, 1972.

Corrections to the transmitted frequency or phase are regularly determined with respect to the NBS time standard and are published monthly (since March 1966) in the *NBS Time and Frequency Services Bulletin.*

1.2. STANDARD AUDIO FREQUENCIES

Program

The hourly broadcast format of WWV and WWVH is presented in Fig. 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 minues after the hour at WWVH.

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 which is transmitted continuously from WWV and WWVH does contain this frequency and may be used as a standard with the same accuracy as the audio frequencies.

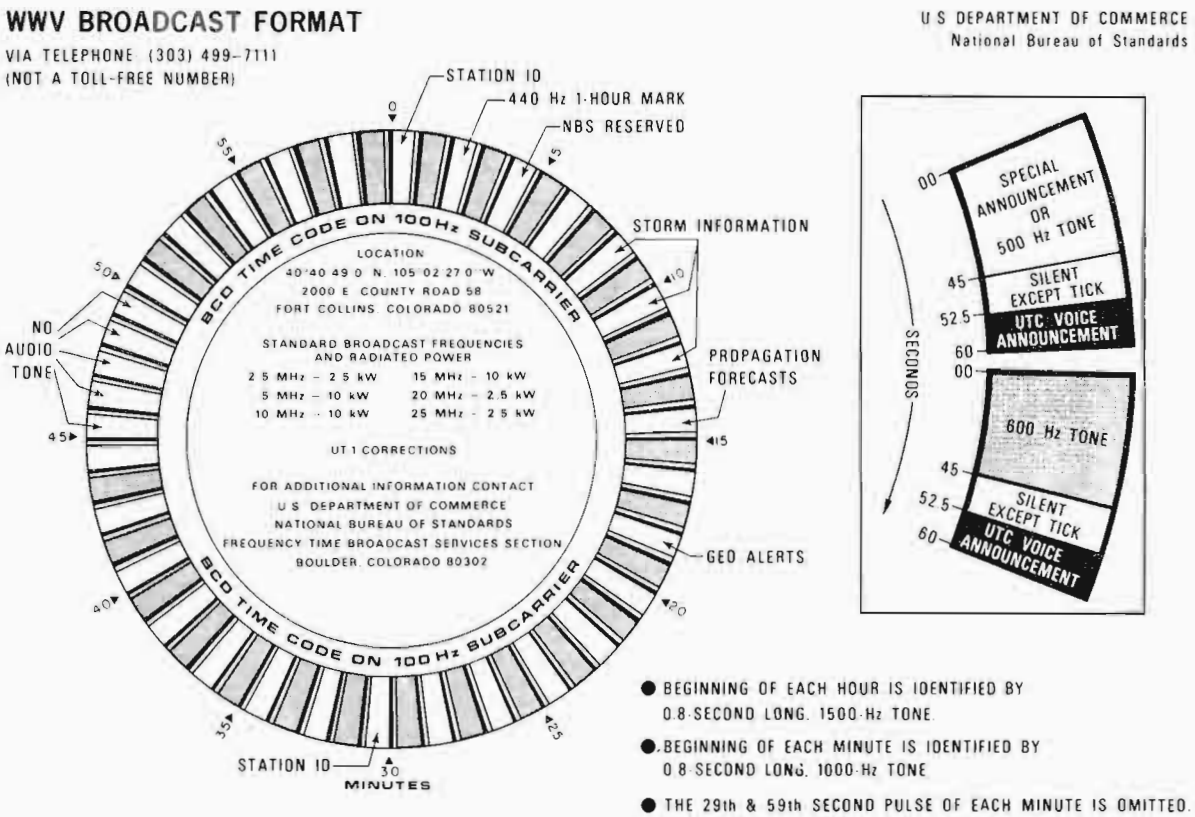
1.3. STANDARD MUSICAL PITCH

The frequency 440 Hz, for the note A above middle C, is the standard in 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

UTC 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. Each 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



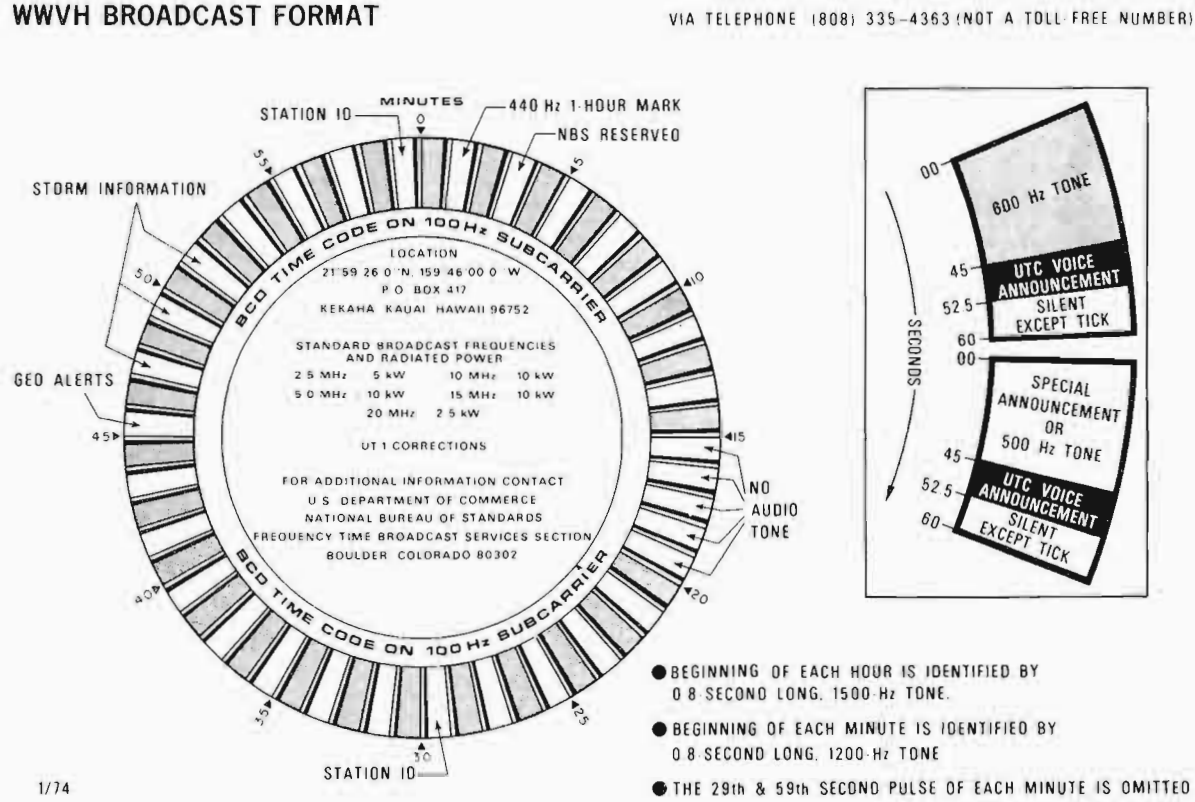


Fig. 1. The hourly broadcast schedules of WWV and WWVH.

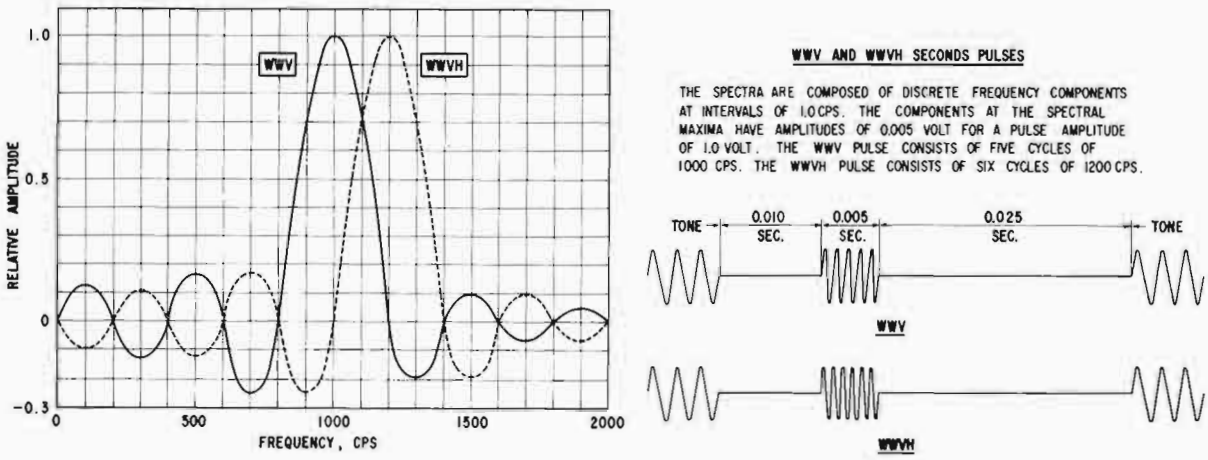


Fig. 2. Sample characteristics of time pulse broadcast from NBS radio stations WWV and WWVH.

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 Fig. 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

Program

Because of the common usage of the name Greenwich Mean Time, the time announcements on WWV and WWVH are referred to by this name. More precisely, the actual reference time scale is the Coordinated Universal Time Scale as maintained by the National Bureau of Standards, UTC (NBS).

The 0 to 24 hour system is used starting with 0000 for midnight at longtitude 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 0.8 second long audio tone begins.

At WWV a voice announcement of Greenwich Mean Time is given during the last 7.5 seconds of every minute. At 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 45 seconds to 52.5 seconds after the minute. It should be noted that the voice announcement for WWVH precedes 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.

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 1, 1971 at 23h 59 min 60.107600 sec. UTC (i.e., GMT), UTC (NBS) "was retarded 0.107600 second" to give the new UTC scale an initial difference of 10 seconds late with respect to International Atomic Time (IAT) as maintained by the Bureau of International de L'Heure (BIH) in Paris, France.

Corrections to UTC will be made in step adjustments of exactly 1 second when the BIH determines they are needed to keep the broadcast time signals within ± 0.7s of astronomical time, UT1. (Note: the corrections no longer relate to UT2.)

UT1 Corrections

Since the new UTC rate (effective January 1, 1972) is no longer adjusted periodically to agree with the earth's rotation rate, the new UTC departs more rapidly than before from earth rotation time (known as UT1), gaining about 1 second per year. In order to prevent this difference from exceeding 0.7 second, step adjustments of exactly one second, to be called a leap second, will be made as necessary at the end of the UTC month, preferably on 31 December or 30 June.

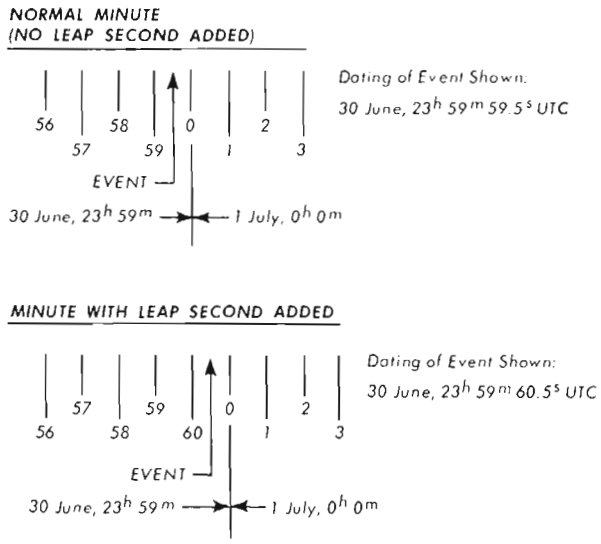


Fig. 3. Illustration of how events are dated in the vicinity of a leap second.

Thus, when required, a leap second will be 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. This is analogous to adding an extra day (which might be called a leap day) during a leap year. Fig. 3 illustrates how events will be dated in the vicinity of a leap second. The BIH will announce the occurrence of leap seconds two months in advance.

The method of coding the UT1 corrections uses a system of double seconds pulses. The first through the seventh seconds pulse, when marked by a double pulse, will 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 second pulses are doubled, the UT1 correction is "plus" 0.3 second. Or in the ninth, tenth, eleventh, twelfth, thirteenth, and fourteenth seconds pulses are doubled, the UT1 ccorrection is "minus" 0.6 second. To obtain UT1, use the relationship

$$\text{UT1—Broadcast} = \text{Correction}.$$

That is, add the correction to the time broadcast if "plus" is transmitted, subtract if "minus" is 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.

The UT1 corrections are also encoded in the time code transmitted continuously on a 100-Hz subcarrier from WWV and WWVH. The value of the correction is indicated by the weight of the control bits that occur at the end of the code frame. The "plus" or "minus" indication is encoded in the first control bit; i.e., if the bit is a binary one the correction is "plus," if it is a binary zero it is "minus." The correction is 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 the National Bureau of Standards.

All segments except those reserved for NBS use and the semisilent 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, Colorado 80302.

Propagation Forecasts

A forecast of radio propagation conditions is broadcast in voice during part of every 15th minute of each hour from WWV. 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 Office of Telecommunications Services Center, OT, Boulder, Colorado.

The broadcast consists of the statement, "The radio propagation quality forecast at . . . (one of the following times: 0100, 0700, 1300, or 1900 UTC) 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)."

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 during the 19th minute of each hour from WWV and during the 46th minute of each hour from WWVH. 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 in the past 24 hours. Information concerning these forecasts are prepared by the Space Environment Laboratory, NOAA, Boulder, Colorado.

Weather Information

Weather information about major storms in the Atlantic and Pacific areas is broadcast from WWV and WWVH, respectively. 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, 1600, and 2300 UTC by WWV and 0000, 0600, 1200, and 1800 UTC by 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 during the 11th and 13th minute from WWV and during the 50th and 52nd minute from WWVH.

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 degrees 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, seas 15 feet."

1.7. WWV/WWVH TIME CODE

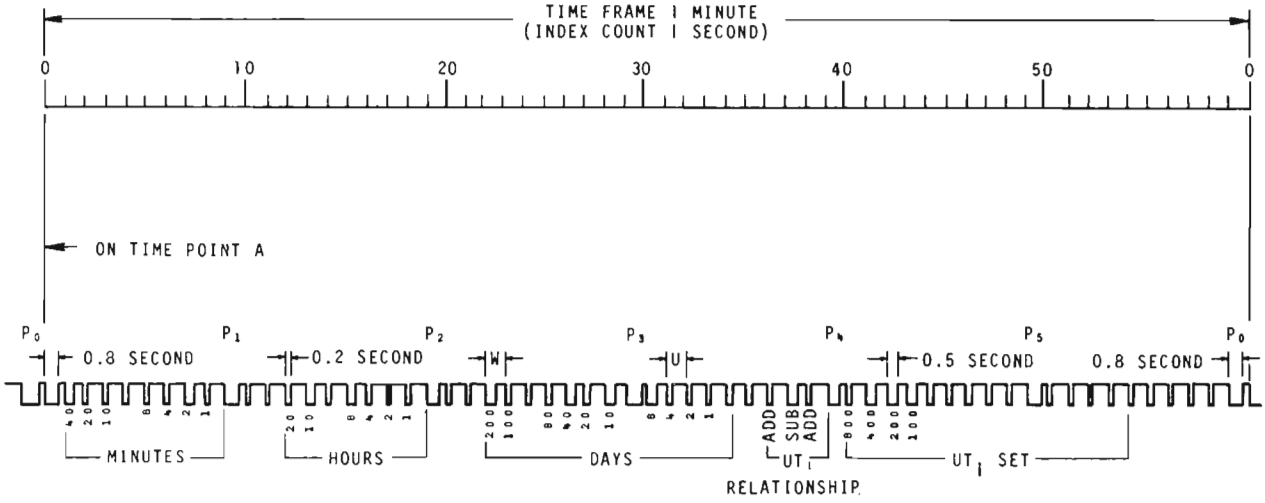
On July 1, 1971, WWV commenced broadcasting the time code shown in Fig. 4. The time code is now transmitted continuously by both WWV and WWVH on a 100-Hz subcarrier. This time code provides a standardized timing base for use when scientific observations are made simultaneously at widely separated locations. 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 code contains UTC time-of-year information in minutes, hours, and day of year. Seconds information may be obtained by counting pulses. The code is synchronous with the frequency and time signals.

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. "On-time" occurs at the positive-going leading edge of all pulses.



1 PPM FRAME REFERENCE MARKERS
BINARY CODED DECIMAL TIME-OF-YEAR CODE WORD (23 DIGITS)
CONTROL FUNCTIONS (15 DIGITS) USED FOR UT_1 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)

UTC AT POINT A	UT1 AT POINT A
258 DAYS	258 DAYS
18 HOURS	18 HOURS
42 MINUTES	41 MINUTES
	59.3 SECONDS

Fig. 4. Chart of time code transmissions from NBS radio stations WWVB.

The code contains 60 markers per minute clocking rate, 6 per minute position identification markers, and a 1 per minute reference marker. The 100-Hz subcarrier is synchronous with the code pulses so that 10-millisecond resolution is readily obtained.

The 6 per minute position identification markers consist of 0.8 second pulses preceding each code group. The 1 per minute reference marker consists of one 0.8 second pulse followed by a 1.03 second "hole" in the code followed by eight binary zero pulses. The minute begins with the 1.03 second "hole" at the beginning of the code.

A binary zero pulse consists of 20 cycles of 100-Hz amplitude modulation, and the binary one pulse consists of 50 cycles of 100-Hz amplitude modulation. The leading edges of the time code pulses coincide with positive-going zero-axis-crossings of the 100-Hz modulating frequency.

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

Radiated Power

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

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.

Modulation

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

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).

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].

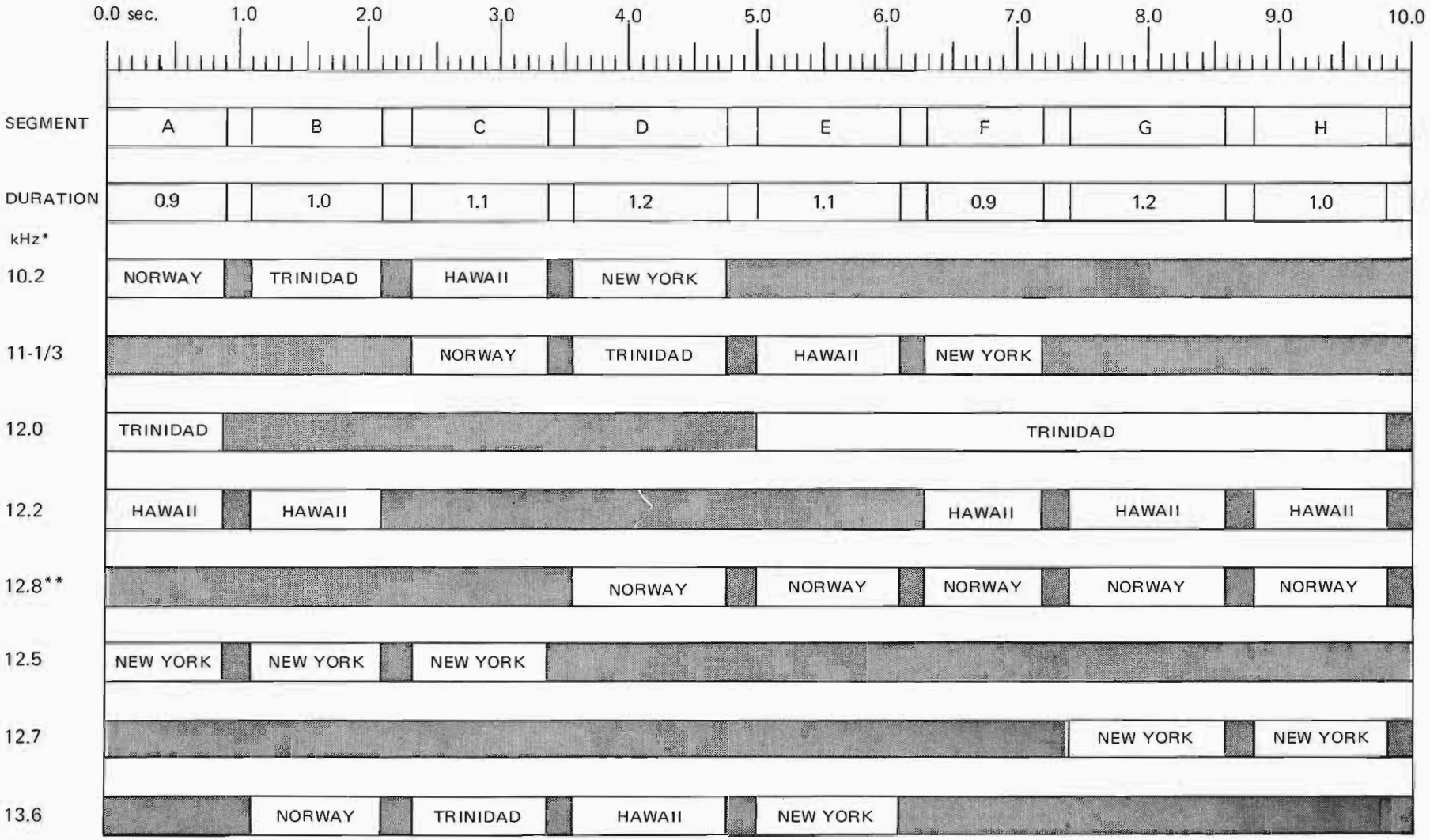
Station Identification

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.

Radiated Power, Antenna, and Modulation

The effective radiated power from WWVB is 13 kW. The antenna is a 122-meter, top-loaded vertical installed over a radial ground screen. The station uses 10-dB carrier-level reduction in transmitting its time code.

CHART A
OMEGA SIGNAL FORMAT



*Frequency is offset according to the current rate for UTC.
**Transmissions on unique frequency from Norway have started for testing purposes.

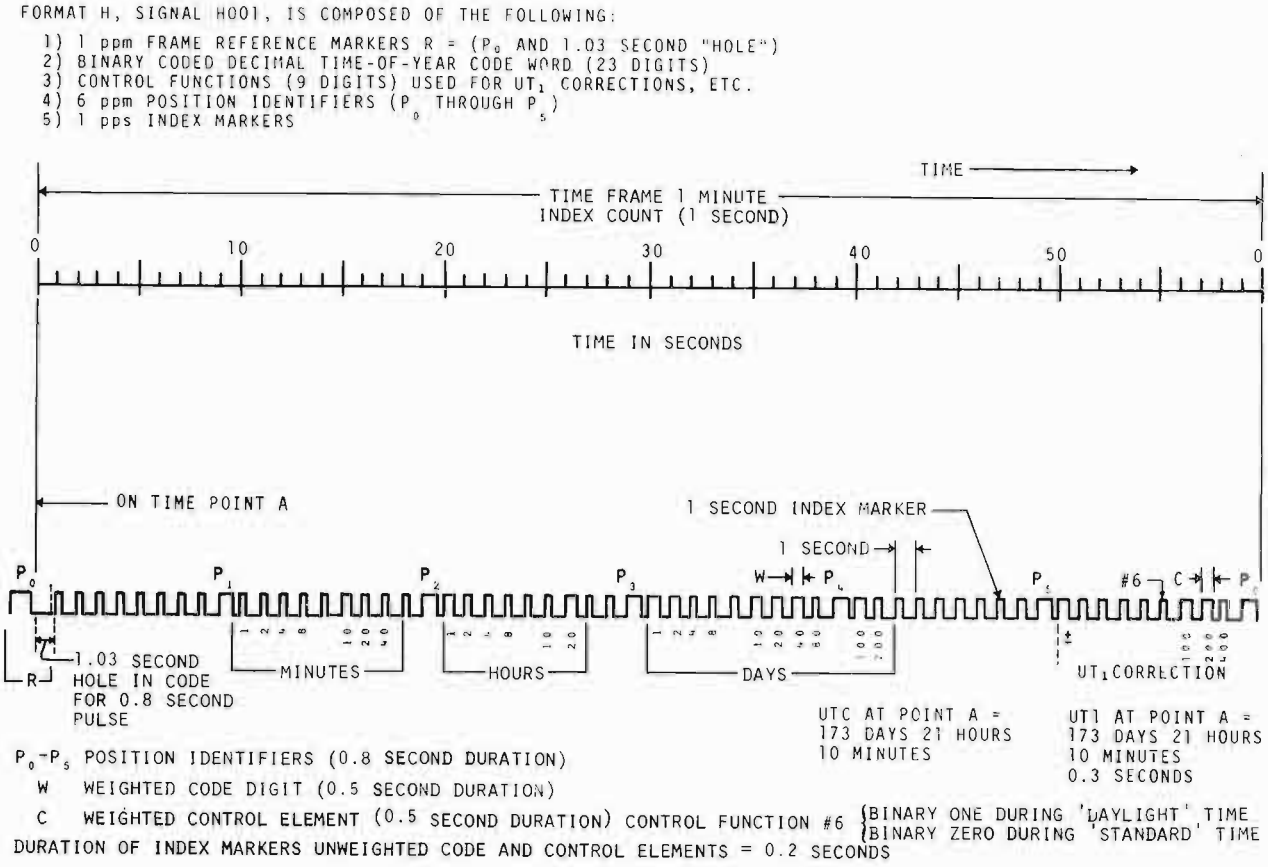


Fig. 5. Chart of time code transmissions from NBS radio stations WWV and WWVH.

2.1. WWVB TIME CODE

Code and Carrier

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

Marker Generation

As shown in Fig. 5, 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 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. Several examples of binary ones are indicated by I in Fig. 5. The leading edge of every negative-going pulse is on time.

Marker Order and Groups

The 10-second position markers, labeled P0 to P5 on the diagram, occur respectively in the 60th, 10th, 20th, 30th, 40th, and 50th seconds of each minute.[2] The minute reference marker occurs in the 1st second of the minute. Uncoded markers occur periodically in the 5th, 15th, 25th, 35th, 45th, and 55th seconds of each minute, and also in the 11th, 12th, 21st, 22nd, 36th, 56th, 57th, 58th, and 59th seconds. Thus, every minute contains 12 groups of 5 markers, each group ending either with a position marker or an uncoded marker. The signal pulses lasting for 0.2 seconds after a position marker are shown blackened in Fig. 4; the signal pulses lasting for 0.8 seconds after a periodically uncoded marker are shaded; other signal pulses following uncoded markers are labeled with a U.

With the exception of the uncoded and reference markers specifically mentioned above, the remaining markers in each of the groups are utilized to convey additional information.

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

Information Sets

Each minute the code presents time-of-year information in seconds, minutes, hours, and day of the year and the actual milliseconds difference between the time as broadcast and the best known estimate of UT1. The first two BCD groups in the frame specify the minute of the hour; the third and fourth BCD groups make up 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 BCD groups, specifies the number of milliseconds to be added or subtracted from the code time as broadcast in order to obtain UT1. The twelfth group is not used.

The relationship of the UT1 scale to the time as coded is indicated in the eighth group. If UT1 is late with respect to the code time, a binary one, labeled SUB in Fig. 5, will be broadcast in the eighth group during the 38th second of the minute. If UT1 is early with respect to the code time, binary ones, labeled ADD, will be broadcast in the eighth group during the 37th and 39th seconds of the minute.

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 indexes 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 indexes 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 Fig. 5. 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 "days 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, 40 + 1 = 41 milliseconds to get the best estimate of UT1. For example, the 35th UT1 interval would end 41 milliseconds *later* than the end of the 35th second; or, in other words, the UT1 scale reading for the end of the 35th second would be 18h 42 min. 34.959 sec. since 35.000 - 0.041 = 34.959.

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.

Alternating its scheduled maintenance periods with those of WWVB, it suspends operation for several hours between 1300 UTC and 2400 UTC every other Tuesday. Otherwise the programs are continuous.

Effective 0000 hours UTC, January 1, 1972, all transmissions from WWVL will be on an intermittent and experimental basis only. These broadcasts are planned to be curtailed within a few months thereafter. Users of this service are urged to explore alternative solutions to their needs.

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 transmissions presently alternate between 20.0 kHz and 19.9 kHz on a 50% duty cycle with each frequency being broadcast for 10 seconds. The 20.0 kHz transmissions commence on the minute. The format and frequencies used by WWVL are subject to change to meet the requirements of the particular experiment being conducted.

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.

Station Identification

WWVL is identified only by its unique program format.

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.

CHART B

U.S. NAVAL OBSERVATORY
SCHEDULE OF TIME AND FREQUENCY TRANSMISSIONS
ON VLF FROM U.S. NAVAL RADIO STATIONS

Station	Location	Frequency (kHz)*	Nominal Radiated Power (kw)	Maintenance	Special Transmissions
NAA	Cutler, Maine 44°38!9N, 67°16! 9W	17.80	1,000 (1)	1400 to 1800 UT each Friday	FSK for two hours followed by CW for one hour. Phase stable on 17.80 but not on 17.85 kHz.*
NBA	Balboa, Canal Zone 09°03!3N, 79°38!9W	24.00	150 (2)	1200 to 1800 UT each Monday	Time signals on CW Morse from 55 to 60th minute every even hour except 2355 to 2400 UT. FSK continuous at other times. Phase stable on 24.00 but not on 24.05 kHz.*
NLK	Jim Creek, Wash. 48°12!2N, 121°55!0W	18.60	250	1700 to 2200 UT 1st & 3rd Thursday of each month	FSK continuous except five minutes before each even hour on locked key. Phase stable on 18.60 but not on 18.65 kHz.*
NPM	Lualualei, Hawaii 21°25!5N, 158°09!3W	23.40	140	1700 UT Monday to 0200 UT Tuesday 1st & 3rd Monday of each month	FSK continuous. Phase stable on 23.40 but not on 23.45 kHz.
NSS	Annapolis, Md. 38°59!1N, 76°27!2W	21.40	85	1300 to 1900 UT each Wednesday	Time signals from 55 to 60th minute each hour. CW Morse continuous. Phase stable.
NWC	North West Cape, Australia 21°49!0S, 114°09!8E	22.30	1,000	0000 to 0300 UT each Monday (3)	FSK and CW. Phase stable on 22.30 but not on 22.35 kHz.* (4)

*Frequency is offset according to the current rate for UTC.

Notes: (1) Each Wednesday and Thursday 1200 to 2000 UT, transmitter will operate at half power for limited maintenance.

(2) Each Tuesday 1200 to 2000 UT, radiated power will be reduced from 150 kw to 90 kw for limited maintenance.

(3) Maintenance schedule may be extended to 0600 UT when required.

(4) Transmissions will be CW first half hour of each even hour followed by FSK for 1½ hours. CW may be replaced by FSK transmissions as required.

(5) *Omega Segment Assignments.* The Omega navigational transmitters operate on the UTC system. The transmissions have 8 scheduled segments each, repeating with a period of 10 seconds. Segment A starts at the zero second and repeats each 10 seconds thereafter. Segment E starts at five seconds and repeats each 10 seconds thereafter. A schematic of the segment duration is attached.

The Omega Project Management Office controls the phase of the Omega transmissions. The system maintains internal synchronization using very long integration times. All Omega emissions will normally be within 10 μs of the U.S. Naval Observatory Master Clock.

(6) All stations transmit from cesium beam oscillators.

(7) The coordinates of the receiving antenna of the U.S. Naval Observatory monitoring and control station in Washington, D.C. are: 38°55!2N, 77°04!0W.

(8) The use of Navy VLF controlled transmissions for precise timing applications is explained in some detail in the U.S. Naval Observatory's Time Service Letter of 30 September 1968. This publication, as well as others, is available free of charge upon request.

(9) For information concerning precise time and frequency services, address your requests to: Superintendent, Attn: Time Service Division, U.S. Naval Observatory, Washington, D.C. 20390.

CHART A (Continued)

Station	Location	Frequency (kHz)*	Estimated Radiated Power (kw)	Maintenance
Omega Norway	Aldra, Norway 66°25′15″N, 13°09′10″E	10.2 Seg A 11 1/3 Seg C 12.3 Seg D,E,F,G,H 13.6 Seg B	4	When routine maintenance is required, advance notice will be given. This maintenance will be accomplished during the 24-hour day (UT) Tuesday.
Omega Trinidad	Trinidad, West Indies, 10°42′06″N, 61°38′20″W	10.2 Seg B 11 1/3 Seg D 12.0 Seg A,E,F,G,H 13.6 Seg C	1	When routine maintenance is required, advance notice will be given. This maintenance will be accomplished during the 24-hour day (UT) Wednesday.
Omega Hawaii	Haiku, Hawaii 21°24′21″N, 157°49′48″W	10.2 Seg C 11 1/3 Seg E 12.2 Seg A,B,F,G,H 13.6 Seg D	2	When routine maintenance is required, advance notice will be given. This maintenance will be accomplished during the 24-hour day (UT) Thursday.
Omega New York	Forestport, New York, 43°26′41″N, 75°05′10″W	10.2 Seg D 11 1/3 Seg F 12.5 Seg A,B,C 12.7 Seg G,H 13.6 Seg E	0.25	When routine maintenance is required, advance notice will be given. This maintenance will be accomplished during the 24-hour day (UT) Friday.

FEDERAL COMMUNICATIONS COMMISSIONS RULES PERTAINING TO REBROADCAST OF TIME SIGNALS

73.1207 Rebroadcast

(a) The term "rebroadcast" means reception by radio of the programs of a radio station, and the simultaneous or subsequent retransmission of such programs by a broadcast station.

Note: As used in § 73.1207 "program" includes any complete program or part thereof.

The transmission of a program from its point of origin to a broadcast station entirely by common carrier facilities, whether by wire line or radio, is not considered a rebroadcast.

(b) No broadcasting station shall rebroadcast the program, or any part thereof of another U.S. broadcasting station without the express authority of the originating station. A copy of the written consent of the licensee originating the program shall be kept by the licensee of the station rebroadcasting such program and shall be made available to the Commission upon request. Stations originating emergency communications under a Detailed State EBS Operational Plan, shall be deemed to have conferred rebroadcast authority on other participating stations. The broadcasting of a program relayed by a remote pickup broadcast station (§ 74.401 of this chapter) is not considered a rebroadcast.

(c) The rebroadcast of time signals originated by the Naval Observatory and the National Bureau of Standards is permitted without further Commission authorization under the conditions set forth in Note 1 to this paragraph. The rebroadcast of National Weather Service (NWS) transmissions is permitted without further Commission authorization under the conditions set forth in Note 2 to this paragraph. Programs originated by the Voice of America (VOA) and the American Forces Radio and Television Service (AFRTS) cannot, in general, be cleared for domestic rebroadcast, and may therefore be rebroadcast only by special arrangement among the parties concerned. Except as otherwise provided by international agreement, programs originated by foreign broadcasting stations may be rebroadcast without the consent of the originating station. In the case of retransmissions of subcarrier background music and other FM multiplex subscription services, permission must first be obtained from the originating station. The retransmission of point-to-point messages originated by government and privately owned nonbroadcast stations must be authorized by the Commission prior to retransmission; such authority may be requested informally by telephone, to be followed within one week with a written confirmation accompanied by the written consent of the originating station.

Note 1: (a) *Naval Observatory Time Signals.* (1) The time signal rebroadcast must be obtained by direct radio reception from a naval radio station.

(2) Announcement of the time signal must be made without reference to any commercial activity.

(3) Identification of the Naval Observatory as the source of the time signal must be made by an announcement, substantially as follows: "With the signal, the time will be_____, courtesy of the U.S. Naval Observatory."

Schedules of time signal broadcasts may be obtained upon request from the Superintendent, U.S. Naval Observatory, Washington, D.C. 20390.

(b) *National Bureau of Standards Time Signals.* (1) Time signals for rebroadcast must be obtained by direct radio reception from an NBS station.

(2) Use of receiving and rebroadcasting equipment must not delay the signals by more than 0.05 seconds.

(3) Signals must be rebroadcast live, not from tape or other recording.

(4) Voice or code announcements of the call letters of NBS stations are not to be rebroadcast.

(5) Identification of the origin of the service and the source of the signals must be made by an announcement substantially as follows: "At the tone, 11 hours 25 minutes Greenwich mean time. This is a rebroadcast of a continuous service furnished by the National Bureau of Standards, Time and Frequency Division, Boulder, Colo." No commercial sponsorship of this announcement is permitted and none may be implied.

(6) Notice of use of NBS time signals for rebroadcast should be forwarded semiannually to Frequency-Time Broadcast Services, Time and Frequency Division, National Bureau of Standards, Boulder, Colo. 80302.

(7) In the rebroadcasting of NBS time signals, announcements will not state that they are standard frequency transmissions. Voice announcements of G.m.t. are given in voice every minute. Each minute, except the first of the hour, begins with a 0.8-second long tone of 1000 Hz at WWV and 1200 Hz tone at WWVH. The first minute of every hour begins with an 0.8-second long tone of 1500 Hz at both stations. This tone is followed by a 3-second pause, then the announcement, "National Bureau of Standards Time." This is followed by another 3-second pause before station identification. This arrangement allows broadcast stations sufficient time to retransmit the hour time tone and the words "National Bureau of Standards Time" either by manual or automatic switching.

(8) Time signals or scales made up from integration of standard frequency signals broadcast from NBS stations may not be designated as national standard scales of time or attributed to the NBS as originator. For example, if a broadcasting station transmits time signals obtained from a studio clock which periodically calibrated against the NBS time signals from WWV or WWVH, such signals may not be announced as NBS standard time or as having been originated by the NBS.

Schedules of time signal broadcasts may be obtained upon request from Frequency-Time Broadcast Services Section, Time and Frequency Division, National Bureau of Standards, Boulder, Colo. 80302.

Note 2: (a) Messages must be rebroadcast within 1 hour of receipt from the National Weather Service (Weather Bureau).

(b) If advertisements are given in connection with a weather rebroadcast, these advertisements shall not directly or indirectly convey an endorsement by the Government of the products or services so advertised.

(c) Credit must be given to indicate that the rebroadcast messages originate with the National Weather Service (Weather Bureau). [37 FR 23726, Nov. 8, 1972, as amended at 38 FR 18378, July 10, 1973.]