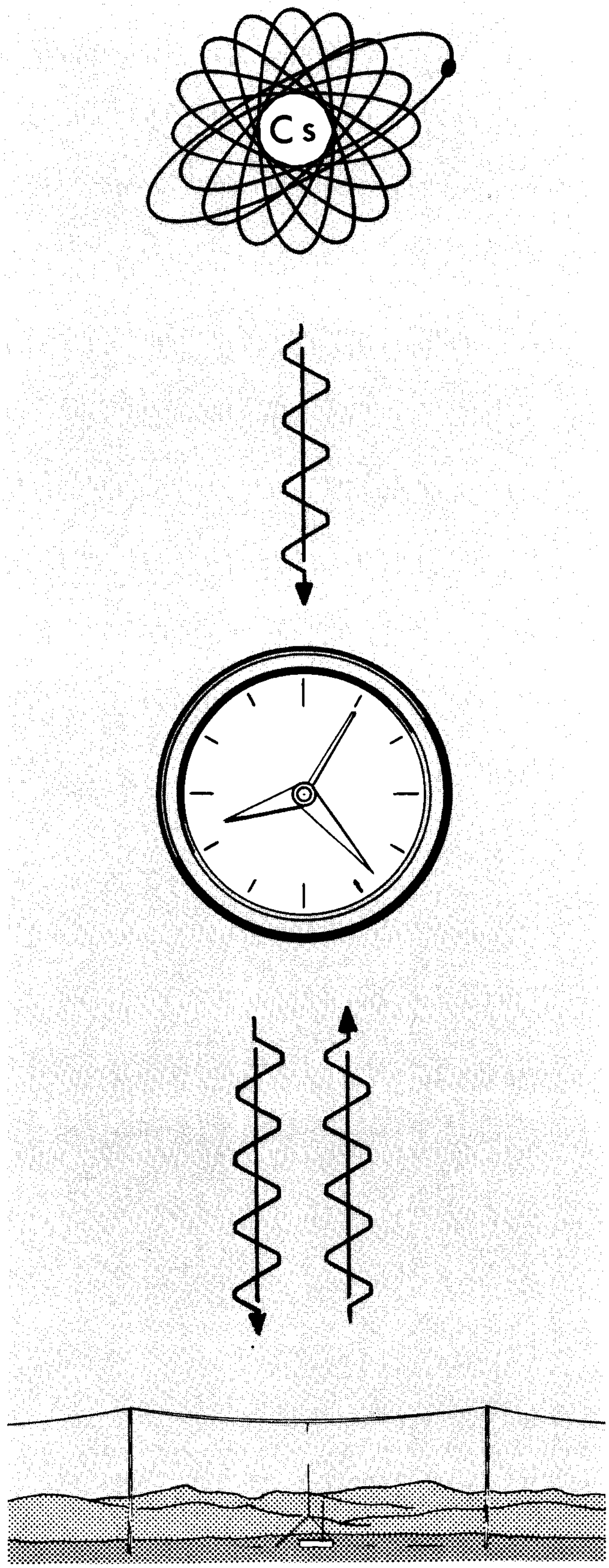
MISCELLANEOUS PUBLICATION 236
1966 EDITION



NBS STANDARD FREQUENCY AND TIME SERVICES

Radio Stations
WWV WWVH WWVB WWVL

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards

NBS STANDARD FREQUENCY AND TIME SERVICES

Radio Stations WWV WWVH WWVB WWVL

U.S. DEPARTMENT OF COMMERCE
John T. Connor, Secretary

NATIONAL BUREAU OF STANDARDS
A. V. Astin, Director

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Services Provided by NBS Standard Frequency Stations
WWV, WWVH, WWVB, and WWVL

Detailed descriptions are given of eight technical services provided by the National Bureau of Standards 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. UT2 corrections; 7. Radio propagation forecasts; and 8. Geophysical alerts. In order to provide users with the best possible services, occasional changes in the broadcasting schedules are required. This publication shows the schedules in effect on January 1, 1966. Annual revisions will be made. Advance notices of changes occurring between revisions will be sent to regular users of these services upon request.[1]

1. Technical Services and Related Information

The standard frequency stations of the National Bureau of Standards provide these services:

Station	Data in service	Radio frequencies	Audio frequencies	Musical pitch	Time intervals	Time signals	UT2 corrections	Propagation forecasts	Geophysical alerts
WWV	1923	√	√	√	√	√	√	√	√
WWVH	1948	√	√	√	√	√	√		√
WWVB	1963	√			√	√	√		
WWVL	1963	√							

The NBS radio stations are located as follows

*WWV —Greenbelt, Maryland
Leo Honea, Engineer-in-Charge
Telephone—301–552–1122
(38°59′33″ N, 76°50′52″ W)

WWVH—Box 578, Puunene, Maui, Hawaii
Sadami Katahara, Engineer-in-Charge
Telephone—79–4111
(20°46′02″ N, 156°27′42″ W)

WWVB—Box 83–E, Route 2, Fort Collins, Colorado
Richard Carle, Engineer-in-Charge
Telephone—303–484–2372
(40°40′28.3″ N, 105°02′39.5″ W)

WWVL Box 83–E, Route 2, Fort Collins, Colorado
Richard Carle, Engineer-in-Charge
Telephone—303–484–2372
(40°40′51.3″ N, 105°03′00.0″ W)

* **Note: On or about July 1, 1966, WWV will be relocated to Fort Collins, Colorado. Services will be substantially the same as presently provided.**

1.1. Standard Radio Frequencies

(a) Program

Station WWV broadcasts on nominal radio frequencies of 2.5, 5, 10, 15, 20, and 25 MHz. The broadcasts are continuous, night and day, except WWV is interrupted for approximately 4 min each hour. The silent period commences at 45 min (plus 0 to 15 sec) after each hour. (fig. 1.)

Station WWVH broadcasts on nominal radio frequencies of 2.5, 5, 10 and 15 MHz. The broadcast is interrupted for approximately 4 min each hour. The silent period commences at 15 min (plus 0 to 15 sec) after each hour.

Station WWVB broadcasts on the standard radio frequency of 60 kHz. The service is continuous.

Station WWVL broadcasts on the nominal radio frequency of 20 kHz. The service is continuous.

(b) Accuracy

Since December 1, 1957 the standard radio transmissions from stations WWV and WWVH have been held as nearly constant as possible with respect to the atomic frequency standards which constitute the United States Frequency Standard (USFS), maintained and operated by the Radio Standards Laboratory of the National Bureau of Standards. Carefully made atomic standards have been shown to realize the idealized Cs resonance frequency, f_{Cs}, to a few parts in 10^{11}. The present USFS realizes this resonance to 1 part in 10^{11}. The frequency f_{Cs} has has been measured in terms of the second[2] to be $f_{Cs}=9,192,631,770\pm20$ Hz.

This uncertainty of 2 parts in 10^9 with which frequency can be expressed in terms of the

[1] Inquiries concerning the broadcast services may be addressed to the Engineer-in-Charge at a particular station or to Mr. David H. Andrews, Frequency-Time Broadcast Services, National Bureau of Standards, Boulder, Colo., 80302. Tel: 303 442-2161.

[2] Markowitz, Hall, Essen, and Parry—Frequency of cesium in terms of ephemeris time—Phys. Rev. Letters 1, 105 (1958).

second has been avoided by defining f_{Cs} exactly equal to the above number. This was officially announced by the International Committee of Weights and Measures at the XIIth General Conference in October 1964.

On January 1, 1960 the USFS was brought into agreement with f_{Cs} as quoted above by arbitrarily increasing its assigned value by 74 parts in 10^{10}. Frequencies measured in terms of the USFS between December 1, 1957 and January 1, 1960 may be referred to the above value of f_{Cs} and to the Ephemeris second by means of this relative correction.[3]

The frequencies transmitted by WWV are held stable to 5 parts in 10^{11} at all times. Deviations at WWV are normally less than 1 part in 10^{11} 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 5 parts in 10^{10}.

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

WWVB and WWVL frequencies are normally stable to 2 parts in 10^{11}. Deviations from day to day are within 1 part in 10^{11}.

The effects of the propagating medium on the received frequencies are much less at LF and VLF. The full transmitted accuracy may be obtained using appropriate receiving techniques.

(c) Corrections

All carrier and modulation frequencies at WWV and WWVH are derived from precision quartz oscillators with stabilities as noted above. These oscillators are intentionally offset from the USFS by a small but precisely known amount to reduce departure between the time signals as broadcast and astronomical time, UT2. The offset for 1960 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 −300 parts in 10^{10}. Although UT2 subject to unpredictable changes readily noted at this level of precision it is expected that a particular offset from the USFS will remain in effect for the entire calendar year.

Corrections to the transmitted frequency are continuously determined with respect to the USFS and are published monthly in the Proceedings of the IEEE. These commenced in May 1958 and included data from December 1, 1957.[4]

The carrier frequency at WWVL (20 kHz) is also offset from the USFS by the same amount noted above.

[3] National standards of time and frequency in the United States, Proc. IRE 48, 105 (1960).

[4] W. D. George, WWV standard frequency transmissions, Proc. IRE 46, 910 (1958) and subsequent issues.

While WWVB (60 kHz) initially transmitted with the offset frequency, since January 1, 1965 the frequency transmitted has been that of the USFS. Thus, one of the NBS transmissions makes available to the users the standard of frequency so that absolute frequency comparisons may be made directly. This frequency will not be subject to annual offset change as are the other stations' frequencies.

1.2. Standard Audio Frequencies

(a) Program

Standard audio frequencies of 440 Hz and 600 Hz are broadcast on each radio carrier frequency at WWV and WWVH. The audio frequencies are transmitted alternately at 5-min intervals starting with 600 Hz on the hour (fig. 1). The first tone period at WWV (600 Hz) is of 3-min duration. The remaining periods are of 2-min duration. At WWVH all tone periods are of 3-min duration.

WWVB and WWVL do not transmit standard audio frequencies.

(b) Accuracy

The accuracy of the audio frequencies, as transmitted, is the same as that of the carrier. The frequency offset mentioned under 1.1.(c) applies. Changes in the propagation medium will sometimes result in fluctuations in the audio frequencies as received.

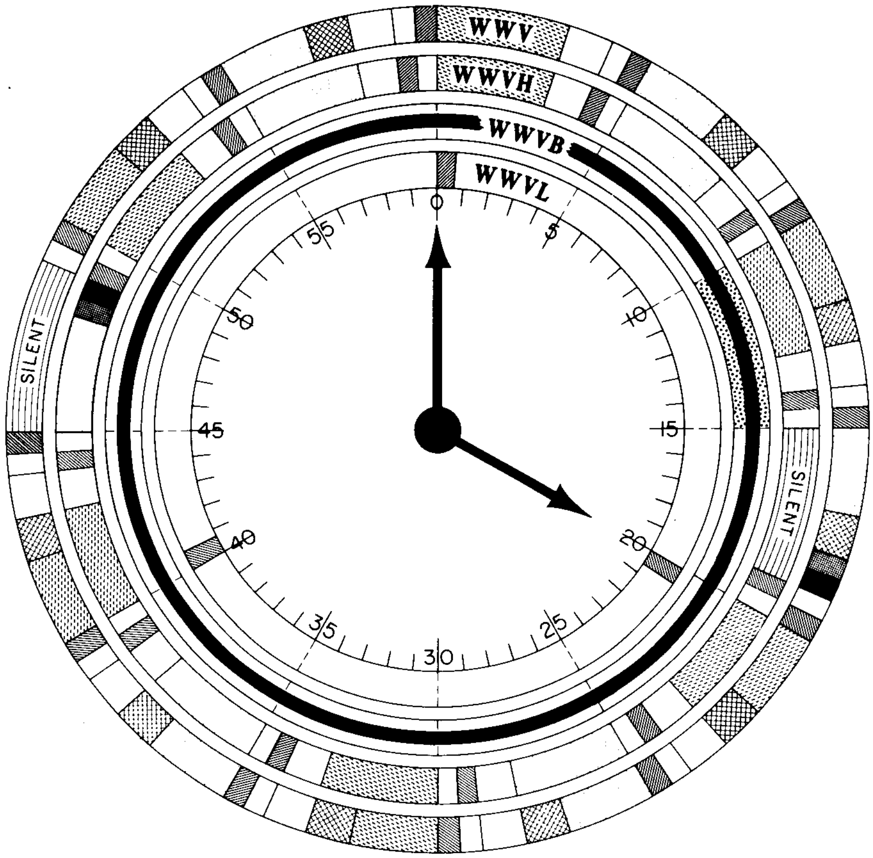
While 1000 Hz is not considered one of the standard audio frequencies, the time code which is transmitted 10 times an hour from WWV does contain this frequency and may be used as a standard with the same accuracy as the audio frequencies.

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 periods of transmission of 440 Hz from WWV and WWVH are shown in figure 1. With this broadcast the standard pitch is maintained, and musical instruments are manufactured and adjusted in terms of this unvarying standard. The majority of musical instruments manufactured can be tuned to this frequency. Music listeners are thus benefited by the improvement in tuning accuracy.

1.4. Standard Time Intervals

Seconds pulses at precise intervals are derived from the same oscillator that controls the radio carrier frequencies, e.g., 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



SECONDS PULSES - WWV, WWVH - CONTINUOUS EXCEPT FOR 59th SECOND OF EACH MINUTE AND DURING SILENT PERIODS

WWVB - SPECIAL TIME CODE

WWVL - NONE

STATION ANNOUNCEMENT

WWV - MORSE CODE - CALL LETTERS, UNIVERSAL TIME, PROPAGATION FORECAST
VOICE - EASTERN STANDARD TIME
MORSE CODE - FREQUENCY OFFSET (ON THE HOUR ONLY)

WWVH - MORSE CODE - CALL LETTERS, UNIVERSAL TIME,
VOICE - HAWAIIAN STANDARD TIME
MORSE CODE - FREQUENCY OFFSET (ON THE HOUR ONLY)

WWVL - MORSE CODE - CALL LETTERS, FREQUENCY OFFSET

100 PPS 1000 Hz MODULATION WWV TIMING CODE

TONE MODULATION 600 Hz

TONE MODULATION 440 Hz

GEOALERTS

IDENTIFICATION PHASE SHIFT

UT-2 TIME CORRECTION

SPECIAL TIME CODE

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

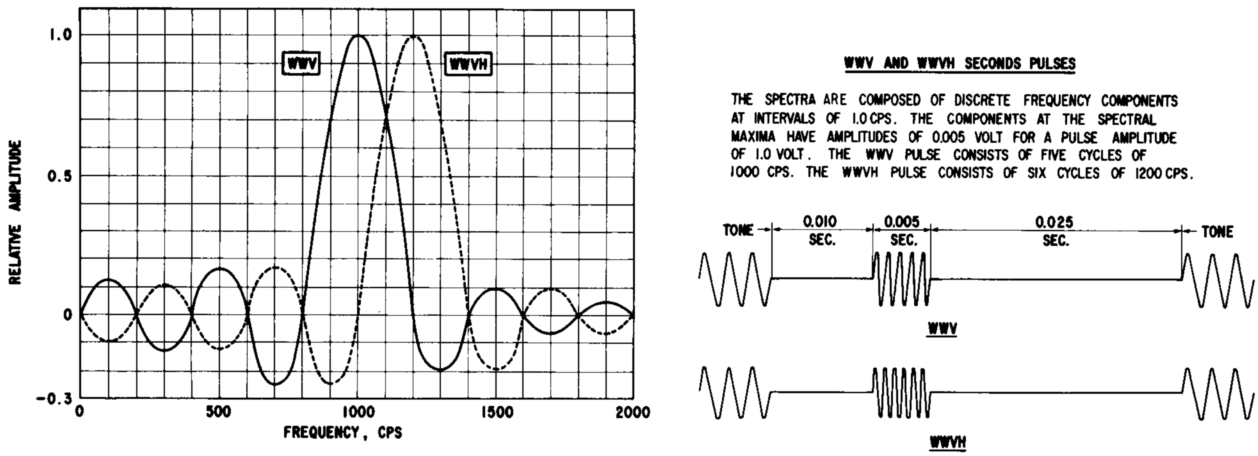


FIGURE 2. *Sample characteristics of time pulses broadcast from NBS stations WWV & WWVH.*

radio carrier frequency. Intervals of 1 min are marked by the omission of the pulse at the beginning of the last second of every minute and by commencing each minute with *two pulses spaced by 0.1 second.*

The first pulse marks the beginning of the minute. The 2-min, 3-min and 5-min intervals are synchronized with the seconds pulses and are marked by the beginning or ending of the periods when the audio frequencies are not transmitted. The pulse duration is 5 milliseconds. The pulse waveform is shown in figure 2. At WWV each pulse contains 5 cycles of 1000 Hz frequency. At WWVH the pulse consists of 6 cycles of 1200 Hz frequency. The pulse spectrum is composed of discrete frequency components at intervals of 1 Hz. The components have maximum amplitudes at approximately 995 Hz for WWV and 1194 Hz for WWVH pulses. The tone is interrupted 40 milliseconds for each seconds pulse. The pulse starts 10 milliseconds after commencement of the interruption.

WWVB transmits seconds pulses continuously using a special time code described in section 1.10.

WWVL does not transmit seconds markers, however, accurate time intervals may be obtained directly from the carrier using appropriate techniques.

1.5. Time Signals

(a) Program

The audio frequencies are interrupted at precisely 3 min before each hour at WWV and 2 min before each hour at WWVH. They are resumed on the hour at WWV and WWVH, and at 5- and 10-minute intervals throughout the hour as indicated in figure 1.

Universal Time (referenced to the zero meridian at Greenwich, England) is announced in International Morse Code each 5 min from WWV and WWVH. This provides a ready reference to correct time where a timepiece may be in error by a few minutes. The 0 to 24 hour system is used starting with 0000 at midnight at 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. For example, at 1655 UT, the four figures 1–6–5–5 are broadcast in code. The time announcement refers to the end of an announcement interval, i.e., to the time when the audio frequencies are resumed.

At station WWV a voice announcement of Eastern Standard Time is given during the last half of every fifth minute during the hour. At 10:35 a.m., EST, for instance, the voice announcement given in English is: National Bureau of Standards, WWV; when the tone returns, Eastern Standard Time will be ten hours, thirty-five minutes.

At WWVH a similar voice announcement of Hawaiian Standard Time occurs during the first half of every fifth minute during the hour.

Time-of-day information is given from WWVB using the time code described in section 1.10.

WWVL does not transmit time-of-day information.

(b) Corrections

Time signals broadcast from WWV and WWVH are kept in close agreement with UT2 (astronomical time) by making step adjustments of 100 milliseconds as necessary. These adjustments are made at 0000 UT on the first day of a month. Advance notice of such adjustments is given to the public upon advice by the Bureau International de l'Heure in Paris that an adjustment is to be made. Decision to adjust the time signals is based upon observations by a network of international observatories and is made by an international committee. Corrections to the time signals are published periodically by the U.S. Naval Observatory.

Seconds pulses broadcast from WWVB will depart from UT2 at a different rate due to the fact that WWVB broadcasts 60 kHz derived from the USFS with no offset (see 1.1(c)). Step time adjustments of 200 milliseconds will be made at 0000 UT on the first day of a month with appropriate advance notice. The National Bureau of Standards will direct such step adjustments at intervals which will maintain the seconds pulses within about 100 milliseconds of UT2.

1.6. UT2 Corrections

Since a majority of time users do not require UT2 information to better than 100 milliseconds the systems described in 1.5.(b) are quite satisfactory. An additional service is provided in cooperation with the U.S. Naval Observatory which makes available the best values of UT2 on a daily basis. Corrections to be applied to the time signals as broadcast are given in International Morse Code during the last half of the 19th min of each hour from WWV and during the last half of the 49th min of each hour from WWVH. Similar information is incorporated in the WWVB Time Code.

The symbols which are broadcast are as follows:

"UT2" then "AD" or "SU"

followed by a three digit number. This number is the correction in milliseconds. To obtain UT2, add the correction to the time indicated by the Time Signal pulse if "AD" is broadcast. Subtract if "SU" is broadcast. Thus, a clock keeping step with the time signals being broadcast will be fast with respect to UT2 if "SU" is the symbol used.

The corrections are extrapolated values of the difference UT2 minus Time Signal furnished by the U.S. Naval Observatory. The probable error is ± 3 milliseconds. Final corrections, with a probable error of ± 1 millisecond, are published in the Time Service Bulletins of the Naval Observatory.

These corrections will be revised daily, the new value appearing for the first time during the hour after 0000 UT, and will remain unchanged for the following 24 hour period.

1.7. Propagation Forecasts

A forecast of radio propagation conditions is broadcast in International Morse Code during the last half of every fifth minute of each hour on each of the standard frequencies from WWV. Propagation notices were first broadcast from WWV in 1946. The five-minute announcement was commenced on November 15, 1963. The present type of propagation forecast has been broadcast from WWV since July 1952 and was broadcast from WWVH from January 1954 until November 1964.

The forecast announcement tells users the condition of the ionosphere at the regular time of issue and the radio quality to be expected during the next six hours. The NBS forecasts are based on data obtained from a worldwide network of geophysical and solar observatories. These data include radio soundings of the upper atmosphere, short wave reception data, observations of the geomagnetic field, solar activity and similar information. Trained forecasters evaluate the information and formulate the forecasts using known sun-earth relationships.

The forecast announcements from WWV refer to propagation along paths in the North Atlantic Area, such as Washington, D.C. to London or New York City to Berlin. The announcements are the short term forecasts prepared by the ESSA, Telecommunications Space Disturbance Service Center, Box 178, Fort Belvoir, Virginia. The regular times of issue of the forecasts are 0500, 1200 (1100 in summer), 1700 and 2300 UT.

The forecast announcement is broadcast as a letter and a number. The letter portion identifies the radio quality at the time the forecast is made. The letters denoting quality are "N," "U" and "W" signifying, respectively, that radio propagation conditions are either normal, unsettled or disturbed. The number portion of the forecast announcement from WWV is the forecast of radio propagation quality on a typical North Atlantic path during the six hours after the forecast is issued. Radio quality is based on the ITSA 1 to 9 scale which is defined as follows:

Disturbed grades (W)	*Unsettled grade (U)*	*Normal grades (N)*
1. useless	5. fair	6. fair-to-good
2. very poor		7. good
3. poor		8. very good
4. poor-to-fair		9. excellent

If, for example, propagation conditions are normal at the time the forecast is issued but are expected to become "poor-to-fair" during the next six hours, the forecast announcement would be broadcast as N4 in International Morse Code.

1.8. Geophysical Alerts

A letter symbol indicating the current geophysical alert (Geoalert) as declared by the World Warning Agency of the International Ursigram and World Days Service (IUWDS) is broadcast in very slow International Morse Code from WWV and WWVH on each of the standard radio carrier frequencies. These broadcasts are made from WWV during the first half of the 19th min of each hour and from WWVH during the first half of the 49th

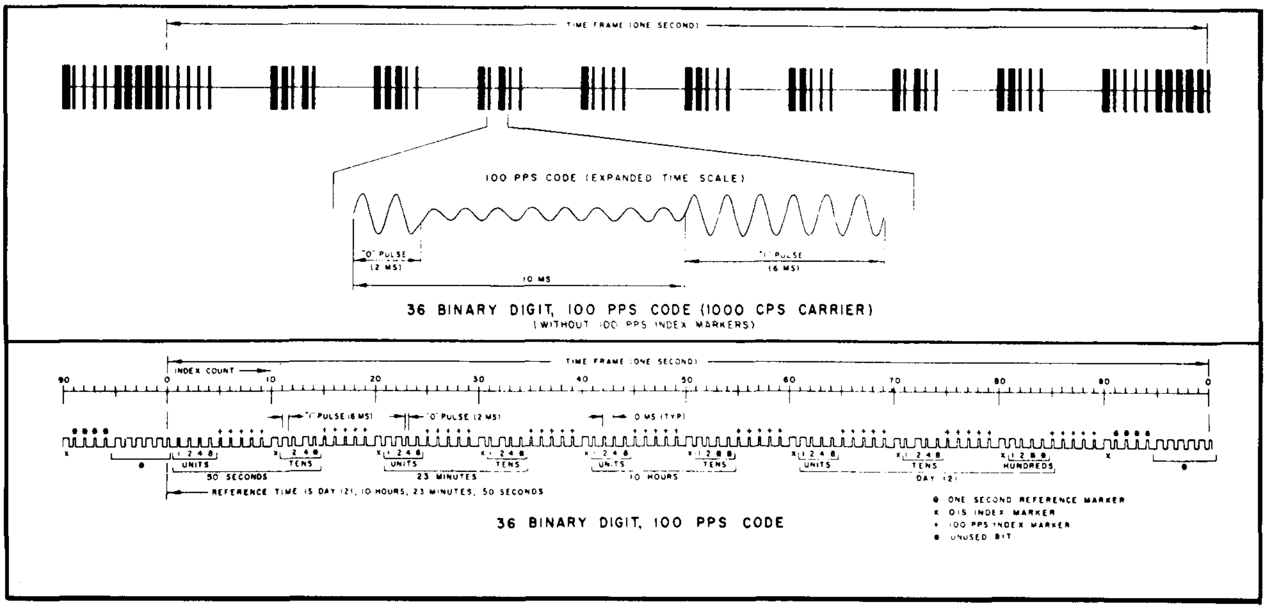


FIGURE 3. *Chart of time code transmissions from NBS radio station WWV.*

min of each hour. Such notices have been broadcast since the International Geophysical Year, 1957–58, and have continued by international agreement.

The symbol indicates to experimenters and researchers in radio, geophysical and solar sciences the content of the IUWDS Geoalert message which is issued daily at 0400 UT to identify days on which outstanding solar or geophysical events are expected or have occurred in the preceding 24-hour period. There are six types of Geoalerts which may be issued and thus there are six letter symbols used to identify them plus a seventh symbol to signify that there is no Geoalert. The various letter symbols used and the type of Geoalert to which each refers are as follows:

M—Magnetic storm
N—Magnetic quiet
C—Cosmic ray event
E—No geoalert issued
S—Solar activity
Q—Solar quiet
W—Stratospheric warming

The Geoalert broadcast is identified by the letters GEO in International Morse Code preceding one of the above letter symbols. The letter symbol is repeated 5 times to insure proper identification. If, for example, solar activity has been outstanding during the previous 24-hour period, the Geoalert broadcast would be GEO SSSSS to signify this fact. If a significant magnetic storm is expected or exists the broadcast would be GEO MMMMM. The no alert symbol, sent as GEO EEEEE signifies that any preceding Geoalert may be considered finished and that there is no alert in progress. Since it is possible that two types of Geoalerts could be in effect at the same time, the symbols will be broadcast in the following priority order:

C, M, W, S, Q, N or E.

1.9. WWV Time Code

On January 1, 1961 WWV commenced broadcasting the time code shown in figure 3 for one minute out of each five, ten times an hour, as shown in figure 1.

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 a thousandth of a second. Astronomical observations may also benefit by the increased timing potential provided by the pulse-coded signals.

The code format being broadcast is generally known as the NASA 36-Bit Time Code. The code is produced at a 100 pps rate and is carried on 1000 Hz modulation.

The code contains time-of-year information (Universal Time) in seconds, minutes, hours and day of year. The code is synchronous with the frequency and time signals.

The binary coded decimal (BCD) system is used. Each second contains 9 BCD groups in this order: 2 groups for seconds, 2 groups for minutes, 2 groups for hours and 3 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 second. The binary groups follow the 1 second reference marker.

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

The code contains 100/second clocking rate, 10/second index markers, and a 1/second reference marker. The 1000 Hz is synchronous with the code pulses so that millisecond resolution is obtained readily.

The 10/second index markers consist of "binary one" pulses preceding each code group except at the beginning of the second where a "binary zero" pulse is used.

The 1/second reference marker consists of five "binary one" pulses followed by a "binary zero" pulse. The second begins at the leading edge of the "binary zero" pulse.

The code is a spaced code format, that is, a binary group follows each of the 10/second index markers. The last index marker is followed by an unused 4-bit group of "binary zero" pulses just preceding the 1/second reference marker.

A "binary zero" pulse consists of 2 cycles of 1000 Hz amplitude modulation, and the "binary one" pulse consists of 6 cycles of 1000Hz amplitude modulation. The leading edges of the time code pulses coincide with positive-going zero-axis-crossings of the 1000 Hz modulating frequency.

1.10. WWVB Time Code

(a) Code and Carrier

On July 1, 1965, Radio Station WWVB, Fort Collins, Colorado, 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. The new system replaces the method whereby seconds pulses of uniform width obtained by level-shift carrier keying were broadcast. The carrier is no longer interrupted for keyed station identificatioon, since the characteristic phase advance by 45° at 10 minutes after every hour followed by a similar phase retardation 5 minutes later continues to serve to identify the station.

(b) Marker Generation

As shown in figure 4, 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 figure 4.

(c) Marker Order and Groups

The 10-second position markers, labelled P0 to P5 on the diagram, occur respectively in the 60th, 10th, 20th, 30th, 40th, and 50th seconds of each minute. 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 twelve groups of five 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 figure 4; the signal pulses lasting for 0.8 second after a periodically uncoded marker are shaded; other signal pulses following uncoded markers are labelled with a U.

Save for the uncoded and reference markers specifically excepted in the foregoing, the remaining markers in each of the groups are utilized to convey additional information.

(d) Information Sets

Each minute the code presents time-of-year information in minutes, hours, and day of the year and the actual milliseconds difference between the time as broadcast and the best known estimate of UT2. A set of groups, containing the first two BCD groups in the minute, specifies 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 to or subtracted from the code time as broadcast in order to obtain UT2.

The relationship of the UT2 scale to the time as coded is indicated in the eighth group.

If UT2 is "slow" with respect to the code time a binary "one", labelled SUB (subtract) in figure 4, will be broadcast in the eighth group during the 38th second of the minute. If UT2 is "fast" with respect to the code time, binary "ones", labelled ADD, will be broadcast in the eighth group during the 37th and 39th seconds of the minute.

The twelfth group is not used to convey information.

(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

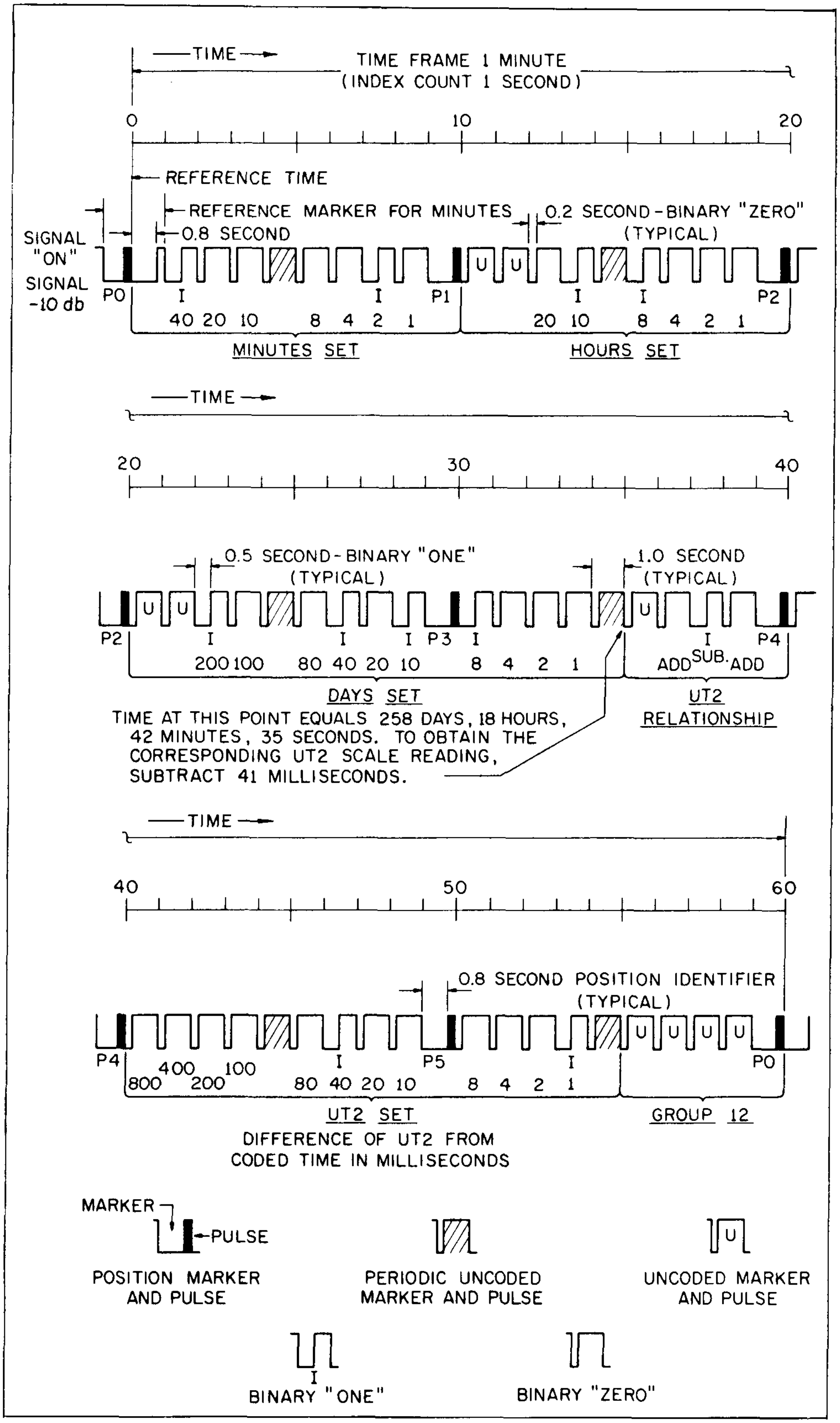


FIGURE 4. *Chart of time code transmissions from NBS station WWVB.*

groups in 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 4. 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 "UT2 Relationship" group and the "UT2 set" that one should *subtract*, from any second in this minute, 40 + 1 = 41 milliseconds to get the best estimate of UT2. For example, the 35th UT2 interval would end 41 milliseconds *later* than the end of the 35th second; or, in other words, the UT2 scale reading for the end of the 35th second would be $18^h\ 42^m\ 34.^s959$ since 35.000 − 0.041 = 34.959.

1.11. Offset Frequencies

WWV, WWVH and WWVL transmit reminders of the fact that all transmitted frequencies are offset from the USFS by a fixed amount. International Morse Code symbols for M300 are transmitted from WWV and WWVH immediately following the "on-the-hour" voice announcement. WWVL transmits International Morse Code for Minus 300 following the station call sign repeated three times. This transmitted during the 1st, 21st, and 41st min of each hour.*

Since WWVB is transmitting a frequency directly related to the USFS no offset reminder is given.

* WWVL frequently alternates between 20.0 kHz and 19.9 or 20.5 kHz, the change being made every 10 seconds. During these experiments the code transmissions are not given.

1.12. Station Identification

WWV and WWVH identify by International Morse Code and voice (in English) every five minutes.

WWVL identifies by International Morse Code during the 1st, 21st, and 41st min of each hour.* WWVB identifies by its unique Time Code (see section 1.10) and by advancing the carries phase 45° at 10 min. after each hour and returning to normal phase at 15 min after each hour.

1.13. Radiated Power, Antennas and Modulation

(a) Radiated Power

Frequency, MHz	Radiated power, kw			
	WWV	WWVH	WWVB	WWVL
0.020	–	–	–	2
0.060	–	–	10	–
2.5	–	1	–	–
5	8	2	–	–
10	9	2	–	–
15	9	2	–	–
20	1	–	–	–
25	0.1	–	–	–

(b) Transmitting Antennas

The broadcasts on 2.5 MHz from WWV and on 2.5 and 5 MHz from WWVH are from vertical quarter-wave antennas. The broadcasts on all other frequencies from WWV and WWVH are from vertical half-wave dipoles. The antennas are omnidirectional.

The antennas used by WWVB and WWVL are 400-foot high vertical antennas with capacity toploading.

(c) Modulation

At WWV and WWVH all modulation is double sideband amplitude, with 75 percent on the steady tones and 100 percent peak for seconds pulses and voice.

WWVB employs 10 percent carrier-level reduction for transmitting time information (See section 1.10).

WWVL uses no amplitude modulation. Various experimental techniques are being studied in an attempt to develop a good timing system at Very Low Frequencies.

2. How NBS Controls the Transmitted Frequencies

In figure 5 a simplified diagram of the NBS frequency control system is shown. The entire system depends upon the basic frequency reference (USFS) shown in this diagram as the Cesium (Cs) Beam. This standard is used to calibrate the oscillators, dividers and clocks which generate the controlled frequency and the NBS time scales. Information from this reference is provided to receivers which monitor the WWVB–VL transmissions and compare the received phase with the standard phase. If an error exists between the reference and received phases a signal is then transmitted by a 50 MHz transmitter to the transmitting site at Fort Collins which in turn operates automatic phase correction equipment

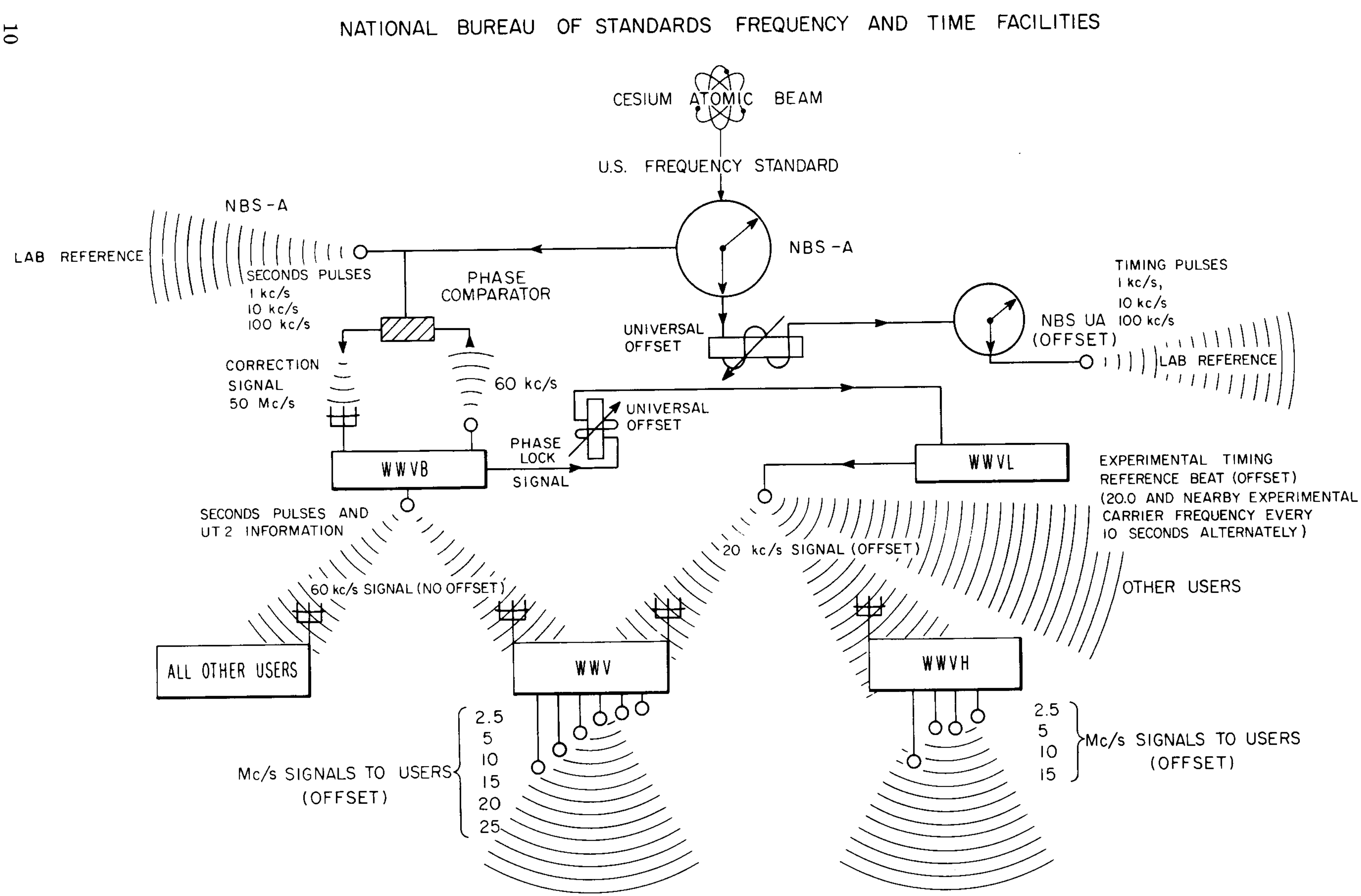


FIGURE 5. *NBS frequency control systems.*

to correct the transmitted phase.

The control of the signals transmitted from WWV and WWVH is performed manually at present based upon signals from WWVB and WWVL which are received by LF and VLF phase-lock receivers. The oscillator controlling the transmitted frequencies and time signals is continuously compared with the LF and VLF signals. Adjustments are then made to the controlling oscillator manually which compensate for the characteristic drift of crystal oscillators. To assure that systematic errors do not enter into the system the NBS time scale is compared with the transmitting station clocks by the use of a very precise portable clock. With these clocks time synchronization to a few millionths of a second can be attained.

THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. Its responsibilities include development and maintenance of the national standards of measurement, and the provisions of means for making measurements consistent with those standards; determination of physical constants and properties of materials; development of methods for testing materials, mechanisms, and structures, and making such tests as may be necessary, particularly for government agencies; cooperation in the establishment of standard practices for incorporation in codes and specifications; advisory service to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; assistance to industry, business, and consumers in the development and acceptance of commerical standards and simplified trade practice recommendations; administration of programs in cooperation with United States business groups and standards organizations for the development of international standards of practice; and maintenance of a clearinghouse for the collection and dissemination of scientific, technical, and engineering information. The scope of the Bureau's activities is suggested in the following listing of its four Institutes and their organizational units.

Institute for Basic Standards. Electricity. Metrology. Heat. Radiation Physics. Mechanics. Applied Mathematics. Atomic Physics. Physical Chemistry. Laboratory Astrophysics.* Radio Standards Laboratory: Radio Standards Physics; Radio Standards Engineering.** Office of Standard Reference Data.

Institute for Materials Research. Analytical Chemistry. Polymers. Metallurgy. Inorganic Materials. Reactor Radiations. Cryogenics.** Office of Standard Reference Materials.

Institute for Applied Technology. Textiles and Apparel Technology Center. Building Research. Industrial Equipment. Information Technology. Performance Test Development. Instrumentation. Transport Systems. Office of Technical Services. Office of Weights and Measures. Office of Engineering Standards. Office of Industrial Services.

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** Located at Boulder, Colorado.

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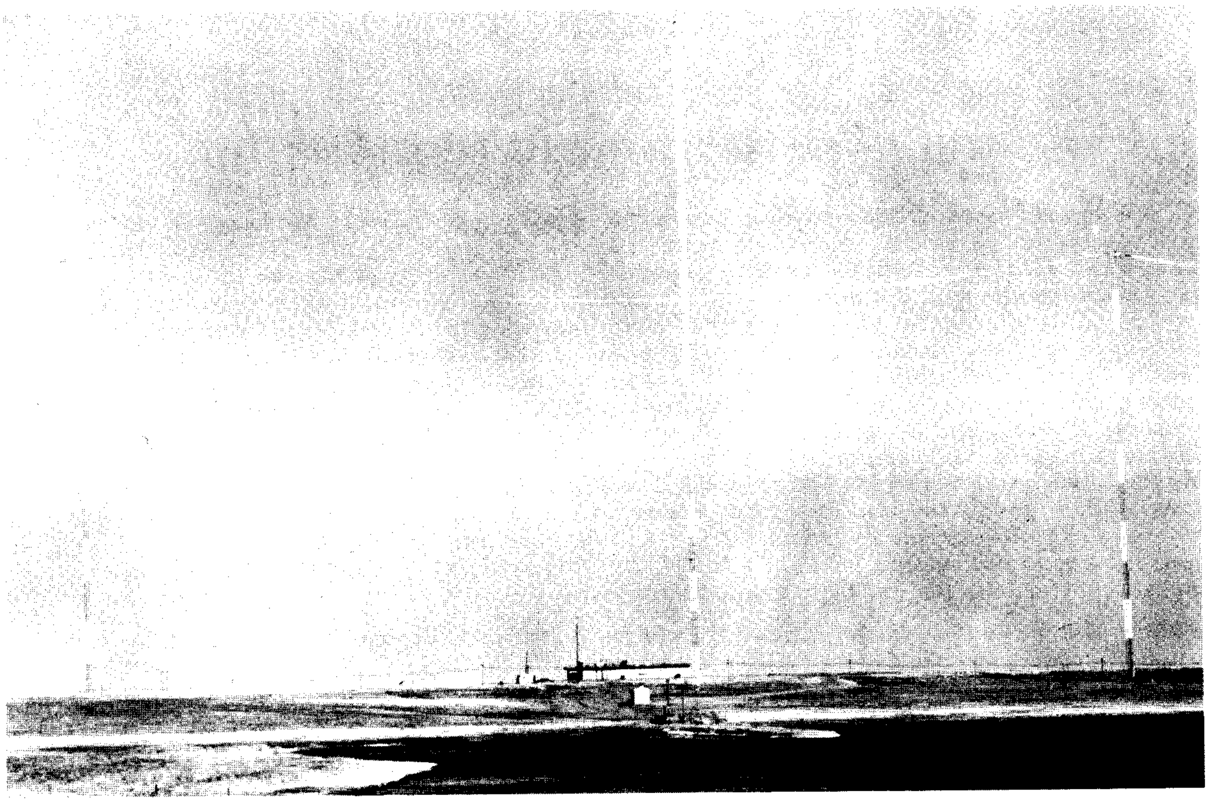

NBS Fort Collins facility in upper photo, showing the WWVB and WWVL transmitter building in the center, new 470-foot standby antenna mast in center, and 400-foot main masts on each side which are part of the two, four-mast antenna systems, WWVL to the left and WWVB to the right. At lower left are WWV transmitter building and antennas at Greenbelt, Maryland. At lower right are antennas, transmitter building, and administrative buildings for WWVH, Maui, Hawaii.