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A STEP IN TIME: CHANGES IN STANDARD-FREQUENCY AND TIME-SIGNAL BROADCASTS - JANUARY 1, 1972

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16. Abstract

An improved coordinated universal time (UTC) system has been adopted by the International Radio Consultative Committee. It was implemented internationally by the standard-frequency and time-broadcast stations on January 1, 1972. The new UTC system eliminates the frequency offset of 300 parts in 10^{10} between the old UTC and atomic time, thus making the broadcast time interval (the UTC second) constant and defined by the resonant frequency of cesium atoms. The new time scale is kept in synchronism with the rotation of the Earth within ±0.7 s by step-time adjustments of exactly 1 s, when needed. A time code has been added to the disseminated time signals to permit universal time to be obtained from the broadcasts to the nearest 0.1 s for users requiring such precision.

The texts of the International Radio Consultative Committee recommendation and report to implement the new UTC system are given in the appendixes. The coding formats used by various standard time broadcast services to transmit the difference between the universal time (UT1) and the new UTC are also given. For users' convenience, worldwide primary VLF and HF transmissions stations, frequencies, and schedules of time emissions are also included. Actual time-step adjustments made by various stations on January 1, 1972, are provided for future reference.

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PREFACE

The purpose of this report is to disseminate information concerning the changes in the coordinated universal time system made in accordance with the decisions of Study Group 7 of the International Radio Consultative Committee at its Interim Meeting of February 1971. The text is written expressly for general users of time. Because of the space limitation in the publication of the original article in the *IEEE Spectrum*, many of the actual data useful to the users were not included. In addition to minor revisions made in the text, detailed information on the DUT1 codes and standard time-signal transmissions of worldwide primary VLF and HF transmission stations is given in Appendixes C to E.

Most of the data are current through November 1972 and were obtained from Circular D of the Bureau International de l'Heure, Time Service Announcements of the U.S. Naval Observatory, and Special Publication 236 of the National Bureau of Standards.

The authors wish to acknowledge the assistance of Laura C. Fisher of the Time Service Division of the U.S. Naval Observatory who provided the updated information on the worldwide primary VLF and HF time-signal transmissions.

CONTENTS

A STEP IN TIME: CHANGES IN STANDARD-FREQUENCY AND TIME-SIGNAL BROADCASTS– JANUARY 1, 1972*

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INTRODUCTION

The time maintained by different national laboratories and observatories is derived from precision clocks that are periodically compared with astronomically determined time, which in turn is based on the theory of dynamics and on observation of the periodic occurrence of events such as the rotation of the Earth about its axis, universal time (UT), or about the Sun, ephemeris time (ET). Before the use of atomic clocks, time was maintained in a laboratory through the use of pendulum clocks or quartz crystal clocks (Reference 1). The stability of these clocks, relative to astronomically determined events, was such that periodic adjustments in rate and/or in steps of a small unit of time were still required to compensate for changing environmental conditions. After World War II, the stability of quartz crystal clocks had improved to such a degree that timekeeping precision in laboratories surpassed the precision of astronomical observations made over a period of a few days. For longer periods, the laboratory clocks still needed corrections with reference to astronomical observations.

In 1935, crystal clocks were compared with astronomical observations of the Earth's rotation on its axis. Because of this comparison, along with more precise measurements made later by various investigators, evidence was accumulated that proved conclusively what theorists have long suspected: the Earth's rotation rate is not constant (References 2 to 5). Therefore, time scales derived from the Earth's rotation are not uniform and thus have time intervals that are not constant. Figure 1 shows the gross, long-term variation between UT and ET from 1820 to 1971. With the advent of cesium atomic clocks, about 1955, it was found that they are more uniform than the best crystal clocks, and up to the present time (Reference 6) no variation of rate derived from these atomic standards is measurable relative to ET, which by definition has a constant rate.

*Revision of article published in *IEEE Spectrum*, January 1972. The use of the original article is with the permission of the Institute of Electrical and Electronics Engineers, Inc.

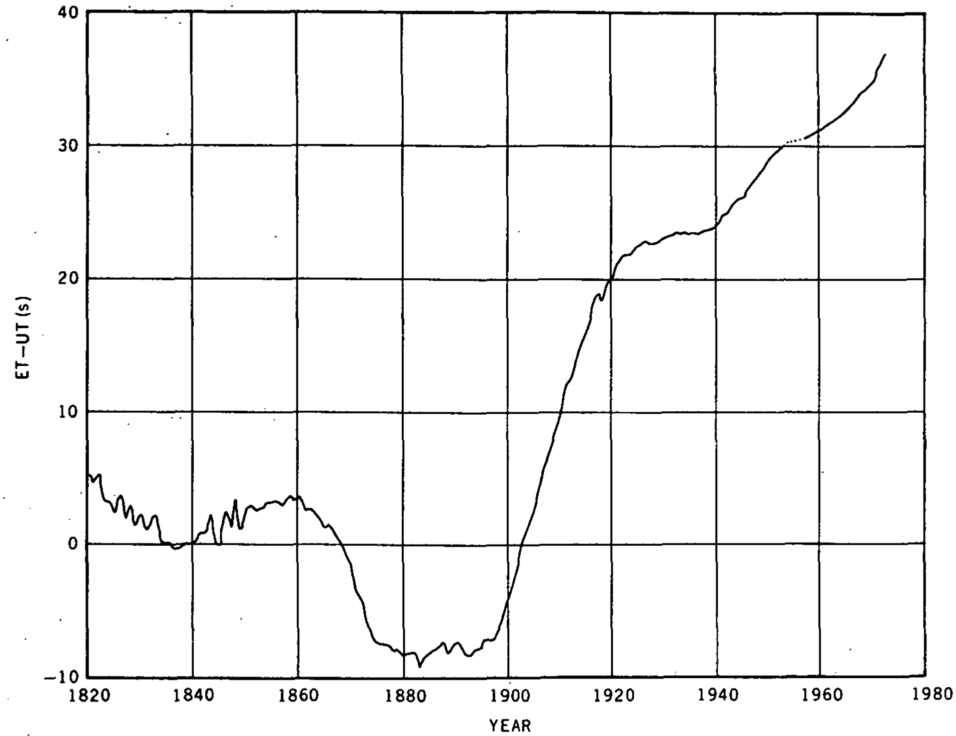

Figure 1—ET − UT in seconds from 1820 to 1971 (courtesy of U.S. Naval Observatory).

OLD UTC SYSTEM

To approximate UT in laboratories, the rate of an atomic clock was changed by offsetting its output frequency, relative to the natural resonant frequency of cesium atoms, by an amount that made the rate of this clock nearly identical with the average rate of rotation of the Earth, with all known polar and seasonal variations removed (UT2). The remaining small differences in time between locally maintained UT and astronomically determined measurements were corrected periodically to maintain synchronism. These periodic time corrections were known as step-time adjustments. The offset-frequency and step-time adjustments were made by the same amount throughout the world by international coordination and agreement through the Bureau International de l'Heure (BIH); thus, the system was called coordinated universal time (UTC). UTC was disseminated by radio stations such as WWV and NAA in the United States and CHU in Canada. From 1961 to 1971, UTC was broadcast with the offsets and step-time adjustments given in Table 1. The difference in time between UTC and UT2, relative to the U.S. Naval Observatory (USNO) atomic scale, A.1, is shown in Figure 2.

PROBLEMS

The variable offset method used in the pre-1972 UTC system was to prevent very frequent step-time adjustments and this system has served astronomical and navigational needs; however, the length

Table 1—Dates and details of offsets and step adjustments of UTC.

[From Table 10 of the BIH Annual Report for 1970]

Date (at 0^h UT) Year	Day	Offset (10^{-10})	Steps (s)	Date (at 0^h UT) Year	Day	Offset (10^{-10})	Steps (s)
1961	Jan. 1	-150		1965	Jan. 1	-150	-0.100
	Aug. 1	-150	0.050		Mar. 1	-150	-.100
1962	Jan. 1	-130			July 1	-150	-.100
1963	Nov. 1	-130	-.100		Sept. 1	-150	-.100
1964	Jan. 1	-150		1966	Jan. 1	-300	
	Apr. 1	-150	-.100	1968	Feb. 1	-300	.100
	Sept. 1	-150	-.100	1971	Jan. 1	-300	
				1972	Jan. 1	0	[a]-.107

[a]See text, "Notice to Users."

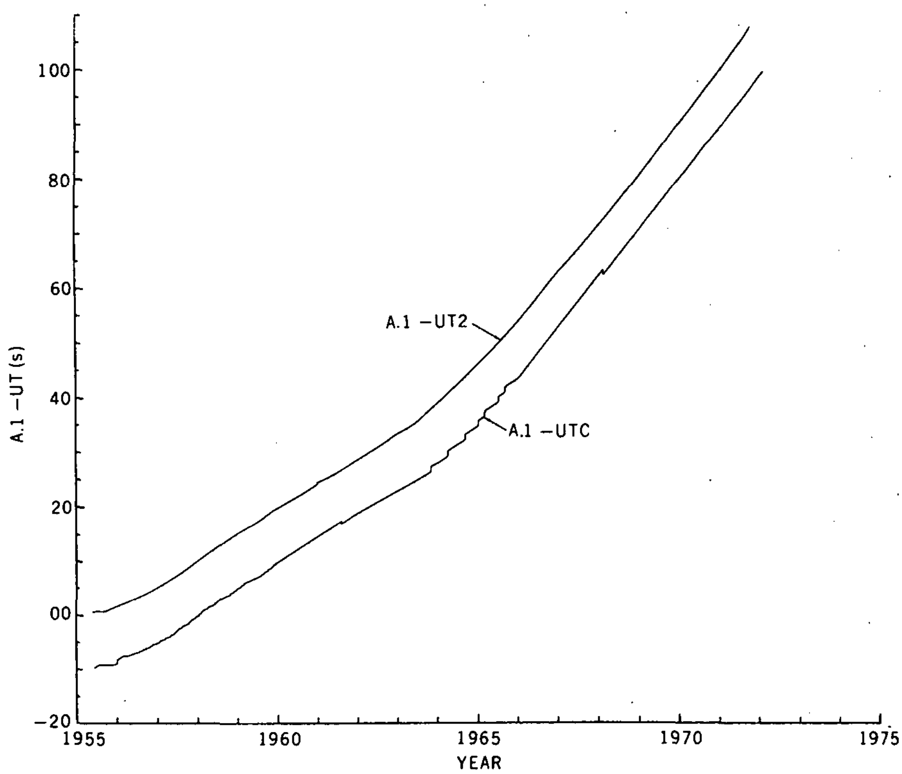

Figure 2—Time difference between an atomic time scale maintained at USNO (A.1) and UTC with step-time corrections from 1955 to 1971 (courtesy of USNO). For clarity, the smooth curve that is displaced upward by 1 s is for A.1 - UT2. The largest discontinuity in the A.1 - UT2 curve in 1961 is due to the change of the adopted longitudes for USNO stations in Washington, D.C., and Richmond, Florida, which introduced a 0.033-s discontinuity in UT2. Two smaller discontinuities, 0.011 s in 1962 and 0.008 s in 1969, also occurred but are not apparent in the figure.

of the broadcast time interval (the UTC second) changed each time an offset change was introduced. The result was that, although the pre-1972 UTC system satisfied the needs of those who required time based on the rotational position of the Earth, there were other users needing time intervals that did not change in length and that were more directly related to atomic standards. These users were not well served by the pre-1972 UTC system.

In 1968, Study Group 7 of the International Radio Consultative Committee (CCIR),[1] at its Interim Meeting at Boulder, Colorado, recognized the desire to make the broadcast time interval (the UTC second) uniform, in conformity with the international definition of the second,[2] and the need to simplify the timekeeping procedure for both scientific and field operations use. Study Group 7 created an International Working Party (IWP 7/1) (Reference 8) and charged it to study this problem and to make recommendations. In 1969, the IWP 7/1 recommendations (Appendix A) were approved by the Interim Meeting of Study Group 7 in Geneva and later adopted by the XIIth Plenary Assembly of the CCIR in 1970 at New Delhi. The detailed instructions for implementing the recommendations are contained in a report adopted by CCIR Study Group 7 in its Interim Meeting of February 1971 in Geneva, as authorized by the Plenary Assembly of 1970; this report is included as Appendix B.

IMPROVED UTC SYSTEM

In summary, the improved UTC system eliminates the changing-frequency offset and increases the size of the step-time adjustments from 0.1 to 1 s, which is called a "leap second." UTC clocks are, therefore, driven at the atomic clock rate but keep their time in synchronism with UT1 (UT corrected for polar variations only) to a tolerance of ±0.7 s by using periodic leap-second adjustments. On January 1, 1972, the standard-frequency and time-signal radio stations of all nations participating in the CCIR (such as WWV, NAA, and CHU, as well as national observatories and timekeeping laboratories) changed their clock time from the old UTC system to the improved UTC system in conformity with instructions given in Appendix B. To assist users (such as navigators, surveyors, and geodesists) who need UT1 to greater accuracy, the time difference between UT1 and UTC (denoted by DUT1) is transmitted in code to a precision of 0.1 s. The DUT1 codes adopted by different national observatories and timekeeping laboratories are given in Appendix C. Detailed information of the standard-frequency and time-signal stations is given in Appendix D. Users who need very precise UT must continue to maintain their own very accurate clocks and to use the predicted and final time data from national or international agencies such as the USNO or the BIH.

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[1]The CCIR is one of three permanent organs of the International Telecommunications Union (ITU). The CCIR was set up by the International Radiotelegraph Conference (Washington, 1927). Article 14, No. 186, of the International Telecommunication Convention, Montreux, 1965, stipulates that "the duties of the International Radio Consultative Committee shall be to study technical and operating questions relating specifically to radiocommunication and to issue recommendations on them." In addition to representatives of the administrations of the 141 countries that are members of the Union, the representatives of 49 recognized private operating agencies, 43 scientific or industrial organizations, and 27 international organizations take part in CCIR work. (See Reference 7 for detailed organizational structure and functions of ITU.)

[2]In October 1967, the International Conference on Weights and Measures defined in its thirteenth General Conference that the second is the duration of 9 192 631 770 periods of radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom.

NOTICE TO USERS

The BIH announced through its Circular D59 dated October 5, 1971, the following changes:

(1) On January 1, 1972, a time step of minus 0.107 757 7 s (see Appendix E) would be applied to the old UTC. This time step would occur on December 31 at 23 hours, 59 minutes, 60.107 757 7 seconds (old UTC). At this instant, the date and time would become January 1, 1972, 0 hours, 0 minutes, 0 seconds exactly (new UTC).

(2) The frequency offset of the presently used UTC (-300×10^{-10}) would be eliminated at the instant of the above time step.

After this step change, the time difference between the international atomic time (TAI) scale[3] maintained by the BIH and the improved UTC (BIH) scale would be exactly 10 s (UTC late relative to TAI) until the next step of exactly 1 s is applied to UTC, at which time the difference will be 11 s. The national agencies and timekeeping authorities of each country participating in the CCIR each introduced a slightly different time step to reduce the existing small time differences between BIH UTC and UTC as kept by each national agency. (See Appendix E.)

In the United States, the offset was also eliminated and the time step was slightly different from the BIH announced value to correct for the small time difference that existed between the U.S. national timekeeping agencies and BIH. The National Bureau of Standards and the USNO announced that the time step to be made on January 1, 1972, would be minus 0.107 600 s. This time step occurred on December 31, at 23 hours, 59 minutes, 60.107 600 seconds (old UTC). At this instant, the date became January 1, 1972, 0 hours, 0 minutes, 0 seconds exactly (new UTC).

Additional information on the broadcast of the improved UTC system by standard-frequency and time-signal stations in the United States can be found in References 9 and 10. Information on USNO publications may be obtained from the Superintendent, U.S. Naval Observatory, Washington, D.C. 20390. Request for additional information on the time and frequency services of the National Bureau of Standards should be referred to the National Bureau of Standards, Time and Frequency Broadcast Services Section, Code 1, Boulder, Colorado 80302.

LEAP-SECOND ADJUSTMENTS

The BIH announced the following in its Circular D65 of April 5, 1972: "The first leap second which is a positive leap second will be introduced in the UTC time scale on the first of July, 1972,

[3]In October 1971, the 14th General Conference of Weights and Measures authorized the International Committee of Weights and Measures to conclude with BIH the arrangement necessary for the realization of the TAI (Temps Atomique International) scale in accordance with the following definition:

> The International Atomic Time is the time-reference coordinate established by the Bureau International de l'Heure on the basis of atomic clock readings functioning in diverse establishments conforming to the definition of the second, the unit of time of the International System of Units.

near 0^h UTC according to the rules of the CCIR Report 517. TAI - UTC will become +11 s at this date." The second leap second, according to BIH announcement, Circular D72, November 3, 1972, will occur at the end of December 31, 1972. On January 1, 1973, TAI - UTC will be +12 s.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, February 11, 1972
310-20-23-02-51

Appendix A

RECOMMENDATION 460: STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS
(Question 1/7)

The C.C.I.R., (1970)

CONSIDERING

(a) the desirability of eliminating all offsets from nominal values in the carrier frequencies and in the time signals;

(b) the desirability of disseminating on a world-wide basis precise time intervals in conformity with the definition of the second (SI), as adopted by the 13th General Conference of Weights and Measures (1967);

(c) the continuing need of many users for Universal Time (UT);

UNANIMOUSLY RECOMMENDS

1. that, from a specified date, carrier frequencies and time intervals should be maintained constant and should correspond to the adopted definition of the second;
2. that the transmitted time scale should be adjusted when necessary in steps of exactly one second to maintain approximate agreement with Universal Time (UT);
3. that the standard-frequency and time-signal emissions should contain information on the difference between the time signals and Universal Time (UT);
4. that detailed instructions on the implementation of this Recommendation be adopted by Study Group 7 after consideration of the report of Interim Working Party 7/1;
5. that the standard-frequency and time-signal emissions should conform to §§ 1, 2, 3 and 4 above from 1 January 1972, 0000 h UT;
6. that this document be transmitted by the Director, C.C.I.R., to all Administrations Members of the I.T.U., to the Scientific Unions (I.A.U., I.U.G.G., U.R.S.I., I.U.P.A.P.), and other organizations such as B.I.H., C.I.P.M., I.C.A.O. and I.M.C.O.

Appendix B

REPORT 517:* STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

Detailed instructions by Study Group 7 for the implementation of Recommendation 460 concerning the improved Coordinated Universal Time (UTC) System, valid from 1 January 1972 (Question 1/7, Resolution 53, 1971)

1. The XIIth Plenary Assembly of the C.C.I.R. adopted unanimously Recommendation 460. According to § 4 of this recommendation, Study Group 7 was entrusted with the task of formulating the detailed instructions for its implementation on 1 January 1972.

   Study Group 7 met from 17-23 February 1971 and adopted the following text for this purpose:

2.

2.1 A special adjustment to the standard-frequency and time-signal emissions should be made at the end of 1971 so that the reading of the UTC scale will be 1 January 1972, $0^h 0^m 0^s$ at the instant when the reading of Atomic Time (AT) indicated by the Bureau International de l'Heure (B.I.H.) will be 1 January 1972, $0^h 0^m 10^s$. The necessary adjustments to emissions which are in accordance with Recommendation 374-2 will be specified and announced in advance by the B.I.H.

2.2 The departure of UTC from UT1 should not normally exceed 0.7 s.**

2.3 Inserted seconds should be called positive leap seconds and omitted seconds should be called negative leap seconds.

2.4 A positive or negative leap second, when required, should be the last second of a UTC month, preferably 31 December and/or 30 June. A positive leap second begins at $23^h 59^m 60^s$ and ends at $0^h 0^m 0^s$ of the first day of the following month. In the case of a negative leap second, $23^h 59^m 58^s$ will be followed one second later by $0^h 0^m 0^s$ of the first day of the following month. (See Annex I.)

*This Report was adopted unanimously.

**Universal Time:

In applications in which errors of a few hundredths of a second cannot be tolerated, it is necessary to specify the form of Universal Time (UT), referred to in Recommendation 460, which should be used.

UT1 is a form of UT in which corrections have been applied for the effects of small movements of the Earth relative to the axis of rotation.

UT2 is UT1 corrected for the effects of a small seasonal change in the rate of rotation of the Earth.

UT1 corresponds directly with the angular position of the Earth around its axis of rotation, and is used in this document. GMT may be regarded as the general equivalent of UT1.

2.5 The B.I.H. should decide upon and announce the occurrence of a leap second; such an announcement is to be made at least eight weeks in advance.

2.6 The time signals of standard-frequency and time-signal emissions should be kept as close to UTC as possible, with a maximum deviation of one millisecond.

3.

3.1 The approximate value of the difference UT1 minus UTC, as disseminated with the time signals should be denoted DUT1, where DUT1 $\approx$ UT1 - UTC. DUT1 may be regarded as a correction to be added to UTC to obtain an approximation of UT1.

3.2 The values of DUT1 should be given in integral multiples of 0.1 s. The B.I.H. is requested to determine and to circulate one month in advance the value of DUT1. Administrations and organizations should use the B.I.H. value of DUT1 for standard-frequency and time-signal emissions whenever possible, and are requested to circulate the information as widely as possible in periodicals, bulletins, etc.

3.3 Where DUT1 is disseminated by code, the code should be in accordance with the following principles:

- The magnitude of DUT1 is specified by the number of emphasized seconds markers and the sign of DUT1 is specified by the position of the emphasized seconds markers with respect to the minute marker. The absence of emphasized markers indicates DUT1 = 0.
- The coded information should be emitted after each identified minute. Full details of the code are given in Annex II.

3.4 Alternatively DUT1 may be given by voice announcement or in Morse code.

3.5 In addition, UT1 - UTC may be given to the same or higher precision by other means, for example, in Morse or voice announcements, by messages associated with maritime bulletins, weather forecasts, etc.; announcements of forthcoming leap seconds may also be made by these methods.

3.6 The B.I.H. is requested to continue to publish in arrears definitive values of the differences UT1 - UTC, UT2 - UTC and AT (B.I.H.) - UTC.

ANNEX I TO REPORT 517: DATING OF EVENTS IN THE VICINITY OF A LEAP SECOND (taken from §2.4 of the report)

A positive or negative leap second, when required, should be the last second of a UTC month, preferably 31 December and/or 30 June. A positive leap second begins at $23^h\,59^m\,60^s$ and ends at $0^h\,0^m\,0^s$ of the first day of the following month. In the case of a negative leap second, $23^h\,59^m\,58^s$ will be followed one second later by $0^h\,0^m\,0^s$ of the first day of the following month.

Taking account of what has been said in the preceding paragraph, the dating of events in the vicinity of a leap second shall be effected in the manner indicated in Figures B1 and B2.

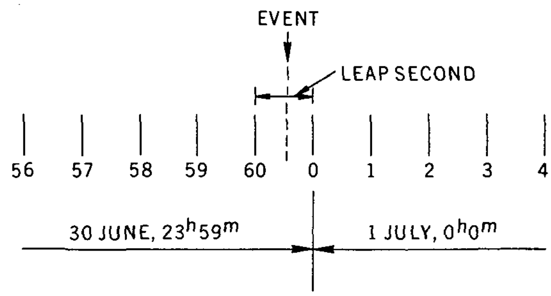

Figure B1—Positive leap second. Designation of the date of the event: 30 June, $23^h 59^m 60.6^s$ UTC.

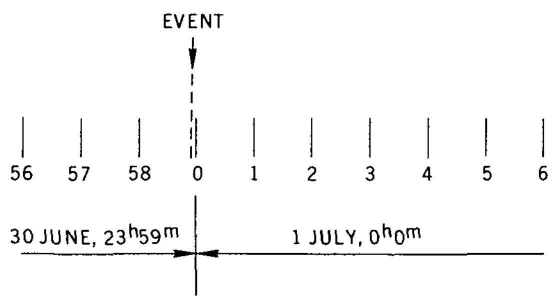

Figure B2—Negative leap second. Designation of the date of the event: 30 June, $23^h 59^m 58.9^s$ UTC.

ANNEX II TO REPORT 517: CODE FOR THE TRANSMISSION OF DUT1

A positive value of DUT1 will be indicated by emphasizing a number (n) of consecutive seconds markers following the minute marker from seconds markers one to seconds marker (n) inclusive; (n) being an integer from 1 to 7 inclusive.

$$\mathrm{DUT1} = (n \times 0.1)\ \mathrm{s}$$

A negative value of DUT1 will be indicated by emphasizing a number (m) of consecutive seconds markers following the minute marker from seconds marker nine to seconds marker ($8 + m$) inclusive; (m) being an integer from 1 to 7 inclusive.

$$\mathrm{DUT1} = -(m \times 0.1)\ \mathrm{s}$$

A zero value of DUT1 will be indicated by the absence of emphasized seconds markers.

The appropriate seconds markers may be emphasized, for example, by lengthening, doubling, splitting, or tone modulation of the normal seconds markers. Examples are given in Figure B3.

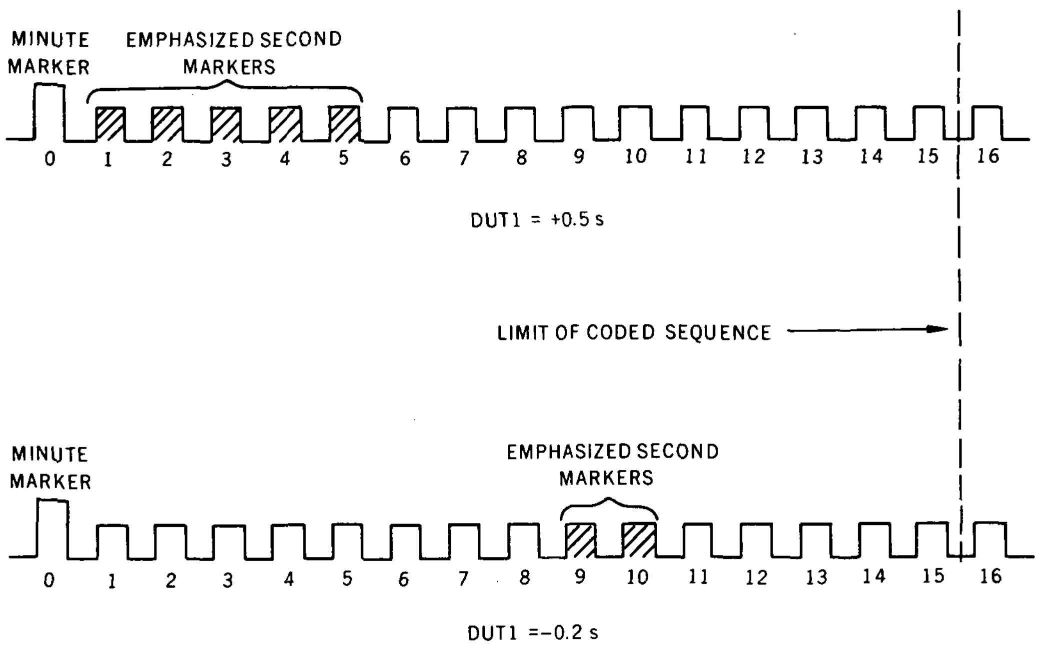

Figure B3—Examples of emphasis on second markers.

Appendix C

DUT1 CODES

TRANSMISSION OF DUT1[4]

Table C1 gives a summary of the information received by the BIH on the transmission of DUT1. For the other characteristics of the time signals, see BIH Annual Report for 1971, Part C.

Table C1.–DUT1 codes.

Time Signal[a]	CCIR Code, Second Markers Emphasized by–	Other Methods of Transmission and Remarks
CHU	Split markers	
DAM, DAN, DAO	Doubling	Code transmitted from minutes 1 to 6
DCF77	Lengthening	DCF77 adheres to new UTC system
DIZ	Doubling	
FFH	Lengthening	
FTA91, FTH42, FTK77, FTN87	No	Morse code ("plus" or "moins" in full spelling)
HBG	No	No transmission of DUT1; not used for navigational purposes
IBF	Doubling	
JJY	Lengthening	Minute indicated by a 600-Hz modulation of 655-ms duration between seconds 59 and 0
MSF, GBR	Doubling	
U.S.S.R. signals	Doubling	Additional information in BIH Circular D60 (See also p. 14.)
NBA, NDT, NPG, NPM, NPN, NSS, NWC	No	Standard Morse code during each minute, between seconds 56 and 59; *A* means "add" or "plus"; *S*, "subtract" or "minus." (See also p. 14.)
WWV, WWVH	Doubling	
ZUO	Lengthening	

[a]See Appendix D for additional time-signal information for these stations and for DUT1 code transmission information for stations not included in this table.

[4]From BIH Circular D62, January 7, 1972.

SPECIAL ADJUSTMENTS OF TIME-SIGNAL EMISSIONS[5]

Several time signals will be adjusted so that the time of emission will be in better agreement with the new UTC, starting from January 1, 1972. The difference between UTC and the signal will be less than 0.0001 s for at least the following time signals: CHU, DAM, DAN, DAO, DCF77, DIZ, FTH42, FTK77, FTN87, HBG, MSF, GBR, OMA, WWV, WWVB, and WWVH.

THE U.S.S.R. EXTENDED FORMAT[6]

The time signals of the U.S.S.R. will follow the CCIR code for DUT1. In addition they will give dUT1, which specifies more precisely the difference UT1 - UTC to multiples of 0.02 s, the total value of the correction being DUT1 + dUT1. Positive values of dUT1 will be transmitted by the marking of p second markers between the 21st and 24th second so that dUT1 = $p \times 0.02$ s. Negative values of dUT1 will be transmitted by the marking of q second markers between the 31st and the 34th second, so that dUT1 = $-q \times 0.02$ s.

THE MORSE CODE METHOD (U.S. NAVAL TIME SIGNALS)[6]

The CCIR Report 517 suggests voice or Morse code as alternate means to the marker method. U.S. naval frequency shift keying (FSK) time signals are described in Reference 12. Because it is planned to convert more of the existing continuous wave (cw) naval time signals to the FSK-cw format, which will increase the precision of reception, consideration had to be given to possible problems that could arise for the unsophisticated user of such signals. Extensive testing has shown that users of simple receivers may tune their receivers to the wrong side of the signal and receive the time marker complement instead of the marker. This possibility of confusion is increased if many successive ticks are split. The U.S. naval time signals will, therefore, use standard Morse code (15 wpm) during each minute. DUT1 corrections will be transmitted once each minute between seconds 56 and 59, which are not used in the American code for time ticks.

The code will give the letter "A" (for add or plus) and one digit to designate a positive DUT1 and the letter "S" and one digit to designate a negative correction. These characters are listed as follows:

A · –	S · · ·
1 · – – – –	6 – · · · ·
2 · · – – –	7 – – · · ·
3 · · · – –	8 – – – · ·
4 · · · · –	9 – – – – ·
5 · · · · ·	10 – – – – –

Example:

· · ·   · – – – –

will mean DUT1 = -0.1 s and UT1 = UTC - 0.1 s.

[5]From BIH Circular D62, January 7, 1972.

[6]From Reference 11 and BIH Circular D60, November 3, 1971.

Appendix D

WORLDWIDE PRIMARY VLF AND HF TIME-SIGNAL TRANSMISSIONS[7]

U.S. NAVAL TIME SIGNALS

Transmissions

The time signals of the U.S. naval radio stations are transmitted on cw or FSK-cw. In FSK-cw, the carrier frequency can be shifted ±50 Hz. However, only the +50-Hz frequency shift above the carrier is presently employed for high-powered naval VLF stations. Equal bit (mark or space) length of 20 ms is used. The key-down position is mark-space reversal. The key-up position is steady tone. Table D1 lists the naval radio stations and gives information concerning transmission of their time signals. Time signals are transmitted for each second of the indicated minute periods with the following exceptions:

(1) No signals are transmitted on the 29th second of any minute.

(2) No signals are transmitted on certain seconds at the end of some minutes to permit minute identification. (See "American Code," below.)

The DUT1 code is transmitted by the Morse code method. (See Appendix C.)

Details and changes in schedules are given in USNO Time Service Announcements, Series 2 and 3. General information on time determination is published in USNO Time Service Announcements, Series 14. All USNO publications are available upon request.

Signal Reception

FSK signals can be received with most VLF receivers. The best method for listening to the code is to use a communication receiver with a beat-frequency oscillator. Care must be exercised to tune slightly to the low side of the assigned frequency to emphasize the tick. This is to reduce the unnecessary interference from the other FSK carrier which is 50 Hz away. Wrong tuning will also make the Morse code unintelligible. For making measurements or recordings, a frequency discriminator may be used as described in Reference 14. This reference also explains how to tune regular communication receivers to an FSK signal.

American Code

The American code is a time code adopted by the U.S. Navy for transmitting time in its rf transmitters. It is designed to transmit hour, minute, half-minute, and second information. It is a pulse code that can be transmitted by an on-and-off keying method or some other modulation technique. The essential code format is shown in Figure D1.

[7]From Reference 13.

Table D1—U.S. naval radio station time signals.

Station	Location	Radiated Power (kW)	Frequency (kHz)	Times of Transmissions (UT)	Type of transmission
NBA	Balboa, C.Z.; lat. 9°03′ N, long. 79°39′ W	[a]150	24	During 5 min preceding every even hour except 24^h and during Mon. maintenance (12^h to 18^h)	FSK-cw
			147.85 5 448.5 11 080 17 697.5	During 5 min preceding 5^h, 11^h, 17^h, 23^h	cw
NDT	Yosami, Japan; lat. 34°58′ N, long. 137°01′ E	50	17.4	([b])	([b])
NLK	Jim Creek, Wash.; lat. 48°12′ N, long. 121°55′ W	250	18.6	([c])	cw
NPG	Dixon (San Francisco), Calif.; lat. 38°06′ N, long. 122°16′ W		3 268 6 428.5 9 277.5 12 966	During 5 min preceding 6^h 12^h, 18^h, 24^h	cw
NPM	Lualualei (Honolulu), Hawaii; lat. 21°25′ N, long. 158°09′ W	600	23.4	([c])	cw
			4 525 9 050 13 655 16 457.5 22 593	During 5 min preceding 6^h, 12^h, 18^h, 24^h	cw
NPN	Guam, Mariana Islands; lat. 13°27′ N, long. 144°43′ E		4 955 8 150 13 380 15 925 21 760	During 5 min preceding 6^h, 12^h, 18^h, 24^h	cw
NSS	Annapolis, Md.; lat. 38°59′ N, long. 76°27′ W	400	[d]21.4		FSK-cw
			[e]88 5 870 8 090 12 135 16 180	During 5 min preceding 5^h 11^h, 17^h, 23^h	cw
			20 225 25 590	During 5 min preceding 17^h, 23^h	cw
NWC	Exmouth, Australia; lat. 21°49′ S, long. 114°09′ E	1000	22.3	During 2 min preceding 0^h30^m, 4^h30^m, 8^h30^m, 12^h30^m, 16^h30^m, 20^h30^m	FSK-cw

[a]Reduced to 90 kW each Tues. from 12^h to 20^h UT for limited maintenance.
[b]To be determined.
[c]Time signals are not transmitted on the VLF carrier.
[d]Transmissions are temporarily suspended.
[e]Replaced by 185 kHz on Tues. at 17^h.

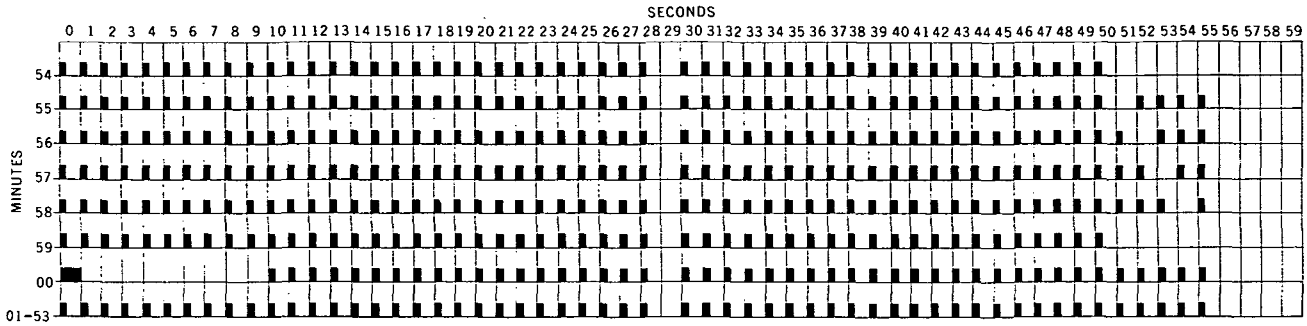

Figure D1—American code format.

The code consists of two types of pulses. One is 0.3 s wide and the other is 1.0 s wide. The 0.3-s pulse is used to identify seconds and minutes and the 1.0-s pulse marks the beginning of the hour. The leading edge of each pulse is the on-time second marker.

The beginning of each minute is preceded by the deletion of four 0.3-s pulses from seconds 56 to 59. Half-minute markers are recognized by the deletion of the 0.3-s pulse at second 29. Seconds of the minutes are therefore identified or marked twice every minute. Seconds marks are identified by the leading edges of the 0.3-s and 1.0-s pulses.

The beginning of each hour is identified by the 1.0-s pulse on the hour and the absence of 0.3-s pulses during the nine seconds, 51 to 59, preceding the hour and the nine seconds, 1 to 9, after the hour marker. It is recognized by the long silence before and after the hour marker. The deletion of the 0.3-s pulses after the hour may be longer than nine seconds depending on the design of the particular transmitter.

In addition, the last five minutes before each hour can be identified. For example, the 0.3-s pulse at the beginning of minute 55 is preceded by the deletion of nine 0.3-s pulses for seconds 51 through 59. Minute 56, which is 4 min before minute 00, is preceded by the deletion of one 0.3-s pulse at second 51 and the presence of the isolated group of four 0.3-s pulses before this minute. The same procedure is followed for minutes 57, 58, and 59, which are 3, 2, and 1 min before minute 00.

NATIONAL BUREAU OF STANDARDS (NBS) TIME SIGNALS

NBS radio stations are listed in Table D2. Included in the information provided by the stations are time intervals, time signals, and corrections to UT1. WWV and WWVH transmit the DUT1 code by doubling; WWVB transmits the DUT1 code by level-shift carrier. (See Appendix C and Reference 9.)

FOREIGN TIME SIGNALS

Table D3 lists the characteristics of the main time-signal emissions and is based primarily on the BIH Annual Report 1971. Any available additional information obtained through private communication and from BIH Circular D after April 1971 through November 1972 has been included. Time signals are adjusted to UT1 in steps of 1 s unless otherwise noted. Details may be obtained from individual stations. DUT1 code information is given in Appendix C and Table D3.

Table D2—NBS radio station time signals.[a]

Station	Location	Radiated Power (kW)	Frequency (kHz)	Times of Transmissions (UT)	Time Signal
WWV	Ft. Collins, Colo., lat. 40°41′ N, long. 105°02′ W	5 10 10 10 2.5 2.5	2 500 5 000 10 000 15 000 20 000 25 000	Continuous	Second markers 29 and 59 are omitted. All markers are 5-ms pulses of 1000 Hz except the first second of each minute which is lengthened to 800 ms. The first second of each hour is also a 800-ms pulse but of 1500 Hz. Male voice announces time every minute.
WWVB	Ft. Collins, Colo.; lat. 40°40′ N, long. 105°03′ W	16	60	Continuous except for scheduled maintenance on alternate Tuesdays between 13^h and 24^h UT	Negative level-shift carrier is used to generate pulses of the 1-2-4-8 binary coded decimal (BCD) time code. Binary "1" is 0.5 s; "0" is 0.8 s. The time frame is 1 min with 1-s resolution (Reference 9). Hours are identified by the 45° phase advance of the carrier for 5 min at 10 min after the hour. At 15 min after the hour the carrier phase is retarded back to normal. DUT1 is also transmitted in BCD code.
WWVH	Kauai, Hawaii; lat. 21°59′ N, long. 159°46′ W	5 10 10 10 2.5	2 500 5 000 10 000 15 000 20 000	Continuous	Same as WWV except 1200 Hz is used in place of 1000 Hz. Female voice announces time every minute.

[a]DUT1 code information is given in Appendix C and Reference 9.

Table D3—Foreign radio station time signals.

Station	Location	Radiated Power (kW)	Frequency (kHz)	Times of Transmissions (UT)	Time Signals
BPV[a,b]	Shanghai, People's Republic of China; lat. 31°12′ N, long. 121°26′ E		5 430	17^h, 19^h, 21^h	Second pulses occur during the 5 min preceding the indicated times, then rhythmic time signals[c] are given.
			9 368	6^h, 11^h, 13^h, 15^h, 17^h, 21^h, 23^h	
			5 000	10^h to 12^h	Second pulses are given by modulation of the carrier during the 3 min following 0^m, 15^m, 30^m, and 45^m of each indicated hour.
			10 000	0^h to 3^h45^m, 6^h to 9^h45^m	
			15 000	4^h to 5^h45^m	
BSF	Taiwan, Republic of China	2	5 000	Between minutes 0 to 5, 10 to 15, 20 to 25, 30 to 35, 40 to 45, 50 to 55 from 1^h to 9^h	A1-type second pulses[d] are of 5-ms duration; minute pulses are 300 ms long. During 29^m and 59^m, Morse code and Chinese announcements of time are made. DUT1 code is given by lengthening.
CHU[e]	Ottawa, Canada; lat. 45°18′ N, long. 75°45′ W	3	3 330	Continuous	Second pulses are 300 cycles of a 1-kHz modulation; minute pulses are 0.5 s long. A French/English announcement of time is made each minute.
		10	7 335		
		3	14 670		
DAM[e]	Elmshorn, Federal Republic of Germany; lat. 53°46′ N, long. 9°40′ E	10	8 638.5	11^h55^m to 12^h6^m	A1-type second pulses[d] are emitted from minutes 0.5 to 6.0; minute pulses are prolonged.
		15	16 980.4		
		5	4 625	23^h55^m to 24^h6^m, from Sept. 21 to Mar. 20	
		10	8 638.5		
		5	6 475.5	23^h55^m to 24^h6^m, from Mar. 21 to Sept. 20	
		15	12 763.5		
DAN[e]	Osterloog, Federal Republic of Germany; lat. 53°38′ N, long. 7°12′ E	2	2 614	11^h55^m to 12^h6^m, 23^h55^m to 24^h6^m	Same as DAM
DAO[e]	Kiel, Federal Republic of Germany; lat. 54°26′ N, long. 10°8′ E	2	2 775	11^h55^m to 12^h6^m, 23^h55^m to 24^h6^m	Same as DAM
DCF77[e]	Mainflingen, Federal Republic of Germany; lat. 50°1′ N, long. 9°0′ E	38	77.5	Continuous except second Tuesday of every month from 4^h to 8^h	Second markers are 0.1 s long, generated by negative level shift of the carrier to 25 percent; second marker 59 is omitted.

NOTE: Footnotes appear at end of table, p. 25.

Table D3—Foreign radio station time signals—continued.

Station	Location	Radiated Power (kW)	Frequency (kHz)	Times of Transmissions (UT)	Time Signals
DGI[b]	Oranienburg, Democratic Republic of Germany; lat. 52°48′ N, long. 13°24′ E	750	185	$5^h59^m30^s$ to 6^h00^m, $11^h59^m30^s$ to 12^h00^m, $17^h59^m30^s$ to 18^h00^m	A2-type second pulses[f] of 0.1-s duration occur for seconds 30 to 40, 45, 50, 58, 59, and 60.
DIZ[e]	Nauen, Democratic Republic of Germany; lat. 52°39′ N, long. 12°55′ E	5	4 525	Continuous except from 8^h15^m to 9^h45^m	A1-type second pulses[d] are of 0.1-s duration. Minute pulses are prolonged to 0.5 s. Hour pulses are marked by prolonged pulses for seconds 58, 59, and 60.
FFH[e]	Chevannes, France; lat. 48°32′ N, long. 2°27′ E	5	2 500	Continuous between 8^h and 16^h25^m except Sat. and Sun.	Second pulses are 5 cycles of a 1-kHz modulation. Minute pulses are prolonged to 0.5 s.
FTA91[e]	Saint André de Corcy, France; lat. 45°55′ N, long. 4°55′ E		91.15	8^h, 9^h, 9^h30^m, 13^h, 20^h, 21^h, 22^h30^m	A1-type second pulses[d] occur during the 5 min preceding the indicated times. Minute pulses are prolonged.
FTH42[e]	Pontoise, France; lat. 49°4′ N, long. 2°7′ E		7 428	9^h and 21^h	Same as FTA91.
FTK77[e]			10 775	8^h and 20^h	
FTN87[e]			13 873	9^h30^m, 13^h, 22^h30^m	
GBR[e]	Rugby, United Kingdom; lat. 52°22′ N, long. 1°11′ W	60	16	3^h, 9^h, 15^h, 21^h	A1-type second pulses[d] occur during the 5 min preceding the indicated times. FSK is used alternately with cw.
HBG[e]	Prangins, Switzerland; lat. 46°24′ N, long. 6°15′ E	20	75	Continuous	Interruption of the carrier occurs at the beginning of every second. Minutes are marked by a double pulse, hours by a triple pulse, and midnight by 4 pulses.
IAM[b]	Rome, Italy; lat. 41°52′ N, long. 12°27′ E	1	5 000	7^h30^m to 8^h30^m and from 13^h00^m to 14^h00^m for 10 min every 15 min except Sun.; advanced by 1 hr in summer	Signals are second pulses of 5 cycles of a 1-kHz modulation and minute pulses of 20 cycles. Announcements and 1-kHz modulations are made 5 min before the emission of time signals.

IBF[e]	Torino, Italy; lat. 45°2′ N, long. 7°42′ E	5	5 000	$7^h, 9^h, 10^h, 11^h, 12^h, 13^h, 14^h, 15^h, 16^h, 17^h, 18^h$; advanced by 1 hr in summer	Signals are second pulses of 5 cycles of a 1-kHz modulation during 15 min preceding indicated hour. Pulses are repeated 7 times at the minute. Voice announcements (Italian, French, English) are made at the beginning and end of each emission.
JG2AE	Koganei, Japan; lat. 35°42′ N, long. 139°31′ E		8 000	20^h59^m to 10^h59^m, interruptions between 25^m and 34^m	Second pulses of a 1600-Hz modulation are made; minute pulses are preceded by a 600-Hz modulation. *DUT1 code is given by lengthening.*
JG2AS	Kemigawa, Chiba, Japan; 35°38′ N, long. 140°4′ E	10	40	0^h to 8^h, except Sun., interruptions during communications	A1-type second pulses[d] are 0.5 s long; second marker 59 is omitted. DUT1 is not transmitted.
JJY[e]	Koganei, Japan; lat. 35°42′ N, long. 139°31′ E	2	2 500 5 000 10 000 15 000	Continuous; interruptions between 25^m and 34^m	Second pulses are 8 cycles of a 1600-Hz modulation; minute pulses are indicated by a 600-Hz modulation of 655 ms between seconds 59 and 60.
LOL1	Buenos Aires, Argentina; lat. 34°37′ S, long. 58°21′ W	2	5 000 10 000 15 000	11^h to 12^h, 14^h to 15^h, 17^h to 18^h, 20^h to 21^h, 23^h to 24^h	Second pulses are 5 cycles of a 1000-Hz modulation; second marker 59 is omitted. Announcement of hours and minutes is made every 5 min, followed by 3 min of 1000- and 440-Hz modulations. DUT1 code is given by lengthening.
LOL2 LOL3	Buenos Aires, Argentina; lat. 34°37′ S, long. 58°21′ W		8 030 17 180	$1^h, 13^h, 21^h$	A1-type second pulses[d] are emitted during the 5 min preceding the indicated times; minute pulses are prolonged. DUT1 code is given by lengthening.
LQB9 LQC20	Planta Gral, Pacheco, Argentina; lat. 34°26′ S, long. 58°37′ W		8 167.5 17 551.5	22^h5^m, 23^h50^m 10^h5^m, 11^h50^m	A1-type second pulses[d] are emitted during the 5 min preceding the indicated times. Second marker 59 is omitted, second marker 60 is prolonged. After the emission, OK is transmitted if the emission is correct, NV if not correct. DUT1 code is given by omission of second markers.
MSF[e]	Rugby, United Kingdom; lat. 52°22′ N, long. 1°11′ W	0.5	60	Continuous except for an interruption for maintenance from 10^h to 14^h on the first Tues. in each month	Interruptions of the carrier are 100 ms for the second pulses and 500 ms for the minute pulses. The signal is given by the beginning of the interruption.
			2 500 5 000 10 000	Between minutes 0 and 5, 10 and 15, 20 and 25, 30 and 35, 40 and 45, 50 and 55	Second pulses are 5 cycles of a 1-kHz modulation; minute pulses are prolonged.

Table D3—Foreign radio station time signals—continued.

Station	Location	Radiated Power (kW)	Frequency (kHz)	Times of Transmissions (UT)	Time Signals
OLB5	Poděbrady, Czechoslovakia; lat. 50°9′ N, long. 15°8′ E	5	3 170	Continuous except from 5^h to 11^h on the first Wed. of every month	A1-type second pulse.[d] DUT1 is not transmitted.
OMA	Liblice, Czechoslovakia; lat. 50°4′ N, long. 14°53′ E	2	50	Continuous except from 5^h to 11^h on the first Wed. of every month	Interruptions of the carrier are 100 ms long at the beginning of every second, 500 ms at the beginning of every minute. The precise time is given by the instant when the amplitude is reduced by 50 percent. DUT1 is not transmitted.
		1	2 500	Between minutes 5 and 15, 25 and 30, 35 and 40, 50 and 60 of every hour except from 5^h to 11^h on the first Wed. of every month	Second pulses are 5 cycles of a 1-kHz modulation; minutes are prolonged. The first pulse of the 5th minute is prolonged to 500 cycles. DUT1 is not transmitted.
PPE	Rio de Janeiro, Brazil; lat. 22°54′ S, long. 43°13′ W		8 721	0^h30^m, 11^h30^m, 13^h30^m, 19^h30^m, 20^h30^m, 23^h30^m	A1-type second pulses[d] are emitted during the 5 min preceding the indicated hours; minute pulses are prolonged. DUT1 code is given by *doubling*.
PPR	Rio de Janeiro, Brazil; lat. 22°54′ S, long. 43°11′ W		435 8 634 13 105 17 194.4	1^h30^m, 14^h30^m, 21^h30^m	Same as PPE. (No DUT1 code information available.)
RAT[e]	Moscow, U.S.S.R.; lat. 55°19′ N, long. 38°41′ E		5 000	Between minutes 30 and 35, 41 and 45, and 50 and 60 of every hour	Second pulses occur; minute pulses are prolonged; rhythmic signals[c] between minutes 1 and 6, at 0^h, 2^h, 4^h, etc.
RBU[e]	Moscow, U.S.S.R.; lat. 55°19′ N, long. 38°41′ E		66 2/3	From 0^m to 5^m every hour except 23^h	A-1 type second pulses[d] are emitted; minute pulses are prolonged.
RCH[e]	Tashkent, U.S.S.R.; lat. 41°19′ N, long. 69°15′ E			Between minutes 15 and 20, 25 and 30, 35 and 40, 45 and 50 for the times:	Second pulses occur; minute pulses are prolonged.

			2 500	0^h to 4^h and 11^h to 24^h in winter; 0^h to 2^h and 16^h to 24^h in summer[g]	
			5 000	5^h30^m to 10^h30^m in winter and 2^h30^m to 15^h30^m in summer[g]	
RID[e]	Irkutsk, U.S.S.R.; lat. 52°46′ N, long. 103°39′ E			Between minutes 15 and 20, 25 and 30, 51 and 60 for the time:	Second pulses occur; minute pulses are prolonged; rhythmic signals[c] given between minutes 1 and 6 at 0^h, 2^h, 4^h, etc.; second pulses are also transmitted between minutes 5 and 10 at 1^h, 3^h, 5^h, etc.
			5 004	0^h to 1^h30^m and 11^h40^m to 24^h in winter; 0^h to 1^h and 18^h to 24^h in summer[g]	
			10 004	1^h40^m to 11^h10^m in winter and 1^h40^m to 17^h in summer[g]	
RIM[e]	Tashkent, U.S.S.R.; lat. 41°19′ N, long. 69°15′ E			Between minutes 15 and 20, 25 and 30, 35 and 40, 45 and 50 for the times:	Second pulses occur; minute pulses are prolonged.
			5 000	0^h to 4^h and 14^h to 24^h in winter; 0^h to 2^h and 16^h to 24^h in summer[g]	
			10 000	5^h30^m to 9^h30^m and 10^h to 13^h30^m in winter; 2^h30^m to 15^h30^m in summer[g]	
RKM[e]	Irkutsk, U.S.S.R.; lat. 52°46′ N, long. 103°39′ E			Between minutes 15 and 20, 25 and 30, 51 and 60 for the times:	Second pulses occur; minute pulses are prolonged; rhythmic signals[c] between minutes 1 and 6 at 0^h, 2^h, 4^h, etc.; second pulses are also transmitted between minutes 5 and 10 at 1^h, 3^h, 5^h, etc.
			10 004	0^h to 1^h10^m and 11^h40^m to 24^h in winter; 0^h to 1^h10^m and 18^h to 24^h in summer[g]	
			15 004	1^h40^m to 11^h10^m in winter and 1^h40^m to 17^h in summer[g]	
RTA[e]	Novosibirsk, U.S.S.R.; lat. 55°4′ N, long. 82°58′ E			Between minutes 5 and 10, 15 and 20, 25 and 29, 35 and 39 for the times:	Second pulses occur; minute pulses are prolonged.

Table D3—Foreign radio station time signals—concluded.

Station	Location	Radiated Power (kW)	Frequency (kHz)	Times of Transmissions (UT)	Time Signals
			4 996	0^h to 1^h30^m and 18^h to 24^h in winter[g]	
			9 996	3^h to 5^h and 14^h to 17^h30^m in winter; 0^h to 2^h and 16^h to 24^h in summer[g]	
			14 996	5^h30^m to 13^h30^m in winter and 3^h to 15^h30^m in summer[g]	
RWM[e]	Moscow, U.S.S.R.; lat. 55°19′ N, long. 38°41′ E	20		Between minutes 30 and 35, 41 and 45, 50 and 60 for the times:	Second pulses occur; minute pulses are prolonged. Rhythmic signals[c] occur between minutes 1 and 6 at 1^h, 3^h, 5^h, etc.
			10 000	0^h to 4^h20^m and 13^h50^m to 24^h in winter; 0^h to 2^h20^m and 13^h50^m to 24^h in summer[g]	
			15 000	4^h50^m to 13^h20^m in winter and 2^h50^m to 15^h20^m in summer[g]	
RTZ[e]	Irkutsk, U.S.S.R.; lat. 52°18′ N, long. 104°18′ E		50	Between minutes 0 and 5 of every hour except 20^h	A1-type second pulses[d] occur; minute pulses are prolonged.
VNG	Lyndhurst, Victoria, Australia; lat. 38°3′ S, long. 145°16′ E	10 (carrier)	4 500	9^h45^m to 21^h30^m	A2-type second pulses[f] are 50 cycles of a 1-kHz modulation. 5 cycles only for seconds 55 to 58; second marker 59 is omitted; for minutes 5, 10, 15, etc., 5 cycles for seconds 50 to 58; identification is made by voice announcement during minutes 15, 30, 45, and 60. DUT1 code is given by 45 cycles of 900-Hz modulation immediately following the normal second markers.
			7 500	Continuous except 22^h30^m to 22^h45^m	
			12 000	21^h45^m to 9^h30^m	

XSG[a,b]	People's Republic of China		458 6 414.5 8 502 12 871.5	$3^h, 9^h$	ONOGO code[h] is given, then rhythmic time signals[c] are emitted.
ZUO[e]	Olifantsfontein, South Africa; lat. 25°58′ S, long. 28°14′ E	4	5 000	Continuous	Pulses of 5 cycles of 1-kHz modulation; second 0 is prolonged.

[a]Recent information not available.

[b]No DUT1 code information is available.

[c]The rhythmic signals are of the Rhythmic (Coincidence) System, a time code that was adopted by the International Time Commission in 1925. It consists of 306 signals transmitted in the space of 300 s. The minute markers are short dashes of 0.4-s duration. Between the dashes, 60 dots of 0.1 s are transmitted. Each minute is therefore divided into 61 intervals. This vernier arrangement permits coincidence to be obtained between the local clock and the received signal.

[d]"A1-type second pulses" refers to modulation of telegraphic type of pulses.

[e]DUT1 code transmission information is given in Appendix C.

[f]"A2-type second pulses" refers to pulses of modulated carrier.

[g]Winter dates are Sept. 1 to Mar. 31; summer dates are Apr. 1 to Aug. 31.

[h]The International (ONOGO) System was adopted at the Conference International de l'Heure in 1912 and amended by the International Time Commission in 1925. It is known as the ONOGO system because these letters are transmitted in Morse code during minutes 57 to 60. In the amended ONOGO code, Morse code letter O (three dashes) is replaced by six dots.

DATA FROM THE BIH ANNUAL REPORT 1971

The carriers of the following time signals are standard frequencies.

Station	Accuracy of the carrier's frequency in 10^{-10}	Station	Accuracy of the carrier's frequency in 10^{-10}
CHU	0.2	MSF (HF)	1
DCF77	0.02	NBA (VLF)	0.5
FFH	2	NSS (VLF)	0.5
GBR	0.2	OMA (all frequencies)	0.5
HBG	0.02	VNG	1
IAM	0.5	WWV	0.1
IBF	0.5	WWVB	0.1
JJY	0.5	WWVH	0.1
LOL1	0.2	ZUO	0.5
MSF (60 kHz)	0.2		

Addresses of the authorities responsible for the time-signal emissions—

Signal	*Authority*
BPV, XSG	ZI-KA-WEI Section Shanghai Observatory Academia Sinica Shanghai, People's Republic of China
BSF	Telecommunication Laboratories Ministry of Communications Chung-Li P.O. Box 71 Taiwan, Republic of China
CHU	National Research Council, Time and Frequency Section Physics Division (M-36) Ottawa K1A OS1, Ontario, Canada Attn: Dr. C. C. Costain
DAM, DAN, DAO	Deutsches Hydrographisches Institut 2 Hamburg 4, Federal Republic of Germany
DCF77	Physikalisch-Technische Bundesanstalt, Laboratorium 1.22 33 Braunschweig Bundesallee 100, Federal Republic of Germany
DGI, DIZ	Central Institute of Physics of the Earth Department Geodesy and Gravimetry Time Service DDR 15 Potsdam Telegraphenberg A 17

FFH	Centre National d'Etudes des Télécommunications Groupement Etudes Spatiales et Transmissions Département Dispositifs et Ensembles Fonctionnels 38, Rue du Général Leclerc 92-Issy-les-Moulineaux, France
FTA91, FTH42, FTK77, FTN87	Observatoire de Paris, Service de l'Heure 61, Avenue de l'Observatoire Paris 14ème, France
GBR, MSF	National Physical Laboratory, Electrical Science Division Teddington, Middlesex, United Kingdom
HBG	Service Horaire HBG Observatoire Cantonal CH 2000 Neuchâtel, Switzerland
IAM	Istituto Superiore Poste e Telecommunicazioni Viale di Trastevere, 189 00100 Rome, Italy
IBF	Istituto Elettrotecnico Nazionale Galileo Ferraris Corso Massimo d'Azeglio, 42 10125 Torino, Italy
JJY, JG2AE, JG2AS	Frequency Standard Division The Radio Research Laboratories Ministry of Posts and Telecommunications Midori-cho, Koganei, Tokyo 184, Japan
LOL	Director Observatorio Naval Av. Costanera Sur, Jovellanos Buenos Aires, Argentina
LQB9, LQC20	Servicio Internacional de la Hora Gral. Savio 865 Villa Maipú San Martin, Pcia. de Buenos Aires, Argentina
NBA, NDT, NPG, NPM, NPN, NSS, NWC	Superintendent U.S. Naval Observatory Washington, D.C. 20390
OLB5, OMA	Time information: Astronomiský ústav CSAV, Budečska 6, Praha 2 Vinohrady, Czechoslovakia Standard frequency information: Ustav radiotechniky a elektroniky CSAV, Lumumbova 1 Praha 8, Kobylisy, Czechoslovakia
PPE, PPR	Time Service Observatório Nacional Rua General Bruce, 586 2000-Rio de Janeiro. GB.ZÇ-08, Brazil

RAT, RBU, RCH, RID, RIM, RKM, RTA, RWM	Comité d'Etat des Normes Conseil des Ministres de l'U.R.S.S. Moscow, U.S.S.R., Leninski prosp., 9
VNG	Time and Frequency Standards Section APO Research Laboratories 59 Little Collins Street Melbourne, VIC. 3000, Australia
WWV, WWVB, WWVH	Frequency-Time Broadcast Services Section Time and Frequency Division National Bureau of Standards Boulder, Colorado 80302
ZUO	National Physical Research Laboratory P.O. Box 395 Pretoria, South Africa

Appendix E

COORDINATED TIME-STEP ADJUSTMENTS MADE ON JANUARY 1, 1972[8]

Table E1 gives the time differences between the old UTC system and various timekeeping laboratories before and after the time-step adjustments and the change to the new UTC system. Most of the laboratories improved the coordination of their UTC(i) with UTC on January 1, 1972. Table E2 gives the time steps really applied, instead of - 107 757.7 μs.[9]

Table E1—Time differences between UTC and UTC(i).

UTC(i)	Location	UTC - UTC(i) (μs)				
		Dec. 14, 1971 (y = 299.5)[a]	Dec. 24, 1971 (y = 309.5)[a]	Jan. 1, 1972 (y = 317.5)[a]		Jan. 3, 1972 (y = 319.5)[a]
				Before	After	
TUA(PTB)[b]	Braunschweig	-180.9	-180.8	-180.8	2.2	2.2
UTC(USNO)	Washington	148.5	148.9	148.9	-9.1	-9.1
UTC(OP)	Paris	12.8	13.1	13.3	.0	.0
UTC(NBS)	Boulder	152.5	152.8	153.2	-4.7	-4.7
UTC(RGO)	Herstmonceux	172.9	172.9	173.1	-2.2	-2.1
UTA(NRC)[c]	Ottawa	314.3	315.2	315.8	-2.3	-2.1
UTC(FOA)[d]	Stockholm	87.0	85.1		-11.4	-11.5
UTC(DHI)	Hamburg	-10.5	-11.3	-11.9	-12.2	-12.3
UTC(ON)	Neuchâtel	14.7	14.4	14.3	14.0	14.0

[a]Julian day number = 2 441 000 + y.
[b]UTC(PTB) replaced TUA(PTB) on Jan. 1, 1972.
[c]UTC(NRC) replaced UTA(NRC) on Jan. 1, 1972.
[d]Dec. 4, UTA - UTC(FOA) = +88.7.

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[8]From BIH Circulars D63, February 4, 1972, and D65, April 5, 1972.

[9]The time step of −107 757.7 μs is calculated on the basis of the old UTC scale; i.e., with the offset frequency of -300×10^{-10}. In terms of the new UTC scale, this time-step change should be −107 758 μs (because the 10-s difference is calculated with the frequency offset; i.e., $10(-300 \times 10^{-10}) = -0.3$ μs.). The time difference in Table E1 after January 1, 1972, is in terms of the new UTC scale.

Table E2–Actual time steps applied to various UTC(i).

i	Laboratory	Time Step (μs)
APO	Postmaster-General's Department (Australian Post Office), Melbourne, Australia	−107 580.0
DHI	Deutsches Hydrographisches Institut, Hamburg, Federal Republic of Germany	−107 757.7
FOA	Research Institute of National Defence, Stockholm, Sweden	−107 662.0
IEN	Istituto Elettrotecnico Nazionale, Torino, Italy	−107 695.0
NBS	National Bureau of Standards, Boulder, Colo.	[a]−107 600.0
NRC	National Research Council of Canada, Ottawa, Canada	[b]−107 440.0
ON	Observatoire de Neuchâtel, Neuchâtel, Switzerland	−107 757.7
OP	Observatoire de Paris, Paris, France	[a]−107 744.7
PTB	Physikalisch-Technische Bundesanstalt, Braunschweig, Federal Republic of Germany	[a, c]−107 941.0
RGO	Royal Greenwich Observatory, Herstmonceux, United Kingdom	−107 582.7
ROJ	Republic Observatory, Johannesburg, South Africa	−107 884.0
RRL	Radio Research Laboratories, Tokyo, Japan	−107 620.0
TAO	Tokyo Astronomical Observatory, Tokyo, Japan	−107 757.7
TCL	Telecommunication Laboratories, Taiwan, Republic of China	−107 650.0
USNO	U.S. Naval Observatory, Washington, D.C.	[a]−107 600.0
ZIPE	Zentralinstitut Physik der Erde, Potsdam, Democratic Republic of Germany	−107 790.0

[a]These UTC(i) are steered to maintain an approximate synchronism. UTC(NBS) and UTC(USNO) are synchronized to ±5 μs; UTC(OP) and UTC(PTB) are maintained close to UTC.

[b]Step is with respect to UTA(NRC), which was replaced by UTC(NRC).

[c]Step is with respect to TUA(PTB), which was replaced by UTC(PTB).

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