RECOMMENDATION ITU-R TF.768-4

Standard frequencies and time signals

(Question ITU-R 106/7)

(1992-1994-1995-1997-2001)

The ITU Radiocommunication Assembly,

considering

a) the continuing need in all parts of the world for readily available standard frequency and time reference signals that are internationally coordinated;

b) the advantages offered by radio broadcasts of standard time and frequency signals in terms of wide coverage, ease and reliability of reception, achievable level of accuracy as received, and the wide availability of relatively inexpensive receiving equipment;

c) that Article 26 of the Radio Regulations (RR) is considering the coordination of the establishment and operation of services of standard-frequency and time-signal dissemination on a worldwide basis;

d) that a number of stations are now regularly emitting standard frequencies and time signals in the bands allocated by the World Administrative Radio Conference (Geneva, 1979) (WARC-79) and that additional stations provide similar services using other frequency bands;

e) that these services operate in accordance with Recommendation ITU-R TF.460 which establishes the internationally coordinated UTC time system;

f) that other broadcasts exist which, although designed primarily for other functions such as navigation or communications, emit highly stabilized carrier frequencies and/or precise time signals that can be very useful in time and frequency applications,

recommends

1 that, for applications requiring stable and accurate time and frequency reference signals that are traceable to the internationally coordinated UTC system, serious consideration be given to the use of one or more of the broadcast services listed and described in Annex 1;

2 that administrations responsible for the various broadcast services included in Annex 2 make every effort to update the information given whenever changes occur. (Administrations are also requested to send such information to the Bureau international des poids et mesures (BIPM).)

ANNEX 1

Characteristics of standard-frequency and time-signal emissions in allocated bands and characteristics of stations emitting with regular schedules with stabilized frequencies, outside of allocated bands

1 The characteristics of stations are contained in Tables 1, 2 and 3. For information concerning changes which may have occurred since the date when this Recommendation was approved, reference may be made to the Annual Report of the time section of the BIPM or directly to the respective authority for each service as listed in Annex 2.

TABLE 1

Characteristics of standard-frequency and time-signal emissions in the allocated bands

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})(1)**	**Method of DUT1 indication**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (MHz)**	**Modulation (Hz)**	**Time signal (min)**	**Audio-modulation (min)**		
ATA	New Delhi, India	28° 34′ N 77° 19′ E	Horizontal folded dipole	8 (PEP)	3	7	24(2)	5, 10, 15	1, 1 000	Continuous	4/15	± 10	
BPM(3)	Pucheng, China	35° 00′ N 109° 31′ E	Omni-directional	10-20	2	7	24(4)	2.5, 5, 10, 15	1, 1 000	20/30 (UTC) 4/30 (UT1)	Nil	± 10	Direct emission of UT1 time signal
HLA	Taejon, Taedok Science Town, Republic of Korea	36° 23′ N 127° 22′ E	Vertical (conical monopole)	2	1	5(5)	7(6)	5	1	Continuous	Continuous	± 10	ITU-R code by double pulse
IAM(7)	Rome, Italy	41° 47′ N 12° 27′ E	Vertical $\lambda/4$	1	1	6	2	5	1	Continuous	Nil	± 10	ITU-R code by double pulse
JJY(7)	Sanwa, Sashima, Ibaraki, Japan	36° 11′ N 139° 51′ E	(8)	2	3	7	24(9)	5, 8, 10	1(10), 1 000(11)	Continuous	30/60	± 10	ITU-R code by lengthening
LOL(7)	Buenos Aires, Argentina	34° 37′ N 58° 21′ E	Horizontal 3-wire folded dipole	2	3	7	5	5, 10, 15	1, 440, 1 000	Continuous	3/5	± 20	ITU-R code by lengthening
OMA(7)	Prague, Czech Republic	50° 07′ N 14° 35′ E	T	1	1	7	24	2.5	1, 1 000(12)	15/30	4/15	± 1 000	

TABLE 1 (*end*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})(1)**	**Method of DUT1 indication**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (MHz)**	**Modulation (Hz)**	**Time signal (min)**	**Audio-modulation (min)**		
ULA-4(7)	Tashkent	41° 19′ N 69° 15′ E	Horizontal dipole	1	2	7	23	2.5, 5, 10	1, 10	40/60	Nil	± 50	ITU-R code by double pulse, additional information dUT1(13)
RID(7)	Irkutsk	52° 32′ N 103° 52′ E	Horizontal dipole	1 1 1	3	7	24	5.004, 10.004, 15.004	1, 10	40/60	Nil	± 10	ITU-R code by double pulse, additional information dUT1(13)
RWM(7)	Moscow	55° 44′ N 38° 12′ E	Horizontal dipole	5 5 8	3	7	24	4.996, 9.996, 14.996	1, 10	40/60	Nil	± 10	ITU-R code by double pulse, additional information dUT1(13)
VNG	Llandilo, New South Wales, Australia	33° 43′ S 150° 48′ E	Omni-directional	10 1	2	7	24	5, 2.5	1, 1 000(14)	Continuous	Nil	± 100	ITU-R code by 45 cycles of 900 Hz immediately following the normal second markers
WWV(7)	Fort Collins, Colorado, United States	40° 41′ N 105° 02′ W	Vertical λ/2 dipoles	2.5-10	5	7	24	2.5, 5, 10, 15, 20(15)	1, 440, 500, 600	Continuous(16)	Continuous(17)	± 10	ITU-R code by double pulse, additional information on UT1 corrections
WWVH(7)	Kekaha, Kauai, Hawaii, United States	21° 59′ N 159° 46′ W	Vertical λ/2 dipole arrays	2.5-10	4	7	24	2.5, 5, 10, 15(15)	1, 440, 500, 600	Continuous(16)	Continuous(17)	± 10	ITU-R code by double pulse, additional information on UT1 corrections

Notes to Table 1:

The daily transmission schedule and hourly modulation schedule is given, where appropriate, in the form of Figs. 1 and 2 supplemented by the following Notes:

(1) This value applies at the transmitter; to realize the quoted uncertainty at the point of reception it could be necessary to observe the received phase time frequency over a sufficiently long period in order to eliminate noise and random effects.

(2) 5 MHz: 1800-0900 h UTC; 10 MHz: 24 h; 15 MHz: 0900-1800 h UTC.

(3) Call sign in Morse and language.

(4) 2.5 MHz: 0730-0100 h UTC; 15 MHz: 0100-0900 h UTC; 5 MHz and 10 MHz: continuous.

(5) Monday to Friday (except national holidays in Korea).

(6) 0100 to 0800 h UTC. Pulses of 9 cycles of 1 800 Hz modulation. 59th and 29th second pulses omitted. Hour identified by 0.8 s long 1 500 Hz tone. Beginning of each minute, identified by a 0.8 s long 1 800 Hz tone, voice announcement of hours and minutes each minute following 52nd second pulse. BCD time code given on 100 Hz sub-carrier.

(7) These stations have indicated that they follow the UTC system as specified in Recommendation ITU-R TF.460. Since 1 January 1972 the frequency offset has been eliminated and the time signals remain within about 0.8 s of UT1 by means of occasional 1 s steps as directed by the International Earth Rotation Service.

(8) Horizontal $\lambda/2$ dipole for 5 and 8 MHz, and vertical $\lambda/2$ dipoles for 10 MHz.

(9) Interrupted from 35 to 39 minutes of each hour.

(10) Pulse consists of 8 cycles of 1 600 Hz tone. First pulse of each minute preceded by 655 ms of 600 Hz tone.

(11) 1 000 Hz tone modulation between the minutes of 0-5, 10-15, 20-25, 30-35, 40-45, 50-55 except 40 ms before and after each second's pulse.

(12) In the period from 1800-0600 h UTC, audio-frequency modulation is replaced by time signals.

(13) The additional information about the value of the difference UT1 – UTC is transmitted by code dUT1. It provides more precisely the difference UT1 – UTC in multiples of 0.02 s. The total value of the correction is DUT1 + dUT1. Possible values of dUT1 are transmitted by marking of p second pulses between the 21st and 24th seconds of the minute, so that $\text{dUT1} = +\,0.02\ \text{s} \times p$. Negative values of dUT1 are transmitted by marking of q second pulses between the 31st and 34th second of the minute, so that $\text{dUT1} = -\,0.02\ \text{s} \times q$.

(14) Pulses of 50 cycles of 1 000 Hz tone, shortened to 5 cycles from the 55th to the 58th second; the 59th pulse is omitted; the minute marker is 500 cycles. At the 5th, 10th, 15th, etc. minutes, pulses from the 50th to the 58th second are shortened to 5 cycles. Voice identification on 5 000 kHz between the 20th and 50th seconds in the 15th, 30th, 45th and 60th minutes. A BCD time incorporating time of day and day number of the year is transmitted between the 20th and 46th second with a binary “0” represented by 100 cycles and a binary “1” by 200 cycles of 1 000 Hz tone. The minute information for the next minute is given from the 21st to the 28th second, hour information from the 29th to the 35th second and day of the year from the 36th to the 46th second; parity bits are included at the end of each code sequence.

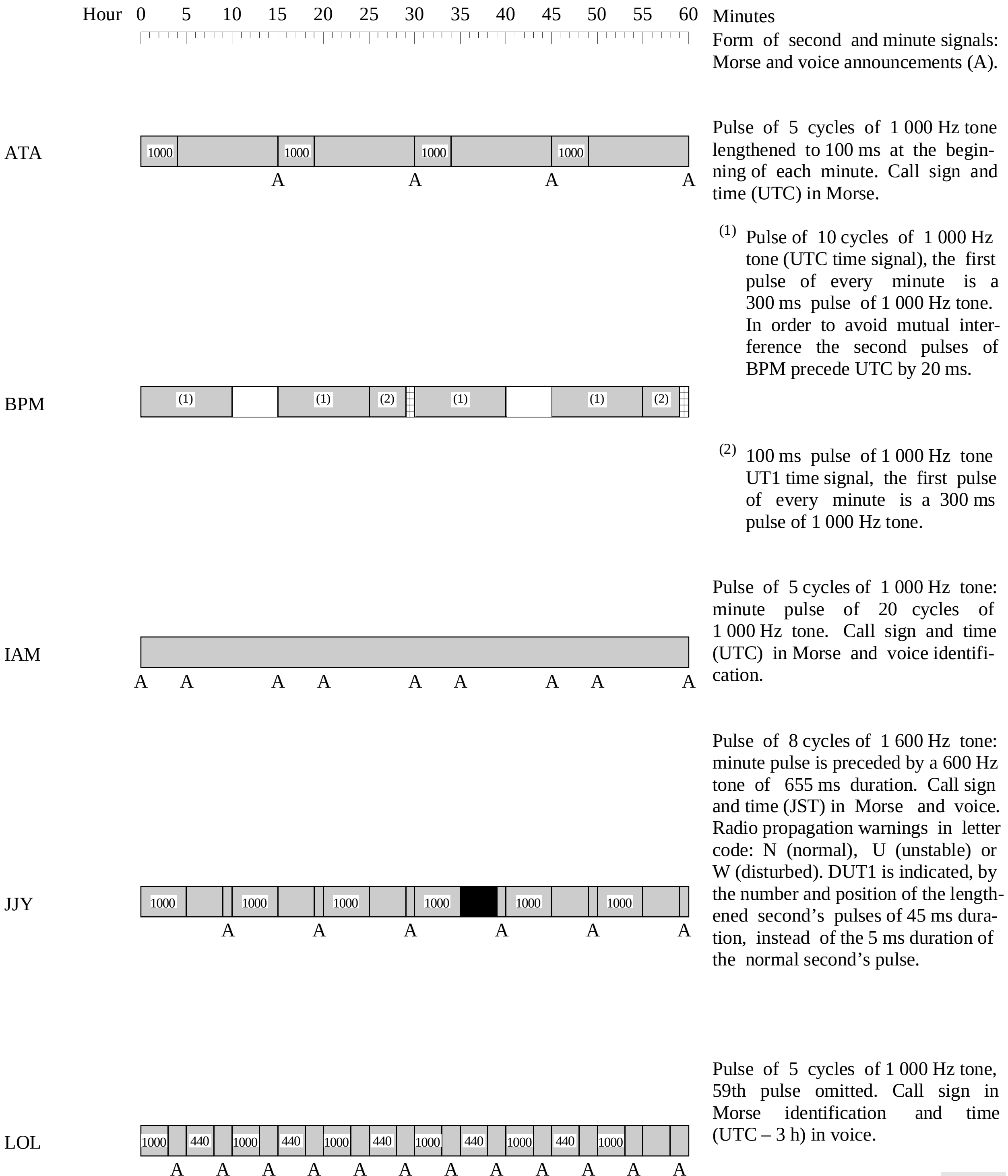
(15) As of 1 February 1977 transmissions on 25 MHz from WWV and 20 MHz from WWVH were discontinued, but may be resumed at a later date.

(16) In addition to other timing signals and time announcements, a modified IRIG-H time code is produced at a 1-pps rate and radiated continuously on a 100 Hz sub-carrier on all frequencies. A complete code frame is 1 min. The 100 Hz sub-carrier is synchronous with the code pulses, so that 10 ms resolution is obtained. The code contains DUT1 values; UTC time expressed in year, day of year, hour and minute; and status indicators relating to impending leap seconds and Daylight Saving Time.

(17) Except for voice announcement periods and the 5 min semi-silent period each hour.

FIGURE 1

Hourly modulation schedule



Form of second and minute signals: Morse and voice announcements (A).

Pulse of 5 cycles of 1 000 Hz tone lengthened to 100 ms at the beginning of each minute. Call sign and time (UTC) in Morse.

(1) Pulse of 10 cycles of 1 000 Hz tone (UTC time signal), the first pulse of every minute is a 300 ms pulse of 1 000 Hz tone. In order to avoid mutual interference the second pulses of BPM precede UTC by 20 ms.

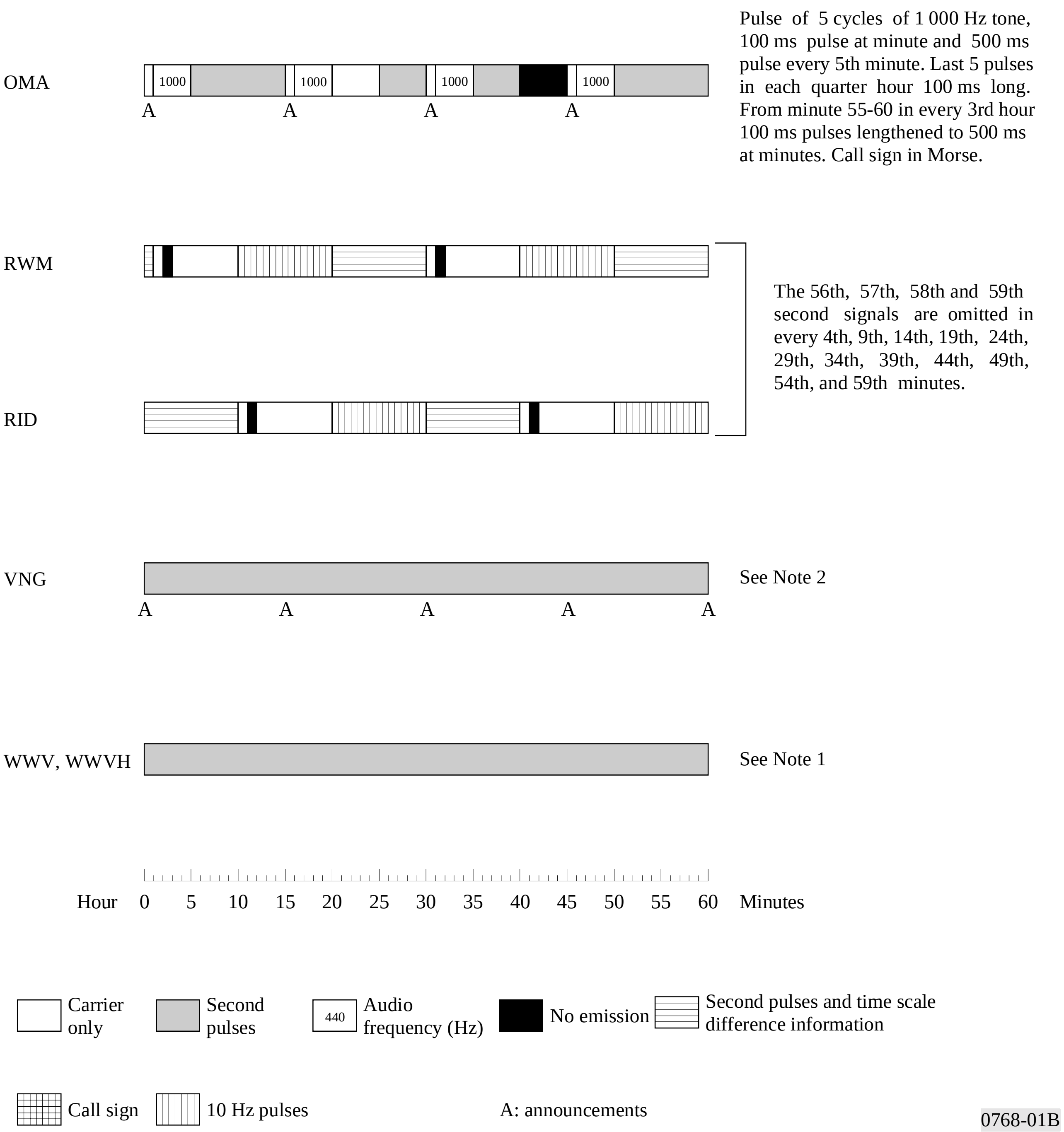
(2) 100 ms pulse of 1 000 Hz tone UT1 time signal, the first pulse of every minute is a 300 ms pulse of 1 000 Hz tone.

Pulse of 5 cycles of 1 000 Hz tone: minute pulse of 20 cycles of 1 000 Hz tone. Call sign and time (UTC) in Morse and voice identification.

Pulse of 8 cycles of 1 600 Hz tone: minute pulse is preceded by a 600 Hz tone of 655 ms duration. Call sign and time (JST) in Morse and voice. Radio propagation warnings in letter code: N (normal), U (unstable) or W (disturbed). DUT1 is indicated, by the number and position of the lengthened second's pulses of 45 ms duration, instead of the 5 ms duration of the normal second's pulse.

Pulse of 5 cycles of 1 000 Hz tone, 59th pulse omitted. Call sign in Morse identification and time (UTC – 3 h) in voice.

FIGURE 1 (*continued*)



Pulse of 5 cycles of 1 000 Hz tone, 100 ms pulse at minute and 500 ms pulse every 5th minute. Last 5 pulses in each quarter hour 100 ms long. From minute 55-60 in every 3rd hour 100 ms pulses lengthened to 500 ms at minutes. Call sign in Morse.

The 56th, 57th, 58th and 59th second signals are omitted in every 4th, 9th, 14th, 19th, 24th, 29th, 34th, 39th, 44th, 49th, 54th, and 59th minutes.

See Note 2

See Note 1

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Notes to Fig. 1:

Note 1 – Pulse of 5 cycles of 1 000 Hz (WWV) or 6 cycles of 1 200 Hz (WWVH) tone, lengthened to 0.8 s at the beginning of each minute. An 0.8 s pulse of 1 500 Hz begins each hour at both stations. 29th and 59th pulses each minute are omitted. Voice time announcements preceding each minute. 45-second audio tones alternating between 500 and 600 Hz each minute, except when special announcements or station identification messages are given in voice. One 45-second segment of 440 Hz is included each hour at 1 minute (WWVH) or 2 minutes (WWV) past the hour. A modified IRIG-H time code, giving the year, day of year, hour, minute, DUT1 value, and information on impending leap seconds and Daylight Saving Time, is broadcast continuously on a 100 Hz sub-carrier. DUT1 information is provided by the number and position of doubled second pulses each minute. All modulations interrupted for 40 ms around each second's pulse.

Note 2 – Voice station identification is provided on the 2 500 kHz, 5 000 kHz and 16 000 kHz frequencies during 15, 30, 45 and 60 minutes without interruption to the time signals. Voice announcement is notched to allow seconds markers to continue, and has the 1 000 Hz components removed.

Morse identification is provided on 8 638 kHz and 12 984 kHz frequencies during the 15, 30, 45 and 60 minutes without interruption to the time signals. VNG is transmitted in slow Morse at a frequency of approximately 400 Hz up to six times per minute. Broken idents may occur at the beginning and end of the minute.

Seconds markers are normally 50 ms of 1 000 Hz, second markers 55 to 58 are 5 ms of 1 000 Hz, second marker 59 is omitted. Minute marker is 500 ms of 1 000 Hz, during 5, 10, 15…etc. minutes, seconds markers 50 to 58 are 5 ms of 1 000 Hz.

DUT1 transmission is from 1 to 16 seconds after the minute. During this time, normal seconds markers are emphasized by 50 ms of 900 Hz tone. Tone immediately follows.

Seconds marker at 20 seconds, has 200 ms duration and designates start of the time code information. BCD time code giving year, hour and minute at the next minute, is given between seconds 20 and 46.

TABLE 2

Characteristics of standard-frequency and time-signal emissions in additional bands

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})(1)**	**Method of DUT1 indication**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Modulation (Hz)**	**Time signal (min)**	**Audio-modulation (min)**		
	Allouis, France	47° 10′ N 02° 12′ E	Omni-directional	1 000 to 2 000	1	7	24	162	1(2)	Continuous	A3E broadcast continuously	± 2	No DUT1 transmission
CHU(3)	Ottawa, Canada	45° 18′ N 75° 45′ W	Omni-directional	3, 10, 3	3	7	24	3 330, 7 335, 14 670	1(4)	Continuous	Nil	± 5	ITU-R code by split pulses
	Donebach, F.R. of Germany	49° 34′ N 09° 11′ E	Omni-directional	250	1	7	24	153	Nil	Nil	A3E broadcast continuously	± 2	
DCF77(3)	Mainflingen, F.R. of Germany	50° 01′ N 09° 00′ E	Omni-directional	30(5)	1	7	24	77.5	1	Continuous(6)	Continuous(7)	± 0.5	No DUT1 transmission
	Droitwich, United Kingdom	52° 16′ N 02° 09′ W	T	400	1	7	22	198(8)	Nil	Nil	A3E broadcast continuously	± 20	
	Westerglen, United Kingdom	55° 58′ N 03° 50′ W	T	50	1	7	22	198(8)	Nil	Nil	A3E broadcast continuously	± 20	
	Burghead, United Kingdom	57° 42′ N 03° 28′ W	T	50	1	7	22	198(8)	Nil	Nil	A3E broadcast continuously	± 20	
HBG(9)	Prangins, Switzerland	46° 24′ N 06° 15′ E	Omni-directional	20	1	7	24	75	1(10)	Continuous	Nil	± 1	No DUT1 transmission

TABLE 2 (*continued*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})(1)**	**Method of DUT1 indication**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Modulation (Hz)**	**Time signal (min)**	**Audio-modulation (min)**		
JJY	Fukushima, Japan	37° 22′ N 140° 51′ E	Omni-directional	10	1	7	24	40	1	Continuous	Nil	± 1	No DUTI transmission
MSF	Rugby, United Kingdom	52° 22′ N 01° 11′ W	Omni-directional	25(5)	1	7	24(11)	60	1(12)	Continuous	Nil	± 2	ITU-R code by double pulse
	Milano, Italy	45° 20′ N 09° 12′ E	Omni-directional	600	1	7	24	900	Nil	Nil	A3E broadcast continuously	± 2	
NAA (3) (13) (14)	Cutler, Maine, United States	44° 39′ N 67° 17′ W	Omni-directional	1 000(5)	1	7	24(15)	24.0(16)	Nil	Nil	Nil	± 10	
NAU (3) (13) (14)	Aguada, Puerto Rico	18° 23′ N 67° 11′ W	Omni-directional	100(17)	1	7	24	28.5	Nil	Nil	Nil	± 10	
NTD (3) (13) (14)	Yosami, Japan	34° 58′ N 137° 01′ E	Omni-directional	50(5)	1	7	24(18)	17.4	Nil	Nil	Nil	± 10	
NLK (3) (13) (14)	Jim Creek, Washington, United States	48° 12′ N 121° 55′ W	Omni-directional	125(5)	1	7	24(19)	24.8	Nil	Nil	Nil	± 10	
NPM (3) (13) (14)	Lualualei, Hawaii, United States	21° 25′ N 158° 09′ W	Omni-directional	600(5)	1	7	24(20)	23.4	Nil	Nil	Nil	± 10	
NSS (3) (13) (14)	Annapolis, Maryland, United States	38° 59′ N 76° 27′ W	Omni-directional	400(5)	1	7	24(21)	21.4	Nil	Nil	Nil	± 10	
NWC (3) (13) (14)	Exmouth, Australia	21° 49′ S 114° 10′ E	Omni-directional	1 000(5)	1	7	24(22)	22.3	Nil	Nil	Nil	± 10	

TABLE 2 (*continued*)

Station			Type of antenna(s)	Carrier power (kW)	Number of simulta-neous trans-missions	Period of operation		Standard frequencies used		Duration of emission		Uncertainty of frequency and time intervals (parts in 10^{12})(1)	Method of DUT1 indication
Call sign	Approximate location	Latitude Longitude				Days/ week	Hours/ day	Carrier (kHz)	Modu-lation (Hz)	Time signal (min)	Audio-modulation (min)		
OMA	Podebrady, Czech Republic	50° 08′ N 15° 08′ E	T	5	1	7	24	50	1(23)	23 hours per day (24)	Nil	± 1 000	No DUT1 transmission
RAB-99	Khabarovsk	48° 30′ N 134° 50′ E	Omni-directional	300	1	7	2	25.0, 25.1, 25.5, 23.0, 20.5	1/60, 1/10, 1, 10, 40(25)	40 min 2 times per day(26)	Nil	± 5	
RBU(3)	Moskva	55° 44′ N 38° 12′ E	Omni-directional	10	1	7	24	$66^{2/3}$	10, 100, 312.5	Continuous DXXXW(27)	Continuous(28)	± 5	ITU-R code by double pulse(29)
RJH-63	Krasnodar	44° 46′ N 39° 34′ E	Omni-directional	300	1	7	2	25.5, 25.1, 25.0, 23.0, 20.5	1/60, 1/10, 1, 10, 40(25)(25a)	34 min twice per day(30)	Nil	± 5	
RJH-69	Molodechno	54° 28′ N 26° 47′ E	Omni-directional	300	1	7	2	25.5, 25.1, 25.0, 23.0, 20.5	1/60, 1/10, 1, 10, 40(25)	40 min twice per day(31)	Nil	± 5	
RJH-77	Arkhangelsk	64° 22′ N 41° 35′ E	Omni-directional	300	1	7	2	25.5, 25.1, 25.0, 23.0, 20.5	1/60, 1/10, 1, 10, 40(25)	40 min twice per day(32)	Nil	± 5	

TABLE 2 (*end*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})(1)**	**Method of DUT1 indication**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Modulation (Hz)**	**Time signal (min)**	**Audio-modulation (min)**		
RJH-86	Beshkeck	43° 03′ N 73° 37′ E	Omni-directional	300	1	7	2	25.5, 25.1, 25.0, 23.0, 20.5	1/60, 1/10, 1, 10, 40 (25)	40 min twice per day(33)	Nil	± 5	
RJH-90	Nizhni Novgorod	56° 11′ N 43° 57′ E	Omni-directional	300	1	7	2	25.0, 25.1, 25.5, 23.0, 20.5	1/60, 1/10, 1, 10, 40(25)	40 min twice per day(34)	Nil	± 5	
RTZ(3)	Irkutsk	52° 26′ N 103° 41′ E	Omni-directional	10	1	7	23	50	1, 10	6/60	Nil	± 5	ITU-R code by double pulse(29)
RW-166	Irkutsk	52° 26′ N 103° 18′ E	Omni-directional	40	1	7	23	198		Nil	A3E broadcast continuously	± 5	
SAJ	Stockholm, Sweden	59° 15′ N 18° 06′ E	Omni-directional	0.02 (e.r.p.)	1	3(35)	2(36)	150 000	Nil	10(37)		± 2	
VNG	Llandilo, New South Wales, Australia	33° 43′ S 150° 48′ E	Omni-directional	10 10 5	2-3	7	24(38)	8 638 12 984 16 000	1, 1 000(39)	Continuous	Nil	± 100	ITU-R code by 45 cycles of 900 Hz immediately following the normal second markers
WWVB(3)	Fort Collins, Colorado, United States	40° 40′ N 105° 03′ W	Top-loaded vertical	13(5)	1	7	24	60	1(40)	Continuous	Nil	± 10	No ITU-R code
EBC	San Fernando, Cadiz, Spain	36° 28′ N 06° 12′ W	Omni-directional	1	1	7	1	12 008 6 840	(41)	10	(42)	± 100	ITU-R code by double pulse

Notes to Table 2:

(1) This value applies at the transmitter; to realize the quoted uncertainty at the point of reception it could be necessary to observe the received phase time frequency over a sufficiently long period in order to eliminate noise and random effects.

(2) Phase modulation of the carrier by + 1 and – 1 radian in 0.1 s every second except the 59th second of each minute. This modulation is doubled to indicate binary 1. The numbers of the minute, hour, day of the month, day of the week, month and year are transmitted each minute from the 21st to the 58th second, in accordance with the French legal time scale. In addition, a binary 1 at the 17th second indicates that the local time is 2 h ahead of UTC (summer time), a binary 1 at the 18th second indicates when the local time is one hour ahead of UTC (winter time); a binary 1 at the 14th second indicates the current day is a public holiday (Christmas, 14 July, etc.), a binary 1 at the 13th second indicates that the current day is the eve of a public holiday.

(3) These stations have indicated that they follow one of the systems referred to in Recommendation ITU-R TF.460.

(4) Pulses of 300 cycles of 1 000 Hz tone: the first pulse in each minute is prolonged.

(5) Figures give the estimated radiated power.

(6) At the beginning of each second (except the 59th second) the carrier amplitude is reduced to 25% for a duration of 0.1 or 0.2 s corresponding to “binary 0” or “binary 1”, respectively. The number of the minute, hour, day of the month, day of the week, month and year are transmitted in BCD code from the 21st to the 58th second. The time signals are generated by the Physikalisch-Technische Bundesanstalt (PTB) and are in accordance with the legal time of the Federal Republic of Germany which is UTC (PTB) + 1 h (Central European Time CET) or UTC (PTB) + 2 h (Central European Summer Time CEST). In addition, CET and CEST are indicated by a “binary” 1 at the 18th or 17th second, respectively. To achieve a more accurate time transfer and a better use of the frequency spectrum available an additional pseudo-random phase shift keying of the carrier is superimposed on the AM second markers.

(7) Call sign is given by modulation of the carrier with 250 Hz tone three times every hour at the minutes 19, 39 and 59, without interruption of the time signal sequence.

(8) No coherence between carrier frequency and time signals.

(9) Coordinated universal time signals.

(10) At the beginning of each second (except the 59th second), the carrier is interrupted for a duration of 0.1 or 0.2 s corresponding to “binary 0” or “binary 1”, respectively, double pulse each minute. The number of the minute, hour, day of the month, day of the week, month and year are transmitted in BCD code from the 21st to the 58th second. The time signals are generated by the Swiss Federal Office of Metrology and in accordance with the legal time of Switzerland which is UTC (CH) + 1 h (Central European Time CET) or UTC (CH) + 2 h (Central European Summer Time CEST). In addition, CET and CEST are indicated by a “binary 1” at the 18th or 17th second, respectively.

(11) The transmission is interrupted during the maintenance period from 1000 to 1400 h UTC (on the first Tuesday of each month).

(12) Carrier interrupted for 100 ms at each second and 500 ms at each minute; fast time code, 100 bit/s, BCD NRZ emitted during min-interruption giving month, day-of-month, hour and minute. Slow time code, 1 bit/s, BCD PWM emitted from seconds 17 to 51 giving year, month, day-of-month, day-of-week, hour and minute together with 8-bit identifier from 52 seconds to 59. ITU-R DUT1 code by double pulse.

(13) MSK (minimum shift keying) in use: a phase-stable carrier can be recovered after suitable multiplication and mixing in the receiver. It will be recalled that the use of minimum shift keying means that no discrete component exists at the respective carrier frequencies which are given in the table. The MSK signal can be expressed as:

$$S(t) = \cos\left[2\pi\, f_c\, t + a_n\,(\pi\, t/2T) + \varphi_n\right]$$

where $a_n = i(-1)$ for mark (space) and $\varphi_n = 0, \pi$ (modulo 2π).

If the transmission is to be useful as a frequency reference it is necessary to recover a phase coherent carrier free from the $\pi/2$ increments introduced by the modulation. There are two approaches.

The MSK signal is considered as a continuous-phase frequency shift keying (CPFSK) with a modulation index of 0.5. Squaring the signal followed by band-pass filtering at centre frequency $2f_c$ produces a CPFSK signal with spectral components at $2f_c + 2f_b$ and $2f_c - 2f_b$, corresponding to mark and space, respectively. The components can be extracted by means of two phase-locked loops (PLL) and the reference carrier recovered by multiplication, division and filtering.

The other approach treats the MSK signal as a form of phase-shift keying (PSK), MSK being obtained by transformations from binary PSK (BPSK) or quadrature PSK (QPSK). The carrier recovery techniques available for PSK such as Costas-loop can thus be applied to MSK; such a demodulator has been realized in a single-chip form.

(14) This station is primarily for communication purposes; while these data are subject to change, the changes are announced in advance to interested users by the US Naval Observatory, Washington, DC, USA.

(15) From 1200 to 2000 h UTC each Sunday while NSS is off the air (until 15 July).

(16) As of 23 January 1984, until further notice.

(17) Became operational on 14 August 1984, 74 kW.

(18) 2300 to 0900 h UTC just first Thursday-Friday, 2300 to 0700 h UTC all other Thursday-Fridays. Half power 2200 to 0200 h UTC each Monday and Friday.

(19) Except from 1600 to 2400 h UTC each Thursday. During Daylight Saving Time 1500 to 2300 h UTC each Thursday.

(20) 2.5 MHz: 0000-1000 h UTC; 5 MHz: 0900-0100 h UTC; 10 MHz: continuous; 15 MHz: 0100-0900 h UTC.

(21) Off the air until 2100 h UTC on 15 July, except for 14 hours each Sunday to cover the period when NAA is off the air.

(22) From 0000 to 0800 h, usually each Monday.

(23) A1A telegraphy signals.

(24) From 1000 to 1100 h UTC, transmission without keying except for call-sign OMA at the beginning of each quarter-hour.

(25) Two types of signal are transmitted during a duty period:

a) A1A signals with carrier frequency 25 kHz, duration 0.0125; 0.025; 0.1; 1 and 10 s with repetition periods of 0.025; 0.1; 1; 10 and 60 s respectively;

b) N0N signals with carrier frequencies 25.0; 25.1; 25.5; 23.0; 20.5 kHz. The phases of these signals are matched with the time markers of the transmitted scale.

(26) From 0706 to 0747 h and 1306 to 1347 h UTC normal time.
From 0606 to 0647 h and 1206 to 1247 h UTC daylight time.

(27) The standard frequencies and time signals are DXXXW type emissions and are made up of carrier sine-wave oscillations with the frequency of $66^{2/3}$ kHz, which are interrupted for 5 ms every 100 ms; 10 ms after an interruption the carrier oscillations are narrow-band phase-modulated for 80 ms by sine-wave signals with sub-carriers of 100 or 312.5 Hz and a modulation index of 0.698. Amplitude-modulated signals with a repetition frequency of 10 Hz are used to transmit time markers. Signals with a sub-carrier of 312.5 Hz are used to indicate second and minute markers, and also “1’s” in the binary code for the transmission of time-scale information; signals with a frequency of 100 Hz are used to indicate “0’s” in the binary code.

(28) N0N signals may be transmitted in individual cases.

(29) The additional information about the value of the difference UT1 – UTC is transmitted by code dUT1. It provides more precisely the difference UT1 – UTC down to multiples of 0.02 s. The total value of the correction is DUT1 + dUT1. Possible values of dUT1 are transmitted by marking of *p* second pulses between the 21st and 24th seconds of the minute, so that dUT1 = + 0.02 s × *p*. Negative values of dUT1 are transmitted by marking of *q* second pulses between the 31st and 34th second of the minute, so that dUT1 = – 0.02 s × *q*.

(30) From 2106 to 2147 h and 1106 to 1147 h UTC normal time.
From 0206 to 0247 h and 0806 to 0847 h UTC daylight time.

(31) From 0206 to 0247 h, 0806 to 0847 h and 1406 to 1447 h UTC normal time.
From 0106 to 0147 h, 0706 to 0747 h and 1306 to 1347 h UTC daylight time.

(32) From 0406 to 0447 h, 1006 to 1047 h and 1606 to 1647 h UTC normal time.
From 0306 to 0347 h, 0906 to 0947 h and 1506 to 1547 h UTC daylight time.

(33) From 0506 to 0547 h and 1906 to 1947 h UTC normal time.
From 0406 to 0447 h and 1806 to 1847 h UTC daylight time.

(34) From 0906 to 0940 h and 1706 to 1740 h UTC normal time.
From 2006 to 2040 h and 0806 to 0840 h UTC daylight time.

(35) Each Monday, Wednesday and Friday.

(36) From 0930 to 1130 h UTC. When Summer Time, add one hour to the times given.

(37) Second pulses of 8 cycles of 1 kHz modulation during 5 min beginning at 1100 h UTC and 1125 h UTC. When Summer Time, add one hour to the instants given.

(38) 8 638 kHz and 12 984 kHz continuous; 16 000 kHz from 2200 to 1000 h UTC.

(39) Pulses of 50 cycles of 1 000 Hz tone, shortened to 5 cycles from the 55th to the 58th second; the 59th pulse is omitted; the minute marker is 500 cycles. At the 5th, 10th, 15th, etc. minutes, pulses from the 50th to the 58th second are shortened to 5 cycles. Voice identification on 16 000 kHz between the 20th and 50th seconds in the 15th, 30th, 45th and 60th minutes. Morse identification "VNG" on 8 638 kHz and 12 984 kHz in the 15th, 30th, 45th and 60th minutes. A BCD time incorporating time of day and day number of the year is transmitted between the 20th and 46th second with a binary "0" represented by 100 cycles and a binary "1" by 200 cycles of 1 000 Hz tone. The minute information for the next minute is given from the 21st to the 28th second, hour information from the 29th to the 35th second and day of the year from the 36th to the 46th second; parity bits are included at the end of each code sequence.

(40) Time code used which reduces carrier by 10 dB at the beginning of each second. The code contains information on the year, day of year, hour, minute, UT1 value and status indicators for impending leap seconds and Daylight Saving Time.

(41) Seconds pulses of a duration of 0.1 s, modulated at 1 000 Hz.
Minutes pulses of a duration of 0.5 s, modulated at 1 250 Hz.

(42) Minutes 00 to 10, 12 008 kHz, A2A.

15 to 25, 12 008 kHz, J3E.

30 to 40, 6 840 kHz, A2A.

45 to 55, 6 840 kHz, J3E.

During the minute immediately preceding each of the periods indicated, transmission of call sign in slow Morse twice.

TABLE 3

Characteristics of some navigational aids

Station			Type of antenna(s)	Carrier power (kW)	Number of simultaneous transmissions	Period of operation		Standard frequencies used		Duration of emission		Uncertainty of frequency and time intervals (parts in 10^{12})
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Pulse repetition (µs)**	**Time signal**	**Audio-modulation**	
Loran-C(1) (7980-Z, 9960-Y)	Carolina Beach, NC, United States	34° 03.8′ N 77° 54.8′ W	Omni-directional	800(2)	1	7	24	100	79 800(3)	Continuous(4)	Nil	± 1
Loran-C (7980-Y)	Jupiter, Florida, United States	27° 02.0′ N 80° 06.9′ W	Omni-directional	400(2)	1	7	24	100	79 800(3)	Continuous(4)	Nil	± 1
Loran-C(1) (5930-Y, 7930-W)	Cape Race, Newfoundland	46° 46.5′ N 53° 10.5′ W	Omni-directional	1 000(2)	1	7	24	100	79 300 59 300(3)	Continuous(4)	Nil	± 1
Loran-C(1) (5930-X, 9960-X)	Nantucket Island, United States	41° 15.2′ N 69° 58.6′ W	Omni-directional	400	1	7	24	100	59 300(3) 99 600	Continuous(4)	Nil	± 1
Loran-C(1) (8970-M, 9960-Z)	Dana, Indiana, United States	39° 51.1′ N 87° 29.2′ W	Omni-directional	400(2)	1	7	24	100	89 700(3) 99 600	Continuous(4)	Nil	± 1
Loran-C(1) (7930-X, 9980-W)	Angissoq, Greenland	59° 59.3′ N 45° 10.4′ W	Omni-directional	760(2)	1	7	24	100	79 300(3) 99 800	Continuous(4)	Nil	± 1
Loran-C(1) (7970-M 9980-X)	Ejde, Faeroe Islands, Denmark	62° 18.0′ N 7° 04.4′ W	Omni-directional	325(2)	1	7	24	100	79 700(3) 99 800	Continuous(4)	Nil	± 1
Loran-C (7970-W)	Sylt, F.R. of Germany	54° 48.5′ N 8° 17.6′ E	Omni-directional	325(2)	1	7	24	100	79 700(3)	Continuous(4)	Nil	± 1
Loran-C (7970-X)	Bo, Norway	68° 38.1′ N 14° 27.8′ E	Omni-directional	165(2)	1	7	24	100	79 700(3)	Continuous(4)	Nil	± 1

TABLE 3 (*continued*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Pulse repetition (μs)**	**Time signal**	**Audio-modulation**	
Loran-C(1) (7970-Y, 9980-M)	Sandur, Iceland	64° 54.4′ N 23° 55.4′ W	Omni-directional	1 500(2)	1	7	24	100	79 700 99 800	Continuous(4)	Nil	± 1
Loran-C (7970-Z)	Jan Mayen, Norway	70° 54.9′ N 8° 44.0′ W	Omni-directional	165(2)	1	7	24	100	79 700(3)	Continuous(4)	Nil	± 1
Loran-C(1) (5930-Z, 7930-M)	Fox Harbour, Canada	52° 22.6′ N 55° 42.5′ W	Omni-directional	800(2)	1	7	24	100	59 300 79 300	Continuous(4)	Nil	± 1
Loran-C (7990-M)	Sellia Marina, Italy	38° 52.3′ N 16° 43.1′ E	Omni-directional	165(2)	1	7	24	100	79 900(3)	Continuous(4)	Nil	± 1
Loran-C (7990-X)	Lampedusa, Italy	35° 31.3′ N 12° 31.5′ E	Omni-directional	325(2)	1	7	24	100	79 900(3)	Continuous(4)	Nil	± 1
Loran-C (7990-Y)	Kargabarun, Turkey	40° 58.3′ N 27° 52.0′ E	Omni-directional	165(2)	1	7	24	100	79 900(3)	Continuous(4)	Nil	± 1
Loran-C (7990-Z)	Estartit, Spain	42° 03.6′ N 3° 12.3′ E	Omni-directional	165(2)	1	7	24	100	79 900(3)	Continuous(4)	Nil	± 1
Loran-C (8930-X)	Minami – Torishima, Japan	24° 17.1′ N 153° 58.9′ E	Omni-directional	1 100(2)	1	7	24	100	89 300(3)	Continuous(4)	Nil	± 1
Loran-C(1) (8930-Y, 5970-W)	Tokatibuto, Japan	42° 44.6′ N 143° 43.2′ E	Omni-directional	1 000(2) 600	1	7	24	100	89 300(3) 59 700	Continuous(4)	Nil	± 1
Loran-C(1) (8930-W, 5970-Y)	Gesashi, Japan	26° 36.4′ N 128° 08.9′ E	Omni-directional	1 000(2) 600	1	7	24	100	89 300(3) 59 700	Continuous(4)	Nil	± 1
Loran-C (8930-M)	Niijima, Japan	34° 24.2′ N 139° 16.3′ E	Omni-directional	1 000(2)	1	7	24	100	89 300(3)	Continuous(4)	Nil	± 1

TABLE 3 (*continued*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Pulse repetition (µs)**	**Time signal**	**Audio-modulation**	
Loran-C (9990-M)	St. Paul, Pribiloff Islands, Alaska	57° 09.2′ N 170° 15.1′ W	Omni-directional	325(2)	1	7	24	100	99 900(3)	Continuous(4)	Nil	± 1
Loran-C (9990-X)	Attu, Alaska	52° 49.7′ N 173° 10.8′ E	Omni-directional	625(2)	1	7	24	100	99 900(3)	Continuous(4)	Nil	± 1
Loran-C(1) (9960-M, 8970-X)	Seneca, NY, United States	42° 42.8′ N 76° 49.6′ W	Omni-directional	800(2)	1	7	24	100	99 600(3) 89 700(3)	Continuous(4)	Nil	± 1
Loran-C(1) (9960-W, 5930-M)	Caribou, ME, United States	46° 48.5′ N 67° 55.6′ W	Omni-directional	800(2)	1	7	24	100	59 300(3) 99 600(3)	Continuous(4)	Nil	± 1
Loran-C(1) (8970-W, 7980-M)	Malone, FL, United States	30° 59.6′ N 85° 10.1′ W	Omni-directional	800(2)	1	7	24	100	89 700(3) 79 800(3)	Continuous(4)	Nil	± 1
Loran-C(1) (8970-Y 8290-W)	Baudette, MN, United States	48° 36.8′ N 94° 33.3′ W	Omni-directional	800(2)	1	7	24	100	89 700(3) 82 900	Continuous(4)	Nil	± 1
Loran-C(1) (7980-W 9610-Z)	Grangeville, LA, United States	30° 43.6′ N 90° 49.7′ W	Omni-directional	800(2)	1	7	24	100	79 800(3) 96 100	Continuous(4)	Nil	± 1
Loran-C(1) (7980-X 9610-Y)	Raymondville, TX, United States	26° 31.9′ N 97° 50.0′ W	Omni-directional	400(2)	1	7	24	100	79 800(3) 96 100	Continuous(4)	Nil	± 1
Loran-C(1) (9990-Y 7960-Z)	Pt. Clarence, Alaska	65° 14.7′ N 166° 53.2′ W	Omni-directional	1 000(2)	1	7	24	100	99 900(3) 79 600	Continuous(4)	Nil	± 1

TABLE 3 (*continued*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Pulse repetition (μs)**	**Time signal**	**Audio-modulation**	
Loran-C(1) (9990-Z, 7960-X)	Narrow Cape, Alaska	57° 26.3′ N 152° 22.2′ W	Omni-directional	400(2)	1	7	24	100	99 900 79 600(3)	Continuous(4)	Nil	± 1
Loran-C (7960-M)	Tok, Alaska	63° 19.7′ N 142° 48.5′ W	Omni-directional	540(2)	1	7	24	100	79 600(3)	Continuous(4)	Nil	± 1
Loran-C(1) (7960-Y, 5990-X)	Shoal Cove, Alaska	55° 26.3′ N 131° 15.3′ W	Omni-directional	540(2)	1	7	24	100	79 600 59 900(3)	Continuous(4)	Nil	± 1
Loran-C(1) (5990-M 8290-Y)	Williams Lake, BC, Canada	51° 58.0′ N 122° 22.0′ W	Omni-directional	400(2)	1	7	24	100	59 900(3) 82 900	Continuous(4)	Nil	± 1
Loran-C(1) (5990-Y, 9940-W)	George, Washington, United States	47° 03.8′ N 119° 44.6′ W	Omni-directional	1 600(2)	1	7	24	100	59 900 99 400(3)	Continuous(4)	Nil	± 1
Loran-C (9940-M)	Fallon, Nevada, United States	39° 33.1′ N 118° 49.9′ W	Omni-directional	400(2)	1	7	24	100	99 400(3)	Continuous(4)	Nil	± 1
Loran-C (9940-X)	Middletown, California, United States	38° 46.9′ N 122° 29.7′ W	Omni-directional	400(2)	1	7	24	100	99 400(3)	Continuous(4)	Nil	± 1
Loran-C(1) (9940-Y 9610-W)	Searchlight, Nevada, United States	35° 19.3′ N 114° 48.3′ W	Omni-directional	540(2)	1	7	24	100	99 400(3) 96 100	Continuous(4)	Nil	± 1
Loran-C (5990-Z)	Port Hardy, BC, Canada	50° 36.5′ N 127° 21.5′ W	Omni-directional	400(2)	1	7	24	100	59 900(3)	Continuous(4)	Nil	± 1
(8000-M)	Briansk	53° 08′ N 34° 55′ E	Omni-directional	650	1	7(5)	10(6)	100	80 000(7)	Continuous(4)	Nil	± 5

TABLE 3 (*continued*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Pulse repetition (µs)**	**Time signal**	**Audio-modulation**	
(8000-4)	Syzran	53° 18′ N 49° 07′ E	Omni-directional	700	1	6(5)	10(6)	100	80 000(7)	(8)	Nil	± 5
(7950-M)	Aleksandrovsk, Sakhalinsky	51° 05′ N 142° 42′ E	Omni-directional	700	1	7(9)	12(10)	100	89 500	Continuous	Nil	± 5
Loran-C (8290-M)	Havre, ND, United States	48° 44.6′ N 109° 58.9′ W	Omni-directional	400(2)	1	7	24	100	82 900	Continuous	Nil	± 1
Loran-C(1) (8290-X, 9610-V)	Gillette, WY, United States	44° 00.2′ N 105° 37.4′ W	Omni-directional	400(2)	1	7	24	100	82 900 96 100	Continuous	Nil	± 1
Loran-C(1) (8970-Z, 9610-M)	Boise City, ID, United States	36° 30.3′ N 102° 54.0′ W	Omni-directional	800(2)	1	7	24	100	89 700 96 100	Continuous	Nil	± 1
Loran-C (9610-X)	Las Cruces, NM, United States	32° 04.3′ N 106° 52.1′ W	Omni-directional	400(2)	1	7	24	100	96 100	Continuous	Nil	± 1
Loran-C (5970-M)	Pohang, Korea	36° 11.1′ N 129° 20.5′ E	Omni-directional	35	1	7	24	100	59 700	Continuous	Nil	± 1
Loran-C (5970-X)	Kwangju, Korea	35° 02.4′ N 126° 32.5′ E	Omni-directional	35	1	7	24	100	59 700	Continuous	Nil	± 1
Loran-C (7950-1)	Petropavlosk, CIS	53° 07.8′ N 157° 41.7′ E	Omni-directional	700	1	7	24	100	89 500	Continuous	Nil	± 1
Loran-C (7950-2)	Ussuriysk, CIS	44° 32.0′ N 131° 38.4′ E	Omni-directional	700	1	7	24	100	89 500	Continuous	Nil	± 1
Loran-C (8000-1)	Petrozavodsk, CIS	61° 45.5′ N 33° 41.7′ E	Omni-directional	700	1	7	24	100	80 000	Continuous	Nil	± 1
Loran-C (8000-2)	Solnim, CIS	53° 07.9′ N 25° 23.8′ E	Omni-directional	450	1	7	24	100	80 000	Continuous	Nil	± 1

TABLE 3 (*continued*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Pulse repetition (μs)**	**Time signal**	**Audio-modulation**	
Loran-C (8000-3)	Simferopol, CIS	44° 53.3′ N 33° 52.5′ E	Omni-directional	550	1	7	24	100	80 000	Continuous	Nil	± 1
Loran-C (6930-M)	Xindu, China	23° 58.1′ N 111° 43.1′ E	Omni-directional	1 000	1	7	24	100	69 300	Continuous	Nil	± 1
Loran-C (6930-1)	Xinhe, China	22° 25.0′ N 107° 21.0′ E	Omni-directional	1 000	1	7	24	100	69 300	Continuous	Nil	± 1
Loran-C (6930-2)	Zhangxi, China	23° 43.7′ N 116° 53.8′ E	Omni-directional	1 000	1	7	24	100	69 300	Continuous	Nil	± 1
Loran-C (7170-M)	Al Khamasin, Saudi Arabia	20° 28.0′ N 44° 34.9′ E	Omni-directional	800	1	7	24	100	71 700	Continuous	Nil	± 1
Loran-C(1) (7170-W, 8990-V)	Salwa, Saudi Arabia	24° 50.0′ N 50° 34.2′ E	Omni-directional	800	1	7	24	100	71 700 89 900	Continuous	Nil	± 1
Loran-C(1) (7170-X, 8990-M)	Afif, Saudi Arabia	23° 48.6′ N 42° 51.3′ E	Omni-directional	800	1	7	24	100	71 700 89 900	Continuous	Nil	± 1
Loran-C(1) (7170-Y, 8990-Y)	Al Lith, Saudi Arabia	20° 13.9′ N 40° 12.5′ E	Omni-directional	200	1	7	24	100	71 700 89 900	Continuous	Nil	± 1
Loran-C(1) (7170-Z, 8990-Z)	Al Muwassam, Saudi Arabia	16° 25.9′ N 42° 48.1′ E	Omni-directional	800	1	7	24	100	71 700 89 900	Continuous	Nil	± 1
Loran-C (8990-W)	Ar Ruqi, Saudi Arabia	29° 01.1′ N 46° 37.4′ E	Omni-directional	200	1	7	24	100	71 700	Continuous	Nil	± 1
Loran-C (8990-X)	Ash Shaykh Humayd, Saudi Arabia	28° 09.3′ N 34° 45.9′ E	Omni-directional	400	1	7	24	100	71 700	Continuous	Nil	± 1

TABLE 3 (*end*)

Station			**Type of antenna(s)**	**Carrier power (kW)**	**Number of simultaneous transmissions**	**Period of operation**		**Standard frequencies used**		**Duration of emission**		**Uncertainty of frequency and time intervals (parts in 10^{12})**
Call sign	**Approximate location**	**Latitude Longitude**				**Days/ week**	**Hours/ day**	**Carrier (kHz)**	**Pulse repetition (μs)**	**Time signal**	**Audio-modulation**	
Omega Ω/A	Aldra, Norway	66° 25′ N 13° 08′ E	Omni-directional	10(11)	1	7	24	11.05-F(12) 10.2-A $11^{1/3}$-C 13.6-B	Nil	(12)	Nil	± 5
Omega Ω/B	Monrovia, Liberia	6° 18′ N 10° 40′ W	Omni-directional	10(11)	1	7	24	11.05-G(12) 10.2-B $11^{1/3}$-D 13.6-C	Nil	(12)	Nil	± 1
Omega Ω/C	Haiku, Hawaii, United States	21° 24′ N 157° 50′ W	Omni-directional	10(11)	1	7	24	11.05-H(12) 10.2-C $11^{1/3}$-E 13.6-D	Nil	(12)	Nil	± 1
Omega Ω/D	Lamoure, North Dakota, United States	46° 22′ N 98° 20′ W	Omni-directional	10(11)	1	7	24	11.05-A(12) 10.2-D $11^{1/3}$-F 13.6-E	Nil	(12)	Nil	± 1
Omega Ω/E	La Reunion	20° 58′ S 55° 17′ E	Omni-directional	10(11)	1	7	24	11.05-B(12) 10.2-E $11^{1/3}$-G 13.6-F	Nil	(12)	Nil	± 1
Omega Ω/F	Golfo Nuevo, Argentina	43° 03′ S 65° 11′ W	Omni-directional	10(11)	1	7	24	11.05-C(12) 10.2-F $11^{1/3}$-H 13.6-G	Nil	(12)	Nil	± 1
Omega Ω/G	Woodside, Victoria, Australia	38° 29′ S 146° 56′ E	Omni-directional	10(11)	1	7	24	11.05-D(12) 10.2-G $11^{1/3}$-A 13.6-H	Nil	(12)	Nil	± 1
Omega Ω/H	Tsushima Islands, Japan	34° 37′ N 129° 27′ E	Omni-directional	10(11)	1	7	24	11.05-E(12) 10.2-H $11^{1/3}$-B 13.6-A	Nil	(12)	Nil	± 1

Notes to Table 3:

(1) Dual-rated stations.

(2) Peak radiated power.

(3) Time pulses appear in groups of 9 for the master station (M) and groups of 8 for the secondary stations (W, X, Y, Z).

(4) Maintained within ± 5 µs of UTC. Time of Coincidence (TOC) with the UTC second changes with the recurrence of leap-seconds and is designated in TOC Tables issued to interested users by the US Naval Observatory, Washington DC, USA.

(5) No transmission on the 10th and 11th of each month.

(6) From 0400 to 1000 h and 1400 to 1800 h UTC.

(7) The signals of primary stations (A) are marked by the transmission of an additional ninth pulse in each group. Each pulse group coinciding with a UTC second marker is marked by the transmission of an additional (tenth) pulse. In the event of coincidence with the minute marker, the subsequent ten groups are additionally marked, and in the event of coincidence with the five-minute marker after 12 s, the subsequent 11 groups are also marked. The UTC second markers are accompanied by characteristic points situated at the leading edges of the eighth pulses at a level of 0.6 of the maximum signal value.

(8) Generally operates without a second marker. In individual cases operates with a second marker shifted in relation to UTC.

(9) No transmission on the 20th or 21st of each month.

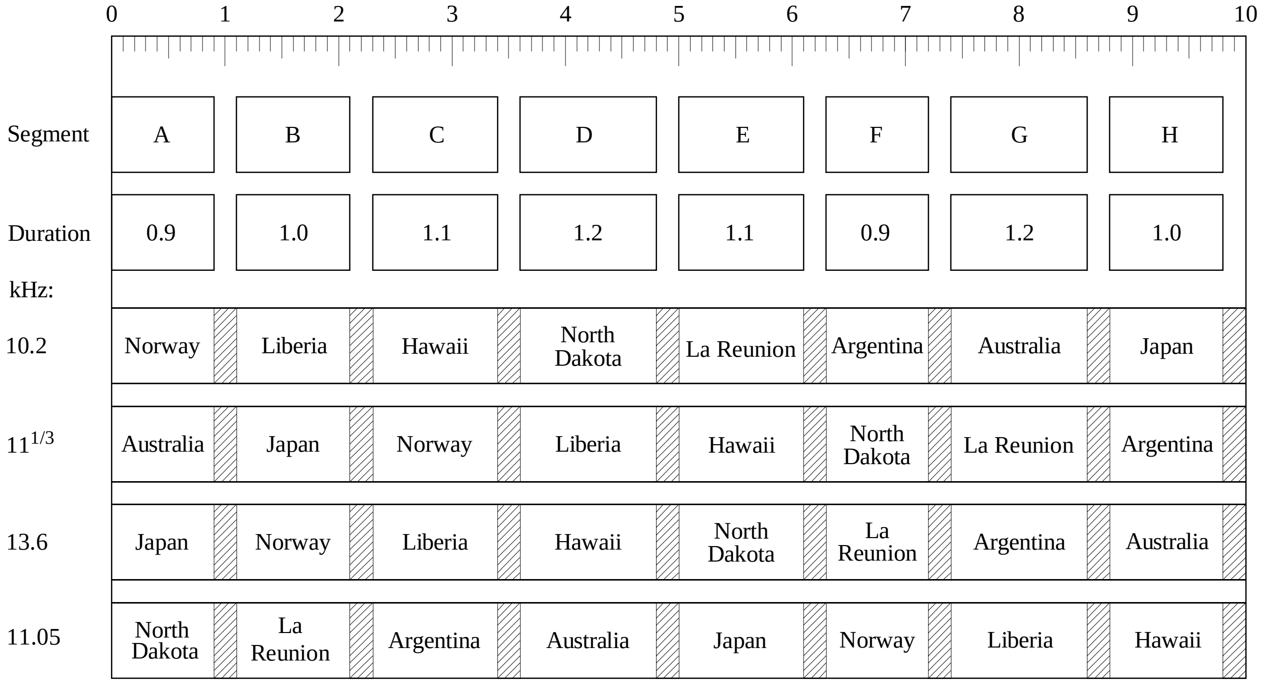
(10) From 2300 to 2400 h and 0000 to 1100 h UTC.

(11) Figures give the estimated radiated power.

(12) See Table 4.

TABLE 4

OMEGA signal format



Segment	A	B	C	D	E	F	G	H
Duration	0.9	1.0	1.1	1.2	1.1	0.9	1.2	1.0
kHz:								
10.2	Norway	Liberia	Hawaii	North Dakota	La Reunion	Argentina	Australia	Japan
$11^{1/3}$	Australia	Japan	Norway	Liberia	Hawaii	North Dakota	La Reunion	Argentina
13.6	Japan	Norway	Liberia	Hawaii	North Dakota	La Reunion	Argentina	Australia
11.05	North Dakota	La Reunion	Argentina	Australia	Japan	Norway	Liberia	Hawaii

Note 1 – Segment A does not begin at 0.0 s UTC. Time of segments changes with leap seconds. Segment A begins at second 44.0 in January, 1992.

Note 2 – The OMEGA stations are for general navigation purposes: while these data are subject to change, the changes are announced in advance to interested users by the United States Coast Guard Commandant*.

Note 3 – In addition to the navigational frequencies of 10.2 kHz, 13.6 kHz and $11^{1/3}$ kHz transmitted by all the stations, the stations transmit “unique frequencies”. These stations and their frequencies/segments are given in Table 5.

* United States Coast Guard Commandant (G-WAN-3/73), 400 Seventh Street, S.W., Washington, DC 20590.

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TABLE 5

OMEGA radionavigation system signal transmission format

Station \ Segment		1	2	3	4	5	6	7	8
Norway	(A)	10.2	13.6	$11^{1/3}$	12.1 (1)	12.1 (1)	11.05	12.1 (1)	12.1 (1)
Liberia	(B)	12.0 (1)	10.2	13.6	$11^{1/3}$	12.0 (1)	12.0 (1)	11.05	12.0 (1)
Hawaii	(C)	11.8 (1)	11.8 (1)	10.2	13.6	$11^{1/3}$	11.8 (1)	11.8 (1)	11.05
North Dakota	(D)	11.05	13.1 (1)	13.1 (1)	10.2	13.6	$11^{1/3}$	13.1 (1)	13.1 (1)
La Reunion	(E)	12.3 (1)	11.05	12.3 (1)	12.3 (1)	10.2	13.6	$11^{1/3}$	12.3 (1)
Argentina	(F)	12.9 (1)	12.9 (1)	11.05	12.9 (1)	12.9 (1)	10.2	13.6	$11^{1/3}$
Australia	(G)	$11^{1/3}$	13.0 (1)	13.0 (1)	11.05	13.0 (1)	13.0 (1)	10.2	13.6
Japan	(H)	13.6	$11^{1/3}$	12.8 (1)	12.8 (1)	11.05	12.8 (1)	12.8 (1)	10.2
Transmission Interval		0.9 0.2	1.0 0.2	1.1 0.2	1.2 0.2	1.1 0.2	0.9 0.2	1.2 0.2	1.0 0.2

10 s

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Frequencies in kHz.

(1) is the unique frequency for the respective station.

ANNEX 2

Authorities responsible for stations appearing in Tables 1 and 2

Station	*Authority*
ALLOUIS	Centre national d'Etudes des Télécommunications Département FRE 196, rue de Paris 92220 Bagneux, France
ATA	Time and Frequency Section National Physical Laboratory S. R. Krishnan Road New Delhi – 110012, India
BPM	Time and Frequency Division Shaanxi Astronomical Observatory Chinese Academy of Sciences Lington, Xian, China (People's Republic of)
CHU	National Research Council Time and Frequency Section Physics Division (m-36) Ottawa K1A OS1, Ontario, Canada
DCF77	Physikalisch-Technische Bundesanstalt Lab. Zeiteinheit Bundesallee 100 38116 Braunschweig, Federal Republic of Germany
EBC	Instituto y Observatorio de Marina (Spanish Naval Observatory) San Fernando (Cádiz), Spain
HBG	Swiss Federal Office of Metrology Time and Frequency Laboratory Lindenweg 50 CH-3003 Bern-Wabern, Switzerland
HLA	Time and Frequency Laboratory Korea Standards Research Institute P.O. Box 3, Taedok Science Town Taejon, Ch'ungnam 300-31, Republic of Korea
IAM	Istituto Superiore Poste e Telecomunicazioni Viale Europa, 190 Ufficio 8°, Rep 2 00100 – Roma, Italy

JJY	Standards and Measurements Division Communications Research Laboratory Ministry of Posts and Telecommunications Nukui-Kitamachi, Koganei, Tokyo, 184-8795, Japan
LOL	Director Observatorio Naval Av. Costanera Sur, 2099 Buenos Aires, Argentine Republic
MSF	National Physical Laboratory Centre for Electromagnetic and Time Metrology Teddington, Middlesex, TW11 OLW United Kingdom
NAA, NDT, NLK, NPM, NSS, NWC, NMO, NPN	Superintendent US Naval Observatory Washington, DC 20390, United States of America
OMA	1. Time information Astronomický ústav CSAV, Budec,ˇská 6 12023 Praha 2, Vinohrady Czech Republic 2. Standard frequency information Ústav radiotechniky a elektroniky CSAV Lumumbova 1 18088 Praha 8, Kobylisy Czech Republic
RAT, RCH, RID, RWM	State Committee of Standards of the Russian Federation Lenisky Prospect 9 117049 Moscow, Russia
SAJ	Swedish Telecommunications Administration Radio Services S-123 86 Farsta, Sweden
VNG	VNG Users Consortium GPO Box 1090 Canberra ACT 2601, Australia
WWV, WWVH, WWVB	Time and Frequency Services Group Time and Frequency Division National Institute of Standards and Technology 325 Broadway, Boulder, Colorado 80303 United States of America
ZUO	Time Standards Section Precise Physical Measurements Division National Physical Research Laboratory P.O. Box 395 0001 – Pretoria, South Africa