XVII A.P.
DÜSSELDORF
21.5-1.6 1990
CCIR

XVIIth PLENARY ASSEMBLY
DÜSSELDORF, 1990

INTERNATIONAL TELECOMMUNICATION UNION

RECOMMENDATIONS OF THE CCIR, 1990

(ALSO RESOLUTIONS AND OPINIONS)

VOLUME VII

STANDARD FREQUENCIES AND TIME SIGNALS

CCIR INTERNATIONAL RADIO CONSULTATIVE COMMITTEE

Geneva, 1990

CCIR

1. The International Radio Consultative Committee (CCIR) is the permanent organ of the International Telecommunication Union responsible under the International Telecommunication Convention ''... to study technical and operating questions relating specifically to radiocommunications without limit of frequency range, and to issue recommendations on them...'' (International Telecommunication Convention, Nairobi 1982, First Part, Chapter I, Art. 11, No. 83).*

2. The objectives of the CCIR are in particular:

a) to provide the technical bases for use by administrative radio conferences and radiocommunication services for efficient utilization of the radio-frequency spectrum and the geostationary-satellite orbit, bearing in mind the needs of the various radio services;

b) to recommend performance standards for radio systems and technical arrangements which assure their effective and compatible interworking in international telecommunications;

c) to collect, exchange, analyze and disseminate technical information resulting from studies by the CCIR, and other information available, for the development, planning and operation of radio systems, including any necessary special measures required to facilitate the use of such information in developing countries.

* *See also the Constitution of the ITU, Nice, 1989, Chapter 1, Art. 11, No. 84.*

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92-61-04231-7

Geneva, 1990

PLAN OF VOLUMES I TO XV
XVIIth PLENARY ASSEMBLY OF THE CCIR

(Düsseldorf, 1990)

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All references within the texts to CCIR Recommendations, Reports, Resolutions, Opinions, Decisions and Questions refer to the 1990 edition, unless otherwise noted; i.e., only the basic number is shown.

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DISTRIBUTION OF TEXTS OF THE XVIIth PLENARY ASSEMBLY OF THE CCIR IN VOLUMES I TO XV

Volumes and Annexes I to XV, XVIIth Plenary Assembly, contain all the valid texts of the CCIR and succeed those of the XVIth Plenary Assembly, Dubrovnik, 1986.

1. Recommendations, Resolutions, Opinions are given in Volumes I-XIV and Reports, Decisions in the Annexes to Volumes I-XII.

1.1 *Numbering of texts*

When a Recommendation, Report, Resolution or Opinion is modified, it retains its number to which is added a dash and a figure indicating how many revisions have been made. Within the text of Recommendations, Reports, Resolutions, Opinions and Decisions, however, reference is made only to the basic number (for example Recommendation 253). Such a reference should be interpreted as a reference to the latest version of the text, unless otherwise indicated.

The tables which follow show only the original numbering of the current texts, without any indication of successive modifications that may have occurred. For further information about this numbering scheme, please refer to Volume XIV.

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* Not reprinted, see Dubrovnik, 1986.

(1) Published separately.

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* Not reprinted, see Dubrovnik, 1986.

(1) Published separately.

1.3.1 *Note concerning Reports*

The individual footnote "Adopted unanimously" has been dropped from each Report. Reports in Annexes to Volumes have been adopted unanimously except in cases where reservations have been made which will appear as individual footnotes.

1.4 *Resolutions*

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53, 54	I	77	XII	101	II
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57	VI	80	XI-1	103	VIII-3
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2. **Questions** (Vols. XV-1, XV-2, XV-3, XV-4)

2.1 *Numbering of texts*

Questions are numbered in a different series for each Study Group: where applicable a dash and a figure added after the number of the Question indicate successive modifications. The number of a Question is completed by an *Arabic figure indicating the relevant Study Group.* For example:

- Question 1/10 would indicate a Question of Study Group 10 with its text in the original state;
- Question 1-1/10 would indicate a Question of Study Group 10, whose text has been once modified from the original; Question 1-2/10 would be a Question of Study Group 10, whose text has had two successive modifications.

Note – The numbers of the Questions of Study Groups 7, 9 and 12 start from 101. In the case of Study Groups 7 and 9, this was caused by the need to merge the Questions of former Study Groups 2 and 7 and Study Groups 3 and 9, respectively. In the case of Study Group 12, the renumbering was due to the requirement to transfer Questions from other Study Groups.

2.2 *Assignment of Questions*

In the plan shown on page II, the relevant Volume XV in which Questions of each Study Group can be found is indicated. A summary table of all Questions, with their titles, former and new numbers is to be found in Volume XIV.

2.3 *References to Questions*

As detailed in Resolution 109, the Plenary Assembly approved the Questions and assigned them to the Study Groups for consideration. The Plenary Assembly also decided to discontinue Study Programmes. Resolution 109 therefore identifies those Study Programmes which were approved for conversion into new Questions or for amalgamation with existing Questions. It should be noted that references to Questions and Study Programmes contained in the texts of Recommendations and Reports of Volumes I to XIII are still those which were in force during the study period 1986-1990.

Where appropriate, the Questions give references to the former Study Programmes or Questions from which they have been derived. New numbers have been given to those Questions which have been derived from Study Programmes or transferred to a different Study Group.

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VOLUME VII

STANDARD FREQUENCIES AND TIME SIGNALS

(Study Group 7)

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STUDY GROUP 7

STANDARD FREQUENCIES AND TIME SIGNALS

Terms of reference:

1. To coordinate services of standard frequency and time-signal dissemination on a world-wide basis.

2. To study the technical aspects of emission and reception, including the use of satellite techniques in these services, and means to improve the accuracy of measurement.

1986-1990 *Chairman:* J. McA. STEELE (United Kingdom)
Vice-Chairman: S. LESCHIUTTA (Italy)

As from the next study period, in conformity with Resolution 61 adopted at the XVIIth Plenary Assembly, Düsseldorf (May-June 1990), the scope of the work which will be undertaken and the names of the Chairman and Vice-Chairmen are as follows.

STUDY GROUP 7

SCIENCE SERVICES

Scope:

1. Systems for space operation, space research, earth exploration and meteorology, including the related use of links in the inter-satellite services.

2. Radioastronomy and radar astronomy.

3. Dissemination, reception and coordination of standard-frequency and time-signal services, including the application of satellite techniques, on a world-wide basis.

1990-1994 *Chairman:* H. G. KIMBALL (United States of America)
Vice-Chairmen: J. SAINT-ÉTIENNE (France)
S. LESCHIUTTA (Italy)
J. WHITEOAK (Australia)

INTRODUCTION BY THE CHAIRMAN, STUDY GROUP 7

1. Overview

The Study Group documentation was reviewed at the Interim and Final Meetings held on 12-19 April 1988 and 5-12 September 1989, respectively. In addition, on each occasion, there were meetings of the committee set up to implement Decision 65 leading to a Handbook on satellite time and frequency dissemination. Apart from one new Study Programme which is noted below in § 3.1 and the deletion of Opinion 70 in the previous Volume as no longer relevant Questions, Study Programmes, Resolutions, Opinions and Decisions remain unaltered from the preceding plenary period. The remainder of this Introduction is given over to a presentation of the more significant changes and additions to the Study Group Recommendations and Reports and some account of the interactions with other international bodies.

2. Section 7A – Glossary

Recommendation 686 contains a Glossary of terms which are considered important and relevant to the work of the Study Group and whose definitions arose initially from the activity of IWP 7/2, under the chairmanship of Professor Egidi (Italy). Only minor changes had been made to the definitions in the Glossary in the ten or so years since the Working Party completed the first stage of its work and it was appropriate, therefore, that a major review of the contents should have been undertaken at the Final Meeting. The majority of the terms in the Glossary are specific to the operational needs of the standard-frequency and time-signal service. Others, such as accuracy, error and uncertainty have more general connotations and the Study Group in adopting its own constrution for these terms was, nevertheless, not unmindful of the definitions already existing in the International Vocabulary of Basic and General Terms on Metrology [ISO, 1984], based on contributions from BIPM, IEC, ISO and OIML. It was decided, also, that given the exposure of the Glossary in Volume VII (in the original form of Report 730) during three plenary periods it was now time to emphasise its validity in the revised form and convert it into a Recommendation.

3. Section 7B – Specification of the standard-frequency and time-signal service

3.1 *System of Coordinated Universal Time (UTC)*

No change has been made to the terms of Recommendation 460 governing the operation of the UTC system with a tolerance of ± 1 ms relative to UTC in the emitted time signals and ± 1 in 10^{10} in the standard frequency. These tolerances are now easily surpassed in the great majority of installations by the use of atomic reference clocks; moreover, these clocks can be intercompared by presently available methods at levels of uncertainty well below 1 µs. In these circumstances it was considered that it would be helpful if a greater degree of synchronization existed in the clocks contributing to UTC. Accordingly Recommendation 685 on the international synchronization of time scales proposes that each timing centre should seek to align its local time, UTC(k), precisely with UTC, the desirable limits being ± 1 µs. The thrust towards greater precision in time reference is also reflected in a Study Programme 5C/7 calling for the investigation of techniques for the world-wide dissemination of time signals with an accuracy of 1 µs or better at the least cost to the user.

In practice it is not possible to realise all the features of Recommendation 460 in some operational systems. For example, the code detailed in Annex II for the dissemination of DUT1 information giving the difference (UT1 – UTC) may not always be compatible with the provision of time and calender codes in the same segment and some stations operating in band 4, e.g. DCF77, HBG, OMA and WWVB do not radiate DUT1 signals in the specified format. Reflecting a sustained increase in the Earth's rate of rotation the incidence of leap seconds has been reduced in recent years with only two positive adjustments since June 1985 on the last days of December 1987 and 1989. As with DUT1 it is not practicable to incorporate these changes in those systems in use for frequency and time transfer but which have navigation or position determination as their primary function. Thus the time reference provided by the Omega signals in band 4 and by the Global Positioning System (GPS) in the satellite field equates to UTC only modulus 1 s, the resulting difference (System Time – UTC) being +15 s for the former and +6 s for the latter at 1 January 1990.

3.2 *Bureau international des poids et mesures (BIPM)*

The responsibility for the system of International Atomic Time (TAI) was formally transferred on 1 January 1988 to the Bureau international des poids et mesures (BIPM) and the consequential changes have been made throughout the Volume VII in converting from the (now superseded) Bureau international de l'heure (BIH) to BIPM, where appropriate. In the formation of UTC it is, of course, necessary to have a knowledge of the Earth's rate of rotation and the decisions on the value of DUT1 and on the insertion of leap seconds are provided by the International Earth Rotation Service (IERS), reference to which also appears as appropriate in the context of UTC. One immediate advantage of the new arrangement is that the BIPM is now directly represented at the Study Group meetings for the first time, thereby bringing to our discussions the experience and expertise of its Time Section.

4. Section 7C – Systems for dissemination and comparison

4.1 *Allocated frequency bands*

Table I in Report 267 (Standard frequencies and time signals) contains the characteristics of all the standard-frequency and time-signal stations currently operating in the allocated bands at frequencies of 2.5, 5, 10, 15 and 20 MHz. The principal change in the present period was the decision of the United Kingdom to cease the operation of its MSF service on 2.5, 5 and 10 MHz in February 1988. This has eased somewhat the situation in respect of mutual interference in the European area and the consequential changes have been made to Report 732 (Proposed reduction of mutual interference between emissions in bands 6 and 7). The text of Report 731 surveying users of s.f. and t.s. emissions has been extended to include the results of a survey carried out by the National Institute of Standards and Technology (NIST) in the United States of America during 1987-88 and embracing not only the WWV and WWVH services but also WWVB on 60 kHz and the GOES satellite time dissemination service.

4.2 *Additional frequency bands*

Tables II and III of Report 267 list some of the other sources which are available for time and frequency reference. These fall mainly in bands 4 and 5 and include navigational (Loran-C and Omega), communication and broadcasting transmissions. Despite the rapid developments in satellite methods these bands continue to be fully exploited: Report 271 on the stability of received VLF and LF signals describes one fruitful development involving DCF 77 on 77.5 kHz where a phase-modulated pseudo-random sequence has been added to the signal format to increase the precision of time determination. The Report also includes the results of extensive measurements on Loran-C signals conducted in the People's Republic of China and Japan over path lengths of up to 2000 km.

4.3 *Other methods for T/F transfer*

Confirming the great diversity of methods which have been developed for T/F transfer Report 363 now includes details of the results obtained in the USSR using (two-way) time transfer by reflection from meteor trails; accuracies in the range 20-30 ns have been obtained over path lengths of about 1000 km. Two-way satellite time is in regular use between NIST and the US Naval Observatory yielding a precision of less than 1 ns in measurements lasting 100 s. Non-radio techniques using telephone lines are also described where only moderate (~ 1 ms) accuracy is required. Great efforts over many years have been expended in the development of satellite dissemination and transfer and Report 518 includes the latest position regarding GPS and also the first definitive information on the equivalent Global Navigation System (GLONASS) being deployed by the USSR. Much of the information in this Report is incorporated in the Handbook on Satellite T/F Dissemination prepared under the terms of Decision 65.

4.4 *Time codes*

Time codes are now in widespread use not only by the stations listed in Tables I and II of Report 267 but by a variety of general broadcasting services. Thus, in western Europe several countries have activated the clock time (CT) option in their Radio Data Service (RDS). In addition to the codes adopted by the "dedicated" T/F stations Report 578 now includes details of the CT implementation in the United Kingdom RDS service. In this case the time is derived from MSF 60 kHz and this practice is in agreement with that advocated in the modified text of Recommendation 583 whereby the time-keeping of all operational time codes should be in agreement with UTC to within $\pm$ 1 ms. Narrow-band phase-modulation is the favoured technique for the dissemination of time codes on existing AM transmitters and the parameters for the codes carried by the LF transmitters in France and the United Kingdom, i.e. France-Inter on 162 kHz and Radio 4 on 198 kHz are included in Report 577.

5. Section 7D – Characterisation of sources and time scale information

The basic information document in this section – Report 364 on the performance of standard-frequency generators operating mainly in the microwave region – has been updated to include the latest results arising from the extensive programmes in many laboratories to improve the capabilities of atomic frequency sources, especially in the field of laboratory primary caesium standards but including also hydrogen masers, superconducting-cavity oscillators, ion storage devices and, at the upper end of the frequency range, the Mg beam standard at 601 GHz. The usefulness of the Report to the user in seeking to select a source to meet a prescribed system performance has been increased by the provision of improved plots of stability and phase spectral density for the commonly available sources as well as tabulated data on environmental sensitivities. Report 1152 characterises the phase spectral density of highly stable sources in the UHF-EHF bands obtained using synchronized oscillators. The methods of characterising frequency and phase noise are brought up-to-date in Report 580 including the use of "overlapping estimates" of the two-sample variance.

At the Interim Meeting it was the view of many delegates that Report 738 on frequency generators in the visible and sub-visible regions of the spectrum was in need of thorough revision and the Study Group therefore welcomed the offer of the French delegation to undertake this task. The reconstructed version of the Report now entitled "Frequency generators in the far infra-red, infra-red and visible light regions of the spectrum" was prepared by the Special Rapporteur, Dr. M. Granveaud (France), in consultation with colleagues in other administrations and approved at the Final Meeting. It is now a compact statement of the present position in this very large interval of frequency. The number of references has been greately reduced while still retaining all the significant publications in the field.

6. Relations with other international bodies

6.1 *Consultative Committee for the Definition of the Second (CCDS)*

The Committee met in April 1989 at the BIPM, Sèvres, preceded by a meeting of its Working Group on TAI and at both events I was privileged to present the views of CCIR. At the conclusion of its meeting the CCDS agreed a total of six Recommendations four of which, S1, S2, S4 and S5, were subsequently endorsed by the CIPM (Comité international des poids et mesures) Recommendation S1 addresses the same subject as Recommendation 685 in seeking to reduce offsets between UTC(k) and UTC but is somewhat less demanding in recommending that existing offsets be reduced "to the region of a few microseconds" rather than "± 1 µs" which is the desirable goal in the CCIR text. The other three Recommendations also reflect CCIR concerns in respect of the importance of the long-term stability of TAI and the possible influence of environmental conditions on the contributing clocks (S2); the need for improved accuracy and greater numbers in the primary clocks contributing to TAI (S4) and the necessity to define the reference coordinates of the antenna in the frame of the IERS in making use of precise one-way satellite time transfer (S5).

6.2 *CCITT activities related to timing* (Study Group XVIII)

The Special Rapporteur to CCITT Study Group XVIII, Dr. P. Kartaschoff (Switzerland), reported on those Recommendations in the G.800 series concerned with timing requirements including those of primary and slave clocks for plesiochronous working, synchronization issues, controlled slip rate objectives and the control of jitter and wander in digital networks. At the Final Meeting the Study Group also approved the terms of a liaison letter to CCITT on the possibilities of telephone time and frequency transfer.

6.3 *Global Positioning System (GPS)*

Dr. D. W. Allan (United States of America), the Special Rapporteur to the Civil GPS Service (CGS) drew attention at the Final Meeting to the implications for international time transfer following the introduction of "Selective availability" which could result in errors in the region of 30-50 ns. This could have major implications for the BIPM which is heavily dependent on the use of GPS signals in combining the indications of clocks distributed world-wide which contribute to the formation of TAI (and UTC). He outlined the steps which the CGS organisation plans to take in providing a precise satellite ephemeris, albeit some weeks in arrears, which should successfully eliminate the major part of such errors.

7. Acknowledgements

It is a pleasure to record the contribution of the Working Group Chairmen, Messrs. H. de Boer, R. J. Douglas, S. Leschiutta, P. K. Seidelmann and B. Sydnor to the success of the Interim and Final Meetings. Mr. G. de Jong acted as Rapporteur on both occasions while Messrs. A. Bates, T. L. Casado, B. Dubouis, P. Mackinlay and B. Sydnor participated in the Editorial Groups at one or both meetings. Thanks are due to the three Special Rapporteurs, Messrs. D. W. Allan, M. Granveaud and P. Kartaschoff and also to Mr. Ch. Stettler, CCIR Counsellor, for his support during this plenary period.

SECTION 7A: GLOSSARY

RECOMMENDATION 686*

GLOSSARY

(1990)

The CCIR,

CONSIDERING

(a) that it is essential for the work of the ITU and of the CCIs that terms should be used in a clearly defined and uniform manner;

(b) that there is a need for a common terminology for the unambiguous specification and description of frequency and time standard systems;

(c) the need to promote a consistent use of terminology in a growing community of users of frequency and time standard systems,

UNANIMOUSLY RECOMMENDS that the following terms be used:

accuracy; *exactitude*; *exactitud*

The degree of conformity of a measured or calculated value to its definition (see "uncertainty").

ageing; *vieillissement*; *envejecimiento*

The systematic change in frequency with time due to internal changes in the oscillator.

Note – It is the frequency change with time when factors external to the oscillator (environment, power supply, etc.) are kept constant.

atomic time scale; *échelle de temps atomique*; *escala de tiempo atómico*

A time scale based on atomic or molecular resonance phenomena.

calibration **; *étalonnage*; *calibración*

The process of identifying and measuring offsets in instruments and/or procedures.

Note – In many cases, e.g. in a frequency generator, the calibration is related to the stability of the device and therefore its result is a function of time and of the averaging time.

clock; *horloge*; *reloj*

A device for time measurement and/or time display.

clock time difference; *différence entre temps d'horloge*; *diferencia de tiempo de reloj*

The difference between the readings of two clocks at the same instant.

Note – In order to avoid confusion in sign, algebraic quantities should be given, applying the following convention. At a time T of a reference time scale, let a denote the reading of a time scale A, and b the reading of a time scale B; the time scale difference is expressed by $A - B = a - b$ at the instant T. The same convention applies to the case where A and B are clocks.

coherence of frequency; *cohérence de fréquence*; *coherencia de frecuencia*

See "coherence of phase".

coherence of phase; *cohérence de phase*; *coherencia de fase*

Exists if two periodical signals of frequency M and N resume the same phase difference after M cycles of the first and N cycles of the second, M/N being a rational number, obtained through multiplication and/or division from the same fundamental frequency.

* The Director, CCIR, is requested to bring this Recommendation to the attention of the CCITT and the International Organization for Standardization (ISO).

** These definitions differ from those in the IEV, but Study Group 7 is of the opinion that they are more appropriate for the standard-frequency and time-signal service.

coordinated clock; *horloge coordonnée*; *reloj coordinado*

A clock synchronized within stated limits to a reference clock which is spatially separated. (See also Report 439, which deals with the concept of coordinate time.)

coordinate time; *temps-coordonnée*; *tiempo-coordenada*

The concept of time in a specific coordinate frame, valid over a spatial region with varying gravitational potential (see Report 439).

Note – If a time scale is realized according to the coordinate time concept, it is called a coordinate time scale.

Example: TAI is a coordinate time scale. Its reference is the surface of the rotating geoid.

coordinated time scale; *échelle de temps coordonnée*; *escala de tiempo coordinada*

A time scale synchronized within stated limits to a reference time scale.

Coordinated Universal Time (UTC); *temps universel coordonné*; *Tiempo Universal Coordinado*

The time scale, maintained by the BIPM and the International Earth Rotation Service (IERS), which forms the basis of a coordinated dissemination of standard frequencies and time signals (see Recommendation 460).

It corresponds exactly in rate with TAI, but differs from it by an integral number of seconds. The UTC scale is adjusted by the insertion or deletion of seconds (positive or negative leap seconds) to ensure approximate agreement with UT1.

date; *date*; *fecha*

The reading of a specified time scale.

Note – The date can be conventionally expressed in years, months, days, hours, minutes, seconds and fractions thereof. Also, "Julian Date" (JD) and "Modified Julian Date" (MJD) are useful dating measures (see "Julian Date" and "Modified Julian Date").

drift (implying frequency drift); *dérive*; *deriva*

The systematic change in frequency with time of an oscillator.

Note – Drift is due to ageing plus changes in the environment and other factors external to the oscillator (see ageing).

DUT1; *DUT1*; *DUT1*

The value of the predicted difference UT1 – UTC, as disseminated with the time signals. DUT1 may be regarded as a correction to be added to UTC to obtain a better approximation to UT1. The values of DUT1 are given by the IERS in integral multiples of 0.1 s (see Universal Time).

error *; *erreur*; *error*

The difference of a value from its assumed correct value.

frequency *; *fréquence*; *frecuencia*

If T is the period of a repetitive phenomenon, then the frequency $f = 1/T$. In SI units the period is expressed in seconds, and the frequency is expressed in hertz.

frequency deviation *; *écart de fréquence*; *desajuste de frecuencia*

The difference of the frequency from the nominal frequency value.

frequency difference; *différence de fréquence*; *diferencia de frecuencia*

The algebraic difference between two frequency values.

frequency drift *; *dérive de fréquence*; *deriva de frecuencia*

See "drift" and "ageing".

* These definitions differ from those in the IEV, but Study Group 7 is of the opinion that they are more appropriate for the standard-frequency and time-signal service.

frequency instability; *instabilité de fréquence*; *inestabilidad de frecuencia*

The spontaneous and/or environmentally caused frequency change within a given time interval.

Note – Generally one distinguishes between systematic effects such as frequency drift effects and stochastic frequency fluctuations. Special variances have been developed for the characterization of these fluctuations. Systematic instabilities may be caused by radiation, pressure, temperature, humidity, etc. It is typically dependent on the measurement system bandwidth and/or on the sample time or integration time. Random or stochastic instabilities are typically characterized in the time-domain and/or frequency-domain (Recommendation 538).

In many contexts the expression "stability" instead of "instability" is used. This usage is acceptable.

frequency offset; *décalage de fréquence*; *separación de frecuencia*

The systematic frequency difference between the realized value and the nominal frequency value.

frequency shift; *déplacement de fréquence*; *desplazamiento de frecuencia*

An intentional frequency change.

frequency stability; *stabilité de fréquence*; *estabilidad de frecuencia*

See "frequency instability".

frequency standard; *étalon de fréquence*; *patrón de frecuencia*

A generator, the output of which is used as a frequency reference.

Note – See "Primary frequency standard" and "Secondary frequency standard".

instant; *instant*; *instante*

A point in time.

International Atomic Time (TAI); *temps atomique international*; *Tiempo Atómico Internacional*

The time scale established by the Bureau international des poids et mesures (BIPM) on the basis of data from atomic clocks operating in several establishments conforming to the definition of the second, the unit of time of the International System of Units (SI).

Julian Date (JD); *date julienne (DJ)*; *Fecha Juliana (FJ)*

The Julian Day Number followed by the fraction of the day elapsed since the preceding noon (12h00 UT).

Example: The date 1900 January 0.5 d UT corresponds to JD = 2 415 020.0.

Note – The Julian Date is conventionally referred to UT1, but may be used in other contexts, if so stated.

Julian day number; *numéro de jour julien*; *número de día juliano*

The number of a specific day from a continuous day count having an initial origin of 12h00 UT on 1 January 4713 BC, Julian proleptic Calendar (start of Julian Day zero).

Example: The day extending from 1900 January 0.5 d UT to 1900 January 1.5 d UT has the number 2 415 020.

leap second; *seconde intercalaire*; *segundo intercalar*

An intentional time step of one second used to adjust UTC to ensure approximate agreement with UT1. An inserted second is called positive leap second and an omitted second is called negative leap second (see Recommendation 460).

Modified Julian Date (MJD); *date julienne modifiée*; *Fecha Modificada del Calendario Juliano*

Julian Date less 2 400 000.5 days (see Recommendation 457).

Modified Julian Day

Integer part of Modified Julian Date.

nominal value *; *valeur nominale*; *valor nominal*

A specified or intended value independent of any uncertainty in its realization.

Note – In a device that realizes a physical quantity, it is the specified value of such a quantity. It is an ideal value and thus it is free from tolerance.

normalized frequency; *fréquence normée*; *frecuencia normalizada*

The ratio between the actual frequency and its nominal value.

normalized frequency deviation; *écart de fréquence normé*; *desajuste de frecuencia normalizado*

See "normalized value".

normalized frequency offset; *décalage de fréquence normé*; *separación de frecuencia normalizada*

See "normalized value".

normalized frequency difference; *différence de fréquence normée*; *diferencia de frecuencia normalizada*

See "normalized value".

normalized frequency drift; *dérive de fréquence normée*; *deriva normalizada de frecuencia*

See "normalized value".

normalized offset; *décalage normé*; *separación normalizada*

See "normalized value".

normalized value; *valeur normée*; *valor normalizado*

The ratio of a value to its nominal value.

Note 1 – This definition can be used in connection with: frequency, frequency deviation, frequency difference, frequency drift, frequency offset, etc.

Note 2 – In place of the term "normalized", the term "relative" is acceptable but the term "fractional" is to be avoided.

offset *; *décalage*; *separación*

The systematic difference between the realized value and the nominal value. (See also "Normalized offset".)

phase; *phase*; *fase*

Generally in a periodic phenomenon, analytically described by a function of time (or space), the phase is any possible and distinguishable state of the phenomenon itself.

It can be identified through the time of its occurrence, elapsed from a specified reference, to be called correctly "phase time" (frequently abbreviated to "phase"). Particularly, if the phenomenon is sinusoidal, the phase can be identified either by the angle or by the time, both measured from an assigned reference, depending on the dimensions assigned to the reference period (namely 2π or T).

In the standard-frequency and time-signal service, phase-time differences are mainly considered, i.e. time differences between two identified phases of the same phenomenon or of two different phenomena.

phase shift; *déphasage*; *desplazamiento de fase*

An intentional change in phase from a reference.

phase deviation; *décalage de phase*; *desviación de fase*

The difference of the phase from a reference.

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* These definitions differ from those in the IEV, but Study Group 7 is of the opinion that they are more appropriate for the standard-frequency and time-signal service.

precision; *précision*; *precisión*

The degree of mutual agreement among a series of individual measurements; often, but not necessarily, expressed by the standard deviation.

primary frequency standard; *étalon primaire de fréquence*; *patrón primario de frecuencia*

A frequency standard whose frequency corresponds to the adopted definition of the second, with its specified accuracy achieved without external calibration of the device.

Note – The second is defined as follows:

"the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium atom-133." (XIII[e] Conférence générale des poids et mesures, 1967.)

primary clock; *horloge primaire*; *reloj primario*

A time standard which operates without external calibration (see "time standard").

proper time; *temps propre*; *tiempo propio*

The local time, as indicated by an ideal clock, in a relativistic sense (see Report 439).

Note – This is distinguished from a coordinate time, which involves theory and computations.

If a time scale is realized according to the proper time concept, it is called a proper time scale.

Examples:

a) for proper time: the second is defined in the proper time of the caesium atom;

b) for proper time scale: a time scale produced in a laboratory, not transmitted outside the laboratory.

reproducibility; *reproductibilité*; *reproductibilidad*

a) With respect to a set of independent devices of the same design, it is the ability of these devices, to produce the same value.

b) With respect to a single device, put into operation repeatedly without adjustments, it is the ability to produce the same value.

Note – A usual measure of the lack of reproducibility is the standard deviation.

resettability *; *fidélité*; *reposicionabilidad*

It is the ability of a device to produce the same value when specified parameters are independently adjusted under stated condition of use.

Note – A usual measure of the lack of resettability is the standard deviation.

secondary frequency standard; *étalon secondaire de fréquence*; *patrón secundario de frecuencia*

A frequency standard which requires external calibration.

standard frequency; *fréquence étalon*; *frecuencia patrón*

A frequency with a known relationship to a frequency standard.

Note – The term standard frequency is often used for the signal whose frequency is a standard frequency.

standard frequency and/or time-signal station; *station de fréquence étalon et/ou de signaux horaires*; *estación de frecuencias patrón y/o de señales horarias*

A station which provides a standard-frequency and/or time-signal emissions.

standard-frequency emission; *émission de fréquences étalon*; *emisión de frecuencias patrón*

An emission which disseminates a standard frequency at regular intervals with a specified frequency accuracy.

Note – In Recommendation 460, the CCIR recommends a normalized frequency deviation of less than 1×10^{-10}.

standard frequency-satellite service; *service des fréquences étalon par satéllite*; *servicio de frecuencias patrón por satélite*

A radiocommunication service using earth satellites for the same purpose as those of the terrestrial standard frequency service.

* This term replaces the previous term "repeatability", considered as not pertinent to frequency generators, but to measuring procedures.

standard-time-signal emission; *émission de signaux horaires*; *emisión de señales horarias*

An emission which disseminates a sequence of time signals at regular intervals with a specified accuracy.

Note – In Recommendation 460, the CCIR recommends standard time-signals to be emitted within 1 ms with reference to UTC and to contain DUT1 information in a specified code.

synchronism; *synchronisme*; *sincronismo*

See "time scales in synchronism".

time; *temps*; *tiempo*

Note – In English "time" is used to specify an instant (time of day) or as a measure of time interval.

time comparison; *comparaison de temps*; *comparación de tiempos*

The determination of a time scale difference.

time code; *code horaire*; *código horario*

An information format used to convey time information.

time interval; *intervalle de temps*; *intervalo de tiempo*

The duration between two instants.

time marker; *repère de temps*; *marca de tiempo*

A reference signal enabling the assignment of dates on a time scale.

time scale; *échelle de temps*; *escala de tiempo*

A system of unambiguous ordering of events.

time scale difference; *différence entre échelles de temps*; *diferencia entre escalas de tiempo*

The difference between the readings of two time scales at the same instant.

Note – In order to avoid confusion in sign, algebraic quantities should be given, applying the following convention. At a time T of a reference time scale, let a denote the reading of a time scale A, and b the reading of a time scale B; the time scale difference is expressed by $A - B = a - b$ at the instant T. The same convention applies to the case where A and B are clocks.

time scales in synchronism; *échelles de temps en synchronisme*; *escalas de tiempo en sincronismo*

Two time scales are in synchronism, when they assign the same date to an instant.

Note – If the time scales are produced in spatially separated locations, the propagation time of transmitted time signals and relativistic effects – including the reference coordinate frame – are to be taken into account (see Report 439).

time scale reading; *lecture d'une échelle de temps*; *lectura de una escala de tiempo*

The value read on a time scale at a specific instant.

Note – The reading of a time scale should be qualified by giving the time scale name (see Recommendation 536).

time scale unit; *unité d'une échelle de temps*; *unidad de escala de tiempo*

The defining basic time interval in a time scale.

Note – This is to be distinguished from the realized time scale unit.

time-signal satellite service; *service des signaux horaires par satellite*; *servicio de señales horarias por satélite*

A radiocommunication service using earth satellites for the same purpose as those of the time-signal service.

time standard; *étalon de temps*; *patrón de tiempo*

a) A device used for the realization of the time unit.

b) A continuously operating device used for the realization of a time scale in accordance with the definition of the second and with an appropriately chosen origin.

time step; *saut de temps*; *salto de tiempo*

A discontinuity in a time scale at some instant.

Note – A time step is positive (+) if the time scale reading is increased, and negative (–) if the reading is decreased at that instant.

uncertainty; *incertitude*; *incertidumbre*

The limits of the confidence interval of a measured or calculated quantity.

Note – The probability of the confidence limits should be specified, preferably by the one sigma value.

Universal Time (UT); *temps universel*; *Tiempo Universal*

Universal Time (UT) is the general designation of time scales based on the rotation of the Earth. In applications in which a precision of a few tenths of a second cannot be tolerated, it is necessary to specify the form of UT such as UT1, which is directly related to the rotation of the Earth as explained in Recommendation 460.

Universal Time Coordinated (UTC); *temps universel coordonné*; *tiempo universal coordinado*

See "Coordinated Universal Time", which is an equivalent expression.

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SECTION 7B: SPECIFICATIONS FOR THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICES

RECOMMENDATION 374-3

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

(1951-1953-1956-1959-1963-1966-1970-1974)

The CCIR,

CONSIDERING

(a) that the World Administrative Radio Conference, Geneva, 1979, allocated the frequencies 20 kHz ± 0.05 kHz, 2.5 MHz ± 5 kHz (2.5 MHz ± 2 kHz in Region 1), 5 MHz ± 5 kHz, 10 MHz ± 5 kHz, 15 MHz ± 10 kHz, 20 MHz ± 10 kHz and 25 MHz ± 10 kHz, to the standard-frequency and time-signal service;

(b) that the same Conference allocated the following frequencies for use by the standard-frequency and time-signal satellite service:

400.1 MHz ± 25 kHz,
4202 MHz ± 2 MHz (Space-to-Earth),
6427 MHz ± 2 MHz (Earth-to-space),
13.4 to 14.0 GHz (Earth-to-space),
20.2 to 21.2 GHz (Space-to-Earth),
25.25 to 27.0 GHz (Earth-to-space),
30.0 to 31.3 GHz (Space-to-Earth);

(c) that additional standard frequencies and time signals are emitted in other frequency bands;

(d) the provisions of Article 33 of the Radio Regulations;

(e) the continuing need for close cooperation between Study Group 7 and the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), the General Conference of Weights and Measures (CGPM) and the concerned Unions of the International Council of Scientific Unions (ICSU),

UNANIMOUSLY RECOMMENDS

1. that CCIR Study Group 7 continue its study of world-wide standard-frequency and time-signal services and explore the application of new techniques for this purpose;

2. that existing standard-frequency and time-signal services be operated in conformity with the detailed Recommendations of the CCIR;

3. that increased efforts be made to reduce the mutual interference between emissions in the allocated bands of item *(a)* above;

4. that all administrations consider alternative methods of disseminating standard frequencies and time signals before adding new emissions in bands 6 and 7.

RECOMMENDATION 375-2

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS IN ADDITIONAL FREQUENCY BANDS

(Question 2/7)

(1959-1963-1966-1982)

The CCIR,

CONSIDERING

(a) that for many purposes a world-wide time synchronization with an uncertainty of less than 1 ms is required;

(b) that precise intercontinental frequency comparisons have been achieved by the use of the frequency-stable emissions operating in band 4;

(c) that time comparisons with an uncertainty of about 1 μs are possible at distances greater than 2000 km by means of pulsed ground-wave signals;

(d) that line-of-sight transmissions in bands 8 and 9, and predominantly ground-wave signals in band 5, provide means of distributing time signals and standard frequencies;

(e) that precise continental and intercontinental frequency and time comparisons have been achieved by the use of satellite techniques;

(f) that new methods for time and frequency comparisons may be developed, using laser techniques,

UNANIMOUSLY RECOMMENDS

1. that the results and methods of measurements of phase instabilities over paths in bands 4 and 5, should be published;

2. that advantage be taken of pulse ground-wave navigation systems, for establishing intercontinental and possibly world-wide time synchronization;

3. that appropriate stations, existing in bands 5 and 6, should be employed as much as possible for distributing standard frequencies by precise control of their carrier frequencies;

4. that existing frequency-modulation sound-broadcasting stations and television stations in bands 8 and 9 should be employed as much as possible for distribution of standard frequency and time signals, which can be added to, or make use of, the existing modulation (including sub-carrier modulation), without interference to the normal programme;

5. that satellite systems, not specifically devoted to the standard-frequency and time-signal service, should be designed to include, whenever possible, standard-frequency and time-signal information or to allow the transmission of time signals.

RECOMMENDATION 376-1

AVOIDANCE OF EXTERNAL INTERFERENCE WITH EMISSIONS OF THE STANDARD-FREQUENCY SERVICE IN THE BANDS ALLOCATED TO THAT SERVICE

(Question 1/7)

(1959–1963–1966)

The CCIR,

CONSIDERING

(a) the importance and increasing use of standard-frequency and time-signal emissions in the allocated bands;

(b) that interference reduces the usefulness of the standard-frequency and time-signal service to a serious degree;

(c) that, despite the efforts made by administrations and the IFRB to clear the standard-frequency bands, some registered users, and many unnotified emissions, remain in these bands, which continue to cause interference with the standard-frequency services,

UNANIMOUSLY RECOMMENDS

1. that to avoid external interference, administrations and the IFRB should continue their efforts to clear the standard-frequency bands;

2. that, in the territory under its jurisdiction, each administration should make every effort to prevent all users of the radio-frequency spectrum from operating other stations in the standard-frequency bands, capable of causing harmful interference to the standard-frequency service;

3. that national monitoring stations should carry out a regular search for external interfering stations in the standard-frequency bands and should make every effort to identify each interfering station, if necessary with international cooperation;

4. that, in each case of external interference, the users of standard-frequency emissions should request the monitoring service of their own country to identify the interfering station;

5. that, in cases of external interference with the standard-frequency service, administrations should apply the provisions of Articles 18, 19, 21 and 22 of the Radio Regulations, and, if desired, should send a copy of relevant correspondence to the IFRB;

6. that, when interference is observed in the standard-frequency bands, even if the source cannot definitely be identified, representatives of administrations, participating in the work of Study Group 7, should exchange information from users of standard-frequency and time-signal transmissions and from the monitoring service. This may later permit identification of the interfering station.

RECOMMENDATION 457-1

USE OF THE MODIFIED JULIAN DATE BY THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICES

(Question 1/7)

(1970–1974)

The CCIR,

CONSIDERING

(a) that for dating purposes a decimal day count is desirable in connection with the use of radio time signals and radio time codes;

(b) that a decimal day count with reference to Universal Time, the Julian Date (JD), has long been established for dating in astronomy, chronology and related sciences;

(c) that a decimal day count is necessary, by which the start of a day is defined at 0000 hours and not at 1200 hours as in the case of the Julian Date;

(d) that a decimal day count is necessary, in particular in association with the time scales UTC and TAI;

(e) that it is necessary to avoid a proliferation of different dating systems;

(f) that a simple change from the Julian Date mentioned above to a modern decimal day count would be advantageous;

(g) that the existing and established Julian Date, based on the start of the day being Greenwich Mean Noon, should be continued without break;

(h) that a Modified Julian Date (MJD), which meets the requirements stated above, is already in use,

UNANIMOUSLY RECOMMENDS

1. that for modern timekeeping and dating requirements, wherever necessary, a decimal day count should be used; the calendar day should be counted from 0000 hours TAI, UTC or UT and be specified by a number with five significant figures;

2. that this "Modified Julian Date" (MJD) equals the Julian Date less 2 400 000.5 and therefore has its origin, in the case of UT, at 0000 hours UT, 17 November 1858.

RECOMMENDATION 458-2

INTERNATIONAL COMPARISONS OF ATOMIC TIME SCALES

(Question 1/7)

(1970-1978-1990)

The CCIR,

CONSIDERING

(a) the need for comparisons between independent local atomic time scales of various laboratories and observatories;

(b) the need for clarity, precision and the minimum delay in the communication of data so as to facilitate the work of the Bureau international des poids et mesures (BIPM) in forming International Atomic Time,

UNANIMOUSLY RECOMMENDS

1. that when a laboratory or observatory "k" keeps both independent local atomic time and an approximation to coordinated universal time, designated herein as TA(k) and UTC(k), the laboratory or observatory should publish the numerical expression of the difference TA(k) – UTC(k) for each period of validity;

2. that time markers having a negligible time departure from UTC(k) should be immediately accessible;

3. that the published time comparisons should relate to UTC(k);

4. that the published phase comparisons should relate to UTC(k);

5. that the published times of emission of radio time signals conforming to the UTC system should relate to UTC(k);

5.1 in the case of a radio time-signal emission generated directly by the laboratory or observatory "k", the measured delay between the time signals and UTC(k) should be published;

5.2 in the case of a radio time-signal emission controlled by a clock at the transmitting station and measured at the laboratory or observatory "k", it should be stated explicitly whether the published times in relation to UTC(k) refer to reception or emission and what corrections for propagation and receiver delays should be or have been applied;

6. that any laboratories or observatories not conforming to the UTC system, but desiring to take part in international comparisons and in the formation of International Atomic Time, should publish detailed data compatible, as far as possible, with the principles of § 1 to 5.

RECOMMENDATION 460-4

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

(1970–1974–1978–1982–1986)

The CCIR,

CONSIDERING

(a) that the World Administrative Radio Conference, Geneva, 1979, allocated the frequencies 20 kHz ± 0.05 kHz, 2.5 MHz ± 5 kHz (2.5 MHz ± 2 kHz in Region 1), 5 MHz ± 5 kHz, 10 MHz ± 5 kHz, 15 MHz ± 10 kHz, 20 MHz ± 10 kHz and 25 MHz ± 10 kHz to the standard-frequency and time-signal service;

(b) that additional standard frequencies and time signals are emitted in other frequency bands;

(c) the provisions of Article 33 of the Radio Regulations;

(d) the continuing need for close cooperation between Study Group 7 and the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), the General Conference of Weights and Measures (CGPM), the Bureau international des poids et mesures (BIPM), the International Earth Rotation Service (IERS) and the concerned Unions of the International Council of Scientific Unions (ICSU);

(e) the desirability of maintaining world-wide coordination of standard-frequency and time-signal emissions;

(f) the need to disseminate standard frequencies and time signals in conformity with the second as defined by the 13th General Conference of Weights and Measures (1967);

(g) the continuing need to make Universal Time (UT) inmmediately available to an accuracy of one-tenth of a second,

UNANIMOUSLY RECOMMENDS

1. that all standard-frequency and time-signal emissions conform as closely as possible to Coordinated Universal Time (UTC) (see Annex I); that the time signals should not deviate from UTC by more than one millisecond; that the standard frequencies should not deviate by more than 1 part in 10^{10}, and that the time signals emitted from each transmitting station should bear a known relation to the phase of the carrier;

2. that standard-frequency and time-signal emissions, and other time-signal emissions intended for scientific applications (with the possible exception of those dedicated to special systems) should contain information on the difference between UT1 and UTC (see Annexes I and II);

3. that this document be transmitted by the Director, CCIR, to all administrations Members of the ITU, to IMO, ICAO, the CGPM, the BIPM, the IERS, the International Union of Geodesy and Geophysics (IUGG), the International Union of Radio Science (URSI) and the International Astronomical Union (IAU);

4. that the standard-frequency and time-signal emissions should conform to RECOMMENDS 1 and 2 above as from 1 January 1975.

ANNEX I

TIME SCALES

A. Universal Time (UT)

Universal Time (UT) is the general designation of time scales based on the rotation of the Earth.

In applications in which an imprecision of a few hundredths of a second cannot be tolerated, it is necessary to specify the form of UT which should be used:

UT0 is the mean solar time of the prime meridian obtained from direct astronomical observation;

UT1 is UT0 corrected for the effects of small movements of the Earth relative to the axis of rotation (polar variation);

UT2 is UT1 corrected for the effects of a small seasonal fluctuation in the rate of rotation of the Earth;

UT1 is used in this document, since it corresponds directly with the angular position of the Earth around its axis of diurnal rotation. (GMT may be regarded as the general equivalent of UT.)

Concise definitions of the above terms and the concepts involved are available in the glossary of the annual publication, *The Astronomical Almanac* (US Government Printing Office, Washington DC and H.M. Stationery Office, London).

B. International Atomic Time (TAI)

The international reference scale of atomic time (TAI), based on the second (SI), as realized at sea level, is formed by the Bureau international des poids et mesures (BIPM) on the basis of clock data supplied by cooperating establishments. It is in the form of a continuous scale, e.g. in days, hours, minutes and seconds from the origin 1 January 1958 (adopted by the CGPM 1971).

C. Coordinated Universal Time (UTC)

UTC is the time-scale maintained by the BIPM, with assistance from the International Earth Rotation Service (IERS), which forms the basis of a coordinated dissemination of standard frequencies and time signals. It corresponds exactly in rate with TAI but differs from it by an integral number of seconds.

The UTC scale is adjusted by the insertion or deletion of seconds (positive or negative leap-seconds) to unsure approximate agreement with UT1.

D. DUT1

The value of the predicted difference UT1 – UTC, as disseminated with the time signals is denoted DUT1; thus DUT1 $\approx$ UT1 – UTC. DUT1 may be regarded as a correction to be added to UTC to obtain a better approximation to UT1.

The values of DUT1 are given by the IERS in integral multiples of 0.1 s.

The following operational rules apply:

1. Tolerances

1.1 The magnitude of DUT1 should not exceed 0.8 s.

1.2 The departure of UTC from UT1 should not exceed $\pm$ 0.9 s (see Note).

1.3 The deviation of (UTC plus DUT1) should not exceed $\pm$ 0.1 s.

Note – The difference between the maximum value of DUT1 and the maximum departure of UTC from UT1 represents the allowable deviation of (UTC + DUT1) from UT1 and is a safeguard for the IERS against unpredictable changes in the rate of rotation of the Earth.

2. Leap-seconds

2.1 A positive or negative leap-second should be the last second of a UTC month, but first preference should be given to the end of December and June, and second preference to the end of March and September.

2.2 A positive leap-second begins at 23h 59m 60s and ends at 0h 0m 0s of the first day of the following month. In the case of a negative leap-second, 23h 59m 58s will be followed one second later by 0h 0m 0s of the first day of the following month (see Annex III).

2.3 The IERS should decide upon and announce the introduction of a leap-second, such an announcement to be made at least eight weeks in advance.

3. Value of DUT1

3.1 The BIH is requested to decide upon the value of DUT1 and its date of introduction and to circulate this information one month in advance. In exceptional cases of sudden change in the rate of rotation of the Earth, the IERS may issue a correction not later than two weeks in advance of the date of its introduction.

3.2 Administrations and organizations should use the IERS value of DUT1 for standard-frequency and time-signal emissions, 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 (except § 3.5 below):

- the magnitude of DUT1 is specified by the number of emphasized second markers and the sign of DUT1 is specified by the position of the emphasized second 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 if this is compatible with the format of the emission. Alternatively the coded information should be emitted, as an absolute minimum, after each of the first five identified minutes in each hour.

Full details of the code are given in Annex II.

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

3.5 DUT1 information primarily designed for, and used with, automatic decoding equipment may follow a different code but should be emitted after each identified minute if this is compatible with the format of the emission. Alternatively, the coded information should be emitted, as an absolute minimum, after each of the first five identified minutes in each hour.

3.6 Other information which may be emitted in that part of the time-signal emission designated in § 3.3 and 3.5 for coded information on DUT1 should be of a sufficiently different format that it will not be confused with DUT1.

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

3.8 The IERS is requested to continue to publish, in arrears, definitive values of the differences UT1 − UTC and UT2 − UTC.

ANNEX II

CODE FOR THE TRANSMISSION OF DUT1

A positive value of DUT1 will be indicated by emphasizing a number (n) of consecutive second markers following the minute marker from second marker one to second marker (n) inclusive; (n) being an integer from 1 to 8 inclusive.

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

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

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

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

The appropriate second markers may be emphasized, for example, by lengthening, doubling, splitting or tone modulation of the normal second markers.

Examples:

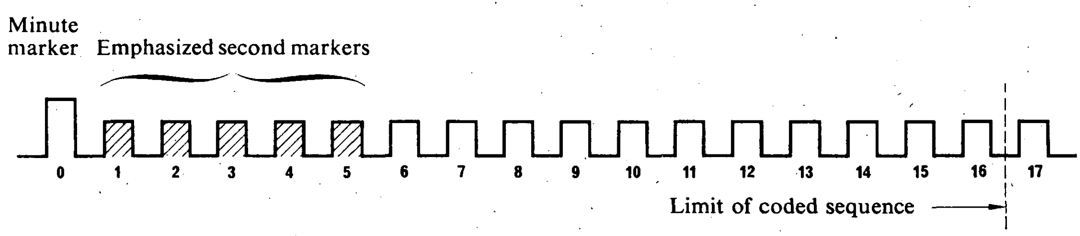

FIGURE 1

DUT1 = +0·5 s

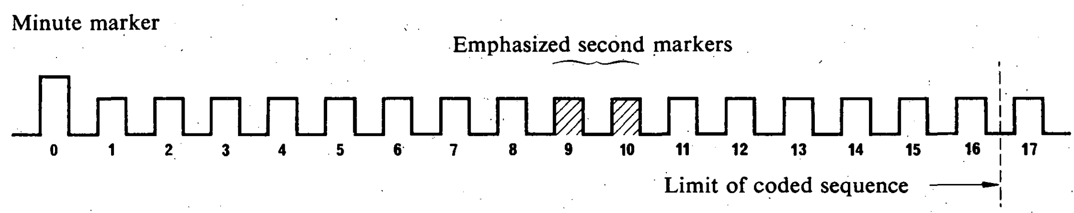

FIGURE 2

DUT1 = −0·2 s

ANNEX III

DATING OF EVENTS IN THE VICINITY OF A LEAP-SECOND

The dating of events in the vicinity of a leap-second shall be effected in the manner indicated in the following figures:

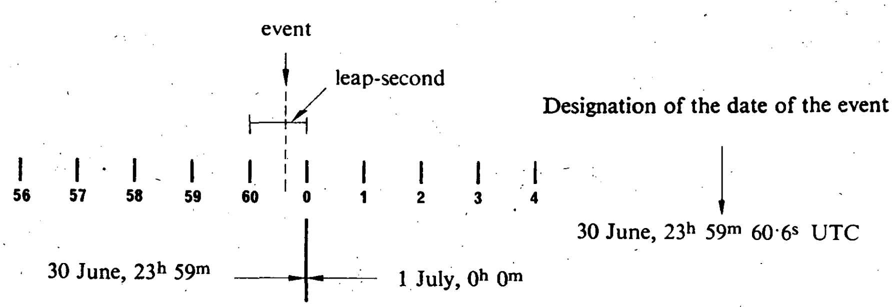

FIGURE 3 – *Positive leap-second*

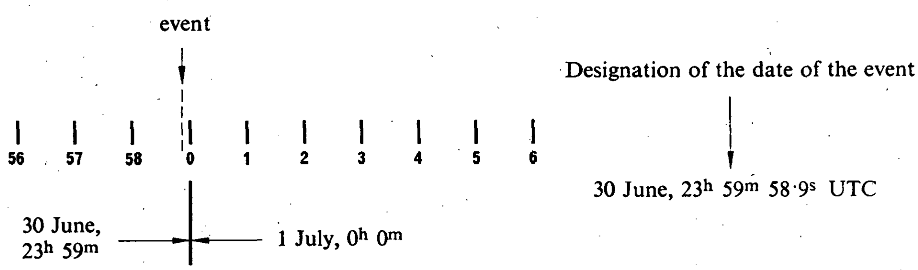

FIGURE 4 – *Negative leap-second*

RECOMMENDATION 485-2

USE OF TIME SCALES IN THE FIELD OF STANDARD-FREQUENCY AND TIME SERVICES

(Question 1/7)

(1974–1982–1990)

The CCIR,

CONSIDERING

(a) that the International Atomic Time scale has been defined by the General Conference of Weights and Measures, 1971;

(b) that in accordance with Recommendation 460, the UTC time scale has been generally accepted since 1972;

(c) that the World Administrative Radio Conference (Geneva, 1979), has decided that UTC shall be used in international radiocommunication activities;

(d) that UTC and TAI are closely related and differ only by a known integral number of seconds;

(e) that the time-service laboratories, in accordance with Recommendation 458, should relate datings to their own time scale UTC(k),

UNANIMOUSLY RECOMMENDS

that time data should be issued wherever possible either with reference to Coordinated Universal Time (UTC) or to International Atomic Time (TAI).

RECOMMENDATION 486-1 *

REFERENCE OF PRECISELY CONTROLLED FREQUENCY GENERATORS AND EMISSIONS TO THE INTERNATIONAL ATOMIC TIME SCALE

(Question 3/7)

(1974–1978)

The CCIR,

CONSIDERING

(a) that, for a user, data concerning the error of a standard-frequency and time-signal emission are of great importance;

(b) that the International Atomic Time scale (TAI) has considerable importance as a reference for time and frequency comparisons;

(c) that, in many cases, it is technically possible to adjust a radiated standard frequency so that the variations of phase with respect to TAI or Coordinated Universal Time (UTC) remain within a narrow tolerance $\pm \Delta t$, which is small compared to the period of the carrier frequency;

(d) that the TAI frequency and the UTC frequency are identical;

(e) that equipment is available which is capable of receiving several nearly synchronous emissions, thereby providing alternative operation in case of transmitter interruption;

(f) that there is a need for universally accepted reference frequencies for use in electronic systems;

(g) that there is an ever-increasing need for frequencies of high stability, particularly with regard to data transmission;

(h) that many new precisely controlled electronic systems (e.g. those controlled by atomic frequency generators) are now coming into use;

(j) that these systems can be better coordinated if they use a common frequency reference,

UNANIMOUSLY RECOMMENDS

1. that the UTC frequency (Ref. Recommendation 460) should be used as the ultimate reference for standard-frequency emissions;

2. that data concerning the accuracy of the standard frequency, with reference to the UTC frequency, should be an average of the relative frequency difference over 10 days or more;

3. that the range $\pm \Delta t$ over which the phase of the standard frequency can vary with reference to UTC should be specified for each LF and VLF emission and the values published by the Administrations responsible for the standard time and frequency services;

4. that the UTC frequency should also be used as the ultimate reference for other electronic systems.

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* The Director, CCIR is requested to bring this Recommendation to the attention of the CCITT.

RECOMMENDATION 535-1 *

USE OF THE TERM UTC

(Question 1/7)

(1978-1982)

The CCIR,

CONSIDERING

(a) that according to Recommendation 460 all standard-frequency and time-signal emissions should conform to the Coordinated Universal Time (UTC);

(b) that since 1972 UTC has been available as a world-wide time reference;

(c) that in 1975 the General Conference of Weights and Measures (CGPM) recommended the use of UTC as the basis of civil time;

(d) that other scientific organizations, particularly the International Astronomical Union (IAU) and the International Union of Radio Science (URSI) have recommended the general use of UTC;

(e) that UTC enables the time of events to be determined with an uncertainty of 1 μs;

(f) that according to Recommendation 536 and in accordance with the recommendation of the General Conference of Weights and Measures the designation UTC is to be used in all languages,

(g) that the World Administrative Radio Conference (Geneva, 1979) has decided that UTC shall be used in international radiocommunication activities,

UNANIMOUSLY RECOMMENDS

that UTC should be used to designate the time in all other international telecommunication activities and in all official documents of the International Telecommunication Union.

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* The Director, CCIR, is requested to bring this Recommendation to the attention of the Joint Advisory Group of the Institute of Navigation (JAG/ION), the International Astronomical Union (IAU), the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO) and the World Meteorological Organization (WMO).

RECOMMENDATION 536

TIME-SCALE NOTATIONS

(Question 1/7)

(1978)

The CCIR,

CONSIDERING

(a) that language independent time-scale notations should be introduced;

(b) that the XIVth General Conference of Weights and Measures (CGPM) in October 1971 defined the International Atomic Time, using the designation TAI;

(c) that the XVth CGPM in May 1975 recommended the use of Coordinated Universal Time, using the designation UTC,

UNANIMOUSLY RECOMMENDS

1. that for all forms of atomic time, the following notations consistent with TAI be used in all languages:

TAI: International Atomic Time, as formed by the BIPM,

TA: atomic time; general designation of a time variable which may be realized on the basis of an atomic or molecular transition,

TA(k): atomic time-scale, as realized by the institute "k";

2. that for all forms of Universal Time, the following notations consistent with UTC be used in all languages:

UT: Universal Time,

UTC: Coordinated Universal Time; this time-scale is maintained by the BIPM and the IERS, according to Recommendation 460,

UTC(k): time-scale realized by the institute "k" and kept in close agreement with UTC,

DUT1: predicted difference UT1 – UTC, as disseminated with time signals.

Note – The Director, CCIR, is asked to transmit this Recommendation to the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), the General Conference of Weights and Measures (CGPM) and also to the International Union of Radio Science (URSI), the International Astronomical Union (IAU), the International Union of Geodesy and Geophysics (IUGG), the International Union of Pure and Applied Physics (IUPAP), the Bureau international des poids et mesures (BIPM), the International Earth Rotation Service (IERS), the International Organization for Standardization (ISO) and the International Association of Institutes of Navigation (IAIN).

ANNEX I

1. Where there may be danger of confusion, UTC (BIPM) may be used instead of UTC.

2. Different forms of UT are listed in Annex I of Recommendation 460.

3. Except for TA, which refers to a principle and not to a specific time-scale, the notations may also be used for characterizing time instants and time-scale differences.

Examples:

(1) 1975 January 1, 0^h UTC

(2) TAI − UTC = 14s, 1975 July 1, 0^h UTC

(3) UTC(k) − UTC = 1 μs, 1976 February 24, 0^h UTC

4. TAI and UTC are evaluated in arrear and are only accessible by means of corrections (published by the BIPM) to existing (realized) time-scales such as TA(k) or UTC(k) including extrapolation.

5. According to Recommendation 458, UTC(k) should be a realized time-scale.

RECOMMENDATION 685*

INTERNATIONAL SYNCHRONIZATION OF UTC TIME SCALES

(Question 1/7)

(1990)

The CCIR,

CONSIDERING

(a) that Recommendation 460 only requires time-signal emissions to be synchronized to UTC to within 1 ms, but also that they should conform to UTC "as closely as possible";

(b) that each timing centre's UTC(k) should be in close agreement with UTC (Recommendation 536);

(c) that the lack of synchronization between the UTC(k) time scales, typically of a few microseconds, causes confusion and difficulty among some users;

(d) that there is an increasing number of users, in communication systems, navigation systems, radioastronomy and geodesy, requiring world-wide synchronization at the few nanoseconds level,

UNANIMOUSLY RECOMMENDS

1. that each timing centre, within the constraints of their operational requirements, pursue improved methods, digital servo techniques, and algorithms for synchronizing their UTC(k) to UTC, one microsecond being a desirable goal;

2. that timing centres, as appropriate, pursue the improvement of the long-term stability of their clocks and of associated methods used to generate their UTC(k);

3. that the timing centres in synchronizing their UTC(k) should seek to coordinate their efforts with the BIPM.

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* The Director of the CCIR is requested to bring this Recommendation to the attention of the Director of the CCITT, the President of the CIPM and of the Director of the BIPM.

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SECTION 7C: SYSTEMS FOR DISSEMINATION AND COMPARISON

RECOMMENDATION 582-1

TIME AND FREQUENCY REFERENCE SIGNAL DISSEMINATION AND COORDINATION USING SATELLITE METHODS

(Question 2/7)

(1982–1990)

The CCIR,

CONSIDERING

(a) that applications for time and frequency reference signals in such areas as navigation, communications and space exploration require time and frequency services with improved coverage, accuracy, and reliability of reception;

(b) that substantial improvements in existing terrestrial time and frequency dissemination and coordination services are, in many cases, technically or economically impractical;

(c) that, because of such limitations, some HF services are being eliminated;

(d) that experiments performed to date using satellite-based techniques for time and frequency dissemination and synchronization have demonstrated significantly improved accuracy, precision, coverage, reliability, and operational convenience;

(e) that the number of satellite systems and vehicles that are potentially available to carry time and frequency signals is increasing rapidly;

(f) that a number of promising satellite systems or techniques for time and frequency dissemination and coordination, including LASSO, television broadcasting satellites, communication satellites, meteorological satellites, the Global Positioning System, and TRANSIT, will be available for evaluation during the next few years offering many opportunities for participation by time and frequency laboratories;

(g) that many time and frequency satellite experiments to date have indicated the advantages of having on-site satellite receiving capabilities at the time and frequency laboratories in order to eliminate the additional uncertainties introduced by auxiliary time-transfer links;

(h) that the Consultative Committee for the Definition of the Second (CCDS) in its Declaration S1 (1989) has asked the BIPM to coordinate the use of two-way satellite links for precise and accurate time transfer,

UNANIMOUSLY RECOMMENDS

1. that organizations interested in, or responsible for, time and frequency reference signal dissemination and coordination participate to the maximum extent possible in experiments to evaluate the relative merits of various satellite-based techniques for improved time and frequency transfer;

2. that time and frequency laboratories establish on-site satellite receiving (and transmitting, if appropriate) capabilities to the maximum extent possible;

3. that satellite-based techniques be given serious consideration in the development of any new time and frequency dissemination and/or coordination services.

RECOMMENDATION 583-1

TIME CODES

(Question 7/7)

(1982-1990)

The CCIR,

CONSIDERING

(a) that in many branches of science and technology there is a need for the dating of events which requires knowledge of the date (year, month, day) and clock time;

(b) that this information can be transmitted in coded form at relatively low bit rates;

(c) that such coded transmissions require relatively small bandwidths resulting in economic spectrum use and enhanced reliability in the received information;

(d) that such codes are in increasingly widespread use and can be disseminated by both AM and FM broadcast services in appropriate data channels without impairing the prime service;

(e) that it is important that such sources of time reference should conform with the standard for time signal emissions (see Recommendation 460);

(f) that commercial production now exists of low-cost radio-controlled clocks, operating from services in band 5, for both public and private use,

UNANIMOUSLY RECOMMENDS

1. that this form of time dissemination should be encouraged;

2. the introduction of new services in areas not adequately served and also the employment of existing transmitters for time code dissemination;

3. that when a time code is operational its time-keeping should conform to the standard laid down in Recommendation 460, i.e., the disseminated time should not differ from UTC by more than 1 ms;

4. that where a new service of time code dissemination is introduced its format (coding and modulation) should conform when practicable with an existing service (see Report 578).

RECOMMENDATION 537

REDUCTION OF MUTUAL INTERFERENCE BETWEEN EMISSIONS OF THE STANDARD-FREQUENCY AND TIME-SIGNAL SERVICE ON THE ALLOCATED FREQUENCIES IN BANDS 6 AND 7

(Study Programme 1A/7)

(1978)

The CCIR,

CONSIDERING

(a) the provisions of Article 33, of the Radio Regulations;

(b) that mutual interference in the standard-frequency and time-signal service is the subject of continuing study;

(c) that additional standard-frequency and time-signal stations in bands 6 and 7 are likely to be required in areas of the world not yet adequately served;

(d) that the principal characteristics of the ionosphere may be satisfactorily modelled,

UNANIMOUSLY RECOMMENDS

1. that the provisions of Article 33 of the Radio Regulations should be applied with a view to improving coordination and the elimination of possible cases of interference;

2. that where mutual interference exists at present the IFRB, at the joint request of the relevant administrations, should carry out simulation studies to determine whether a compatible frequency/time sharing solution can be realized;

3. that, in pursuance of these studies, the full details of all standard-frequency and time-signal emissions, including the power fed to the antenna, the antenna configuration, orientation, height above ground, ground constants etc., should be made available to the IFRB.

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SECTION 7D: CHARACTERIZATION OF SOURCES AND TIME SCALES FORMATION

RECOMMENDATION 538-1*

FREQUENCY AND PHASE STABILITY MEASURES

(Question 3/7)

(1978-1990)

The CCIR,

CONSIDERING

(a) that there is a need for an adequate language with which to communicate the stability characteristics of standard frequency sources;

(b) that major laboratories, observatories, industries, and general users have already adopted some of the Recommendations of the Sub-Committee on Frequency Stability of the Technical Committee on Frequency and Time of the IEEE Society on Instrumentation and Measurement and the existence of the IEEE Standard No. 1139-1988 on "IEEE Standard Definitions of Physical Quantities for Fundamental Frequency and Time Metrology";

(c) that frequency stability measures should be based on sound theoretical principles, conveniently usable, and directly interpretable;

(d) that it is desirable to have frequency stability measures obtainable with simple instrumentation,

UNANIMOUSLY RECOMMENDS

1. that the random instabilities of standard frequency signals should be characterized by the statistical measures $S_y(f)$, $S_\varphi(f)$ or $S_x(f)$, and $\sigma_y(\tau)$ as defined below:

1.1 the measure of the normalized frequency instabilities $y(t)$ in the frequency domain is $S_y(f)$; i.e. the one-sided spectral density $(0 < f < \infty)$ of the normalized frequency instabilities $y(t) = (\nu(t) - \nu_0)/\nu_0$, where $\nu(t)$ is the instantaneous carrier frequency, and ν_0 is the nominal frequency;

1.2 the measure of the phase instabilities $\varphi(t)$ in the frequency domain is $S_\varphi(f)$; i.e. the one-sided spectral density $(0 < f < \infty)$ of the phase instabilities $\varphi(t)$ at a Fourier frequency f;

1.3 the measure of the phase instabilities expressed in time units (phase-time) $x(t)$ in the frequency domain is $S_x(f)$; i.e. the one-sided spectral density $(0 < f < \infty)$ of phase-time instabilities $x(t)$, where $x(t) = \varphi(t)/2\pi\nu_0$; $x(t)$ being related to $y(t)$ by $y(t) = \mathrm{d}x(t)/\mathrm{d}t$;

1.4 the relationships of the above spectral densities are given below:

$$S_y(f) = \frac{f^2}{\nu_0^2} S_\varphi(f) = 4\pi^2 f^2 S_x(f) \qquad (1)$$

The dimensions of $S_y(f)$, $S_\varphi(f)$ and $S_x(f)$ are respectively Hz^{-1}, $\mathrm{Rad}^2\mathrm{Hz}^{-1}$ and $\mathrm{s}^2\mathrm{Hz}^{-1}$;

1.5 the measure of the normalized frequency instabilities $y(t)$ in the time domain is the two-sample standard deviation, $\sigma_y(\tau)$, as defined in Annex I;

* See Report 580 for more complete details.

2. that, when stating statistical measures of frequency instability, non-random phenomena should be recognized, e.g.:

2.1 any observed time dependency of the statistical measures should be stated;

2.2 the method of measuring systematic behaviour should be specified (e.g. an estimate of the linear frequency drift was obtained from the coefficients of a linear least squares regression to M frequency measurements, each with a specified averaging or sample time τ and bandwidth f_h);

2.3 the environmental sensitivities should be stated (e.g. the dependence of frequency and/or phase on temperature, magnetic field, barometric pressure, etc.);

3. that, when stating a measure of frequency stability, all relevant measurement parameters should also be specified:

3.1 the method of measurements;

3.2 the characteristics of the reference signal;

3.3 the nominal signal frequency ν_0;

3.4 the measurement system bandwidth f_h and the corresponding low pass filter response;

3.5 the total measurement time or number of measurements M;

3.6 the calculation techniques (e.g. details of lag-windows when estimating power spectral densities from time domain data, or the assumption of the effect of dead-time in estimating the two-sample standard deviation $\sigma_y(\tau)$);

3.7 the confidence of the estimate;

4. that a graphic illustration or an analytic expression of the measures of the frequency instabilities should be provided and should include confidence intervals (i.e. $S_y(f)$, $S_\varphi(f)$ and $S_x(f)$ as a function of f and/or $\sigma_y(\tau)$ as a function of τ).

ANNEX I

DEFINITION OF THE TIME-DOMAIN MEASURE

The two-sample standard deviation* $\sigma_y(\tau)$ is defined as:

$$\sigma_y(\tau) = \left(< \frac{(\overline{y}_{k+1} - \overline{y}_k)^2}{2} > \right)^{\frac{1}{2}} \tag{2}$$

where

$$\overline{y}_k = \frac{1}{\tau} \int_{t_k}^{t_k+\tau} y(t)\,\mathrm{d}t \tag{3}$$

τ is the averaging time with zero dead-time between successive measurements,

k is an index number such that $t_{k+1} = t_k + \tau$, and

$< >$ denotes an infinite average.

For a finite number M of measurements of $\overline{y}_k$, an estimate of the two-sample standard deviation is given by:

$$\hat{\sigma}_y(\tau) \simeq \left[\frac{1}{2(M-1)} \sum_{k=1}^{M-1} \left(\overline{y}_{k+1} - \overline{y}_k \right)^2 \right]^{\frac{1}{2}} \tag{4}$$

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* The square of the two-sample standard deviation is the two-sample variance (also known as pair variance or two-sample Allan variance).

RESOLUTION 14-4

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS

(Question 1/7)

(1963–1966–1970–1974–1986)

The CCIR,

CONSIDERING

the provisions of Article 33 of the Radio Regulations,

UNANIMOUSLY DECIDES

1. that, whenever an assignment to a station operating standard-frequency emission is put into service, the administration concerned shall notify this assignment to the IFRB, in accordance with the provisions of Article 12 of the Radio Regulations; however, no notice should be submitted to the IFRB until experimental investigations and coordination have been completed, in accordance with Article 33, of the Radio Regulations;

2. that, in addition, each administration should send all pertinent information on standard-frequency stations (such as frequency stability, changes in the phase of time pulses, changes in transmission schedule) to the Chairman, Study Group 7, to the Director, CCIR, and, for official publication, to the Director, BIPM;

3. that Study Group 7 should cooperate with the International Astronomical Union (IAU), the International Union of Radio Science (URSI), the International Union of Geodesy and Geophysics (IUGG), the International Union of Pure and Applied Physics (IUPAP) and the Bureau international des poids et mesures (BIPM) and the International Committee of Weights and Measures (CIPM).

OPINION 26-2

STUDIES AND EXPERIMENTS CONCERNED WITH TIME-SIGNAL EMISSIONS

(Question 1/7)

(1966–1970–1974)

The CCIR,

CONSIDERING

(a) that the standard-frequency and time-signal emissions are used in many fields of pure and applied science;

(b) that Study Group 7 frequently needs the advice of the scientific unions and organizations,

IS UNANIMOUSLY OF THE OPINION

1. that the General Conference of Weights and Measures (CGPM), the Bureau international des poids et mesures (BIPM), the International Union of Radio Science (URSI), the International Astronomical Union (IAU), the International Union of Geodesy and Geophysics (IUGG), and the International Union of Pure and Applied Physics (IUPAP) should be asked to cooperate with CCIR Study Group 7;

2. that the Chairman, Study Group 7, should communicate with the Director, BIPM, and with the Chairmen of the appropriate Commissions of URSI, the IAU, the IUGG, the CGPM and the IUPAP, and that the Director, CCIR, should be informed.

OPINION 27

STANDARD-FREQUENCY AND TIME-SIGNAL EMISSIONS IN ADDITIONAL FREQUENCY BANDS

(Question 2/7)

(1966)

The CCIR,

CONSIDERING

(a) that in certain areas, particularly in industrial centres, it is not always possible to obtain an adequate signal-to-noise ratio with the existing standard-frequency and time-signal service;

(b) that a better service is needed in certain areas and this service may be given by use of frequencies in band 8 and higher,

IS UNANIMOUSLY OF THE OPINION

that each administration should, as far as possible, provide for the distribution of standard frequencies and time signals, on a local basis, two bands 100 kHz wide in bands 8 and 9 respectively, the centre frequencies of which should be whole multiples of 5 MHz.

OPINION 28

SPECIAL MONITORING CAMPAIGNS BY THE IFRB WITH A VIEW TO CLEARING THE BANDS ALLOCATED EXCLUSIVELY TO THE STANDARD-FREQUENCY SERVICE

(1966)

The CCIR,

CONSIDERING

(a) the results of the special monitoring campaigns organized by the IFRB, with a view to clearing the bands allocated exclusively to the standard-frequency service;

(b) the need for achieving a more complete clearance of those bands;

(c) the difficulty experienced by the IFRB in identifying stations not belonging to the standard-frequency service, but operating in the standard-frequency bands,

IS UNANIMOUSLY OF THE OPINION

1. that the IFRB should be asked to increase, as far as practicable, the number of special monitoring programmes per year, covering the bands allocated exclusively to the standard-frequency service;

2. that the IFRB should urge administrations of countries where direction-finding facilities are available to take bearings with a view to determining the position of the stations observed.

OPINION 71-1*

DOCUMENTATION OF TIME TRANSMISSIONS

(Question 1/7)

(1982–1986)

The CCIR,

CONSIDERING

(a) that the transmitted time signals have been kept within various accuracy limits by the introduction of steps or changes in the rate over the past twenty-five years;

(b) that each administration furnishes current information concerning adjustments to frequency and time signals in accordance with Article 33, No. 2771 of the Radio Regulations and CCIR Resolution 14;

(c) that there have been different values of the steps and changes of the rates in the different countries during the period 1955 to 1972, and that the relevant details are not readily available;

(d) that these data will be necessary for the analysis of long-term phenomena,

IS UNANIMOUSLY OF THE OPINION

that all administrations operating a standard-frequency time-signal service should document the details of adjustments to frequencies and time scales in the period 1955 to 1972 and specifically should publish the amount and date of time steps and rate changes in their emissions and also communicate the data to the Bureau international des poids et mesures (BIPM) and to the World Data Centres A, B and C.

ANNEX I

ADDRESSES OF THE WORLD DATA CENTRES

World Data Centre A: WDC-A, Rotation of the Earth
c/o US Naval Observatory
34th Massachusetts Avenue NW
WASHINGTON, DC 20390
United States of America

World Data Centre B: State Time and Frequency Commission
Gosstandart
Leninsky Prospect 9
MOSCOW 117049
USSR

World Data Centre C: Rutherford Appleton Laboratory
Chilton
DIDCOT
Oxon OX11 OQX
United Kingdom

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* The Director, CCIR, is requested to transmit this Opinion to the authorities responsible for standard-frequency and time-signal services listed in Report 267.

OPINION 72*

TIME DISSEMINATION USING METEOROLOGICAL SATELLITES

(Question 2/7)

(1982)

The CCIR,

CONSIDERING

(a) that needs are growing in many application areas, such as geodesy, geophysics, international time coordination, and many other types of coordinated scientific observations for reference time signals that are available world-wide on a highly reliable basis;

(b) that an accurate time code referenced to UTC has been successfully disseminated from two United States GOES meteorological satellites since 1975 and is finding increasing acceptance and use within the western hemisphere;

(c) that the European Meteosat satellites and the Japanese GMS satellites are part of the same world-wide meteorological satellite system as the United States GOES satellites and have similar data formats, including appropriate code bits reserved for possible time code use;

(d) that inexpensive receivers could be used in common with the GOES, Meteosat, and GMS satellites with little or no modification;

(e) that time and frequency organizations in Europe and Japan have expressed interest in implementing time codes on the Meteosat and GMS satellites,

IS UNANIMOUSLY OF THE OPINION

1. that the addition of a time code compatible with the GOES satellites to Meteosat and GMS satellites would provide a valuable world-wide time and frequency dissemination service useful in many applications and requiring no significant modifications to the satellite signal formats, space hardware, or ground equipment;

2. that the World Meteorological Organization should be asked to distribute this Opinion to its national organizations in appropriate countries;

3. that the European Space Agency should be asked to distribute this Opinion to appropriate organizations within Europe that are interested in the METEOSAT program.

* The Director, CCIR, is requested to bring this Opinion to the attention of the International Union of Geodesy and Geophysics (IUGG) and CCIR Study Group 2.

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