# The Role of the ITU-R in Time Scale Definition

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**ABSTRACT**

The International Telecommunications Union (ITU) is the leading United Nations agency for Radio and Telecommunications coordination worldwide. Overall frequency spectrum utilization is managed through Worldwide Radio Conferences, associated radiocommunication conferences and the Radiocommunication Study Groups. These Study Groups and Working Parties are devoted to specialized technical areas providing Member Nations the forum to participate, study and recommend standards to ensure equitable utilization and interference free radio operation. An important aspect of spectrum utilization is the underlying time and frequency determination and coordination established by the international time scale which is used by broadcast services throughout the world. This international time scale is Coordinated Universal Time (UTC). UTC is defined by the International Telecommunication Union (ITU-R) and is maintained by the International Bureau of Weights and Measures (BIPM) in cooperation with the International Earth reference and Rotation Service (IERS). The current definition of UTC is a stepped atomic time scale implemented in 1972 to permit UT1 to be recovered from broadcast values of UTC for celestial navigation. Today's telecommunications and navigation systems utilize continuous timing for their data streams, consequently deliberations have been ongoing within the ITU-R on the issue of modifying the definition of UTC to a continuous time scale.

## 1. INTRODUCTION

Before 1955 time was determined exclusively by astronomical observations that were the concern of the International Astronomical Union (IAU) and coordinated internationally by the Bureau International de l'Heure (BIH). Time radio broadcasts were beginning to find coordination across international boundaries to be problem in that the time actually being broadcast had multiple users and international implications. Since then atomic time has been born and merged with astronomical time to where atomic time is the primary international time scale and astronomical time is a measure of the rotation of the earth determined by Very Long Baseline Interferometry measurements of selected astronomical radio point sources, satellite laser ranging and tracking of Global Positioning System (GPS) satellites. International coordination is now the concern of the International Telecommunications Union - Radiocommunications (ITU-R) Sector. Developments of new observational techniques based on Global Navigation Satellite Systems (GNSS) and other satellite based technology has completely replaced astronomical techniques for the international determination and coordination of time.

The measure and dissemination of time is becoming an increasing more important issue in today's electronic era. With the profusion of electronic devices, cell phones, personal computers, and GPS receivers that have become an essential part of our lives, they are all controlled by clocks and oscillators. These same devices then control and regulate, though perhaps only indirectly, our daily lives. These devices all measure time and time intervals that must be coordinated amongst themselves in order to function properly. How they measure time and are coordinated onto the same time is the purpose behind the establishment of Coordinated Universal Time (UTC) and maintenance of that time both nationally and internationally.

## 2. THE INTERNATIONAL TELECOMMUNICATIONS UNION (ITU)

ITU **i**s the United Nations agency for coordination of radio and communication spectrum and utilization issues. It is the global focal point for governments and the private sector in developing networks and services. For 145 years, ITU has coordinated the shared global use of the radio spectrum, promoted international cooperation in assigning satellite geostationary orbits, worked to improve telecommunication infrastructure in the developing world, and established the worldwide standards to foster seamless interconnection of the vast range of communications systems. Based in Geneva, Switzerland, the ITU membership includes 192 Member Nations and more than 700 Sector Members and Associates from the international commercial and scientific communities. Managing the international radio-frequency spectrum and geostationary satellite orbit resources is a primary concern of the ITU Radiocommunication Sector (ITU-R).

Major tasks of ITU-R also include developing standards for radiocommunication systems, ensuring the effective use of the radio-frequency spectrum and studies concerning the development of radiocommunication systems. The ITU Radio Regulations is an international treaty and its Table of Frequency Allocations are revised and regularly updated to keep pace with the enormous demand for spectrum utilization. The ITU World Radiocommunication Conference (WRC), which convenes every three to four years, is central to the international spectrum management process and constitutes the starting point for national practices. The WRC reviews and revises the Radio Regulations that establish the framework for the utilization of radio frequencies and satellite geostationary orbits among ITU member countries, and considers any question within its purview. The process is implemented through the establishment and activities of the Radiocommunication Study Groups. These groups establish a formalized series of questions, recommendations, reports, handbooks and opinions relevant to the technology and operation in the radio spectrum and satellite transmission parameters. There are currently seven Study Groups covering topics form spectrum management to coordination of the vocabulary. Study Group 7, Science Services has four working parties, the first of which is Working Party 7A (WP7A), Broadcast Time and Frequency Services.

## 3. ITU-R TIME AND FREQUENCY SERVICES

The WP7A is responsible for Time and Frequency Signal (TFS) services, both terrestrial and satellite. The WP7A develops and maintains Questions, the TF Series of Recommendations, Reports, Opinions and Handbooks covering the fundamentals of the TFS generation, measurements and data processing. The ITU-R Recommendations are of importance to telecommunication administrations and industry in fields, such as radio navigation, electric power generation, space technology, scientific and metrological activities. Their documents cover the following topics: Terrestrial FTS transmissions, including HF, VHF, UHF broadcasts; television broadcasts; microwave links; coaxial and optical cables; space-based FTS transmissions, including navigation satellites; communication satellites; meteorological satellites; time and frequency technology, including frequency standards and clocks; measurement systems; performance characterization; time scales; time codes. A major recommendation administered by WP7A, ITU-R TF.460, Broadcast Time and Frequency Services, contains the definition of UTC [1]. The ITU-R then plays a central role in the definition, determination, and maintenance of UTC as the international organization involved with the regulatory aspects of the dissemination and coordination of time and frequency services and standards development [2]. Other organizations involved with TFS can be categorized as those dealing primarily with “metrological standards”, such as the Definition of the Second and those dealing with scientific aspects, such as the temporal relationship of the rotation of the Earth.

## 4. ORIGINS OF UTC

UTC originated as a result of the need to coordinate time being kept at the different timing centers throughout the world and coordinate the time broadcasts that they originated [3]. The rotation of the Earth was the basis for the definition of time scales until the mid-1960s. The Length of the Day (LOD) traditionally determined the length of the Second and it was well known by that time that the LOD was irregular. A more stable definition first sought was based on the orbital motion of the Earth around the Sun. That time scale, known as Ephemeris Time, promised a more stable definition but the advent of atomic standards rapidly overcame that definition. Atomic clocks offered a more accurate method of generating and maintaining time through the standardization of the “Second” from an astronomical variable to a fundamental constant based on atomic physics [4].

Atomic time maintained continuously in various laboratories since 1955 quickly become the basis of all time scales, although it was not formally adopted until 1971 as an international time scale [4]. Direct comparison of time keeping systems by means of radio transmissions became available in about 1961. The BIH, who was responsible for maintaining the then international time, Universal Time (UT), began taking measurements from long range navigation systems and other systems to “Coordinate” time between timing centers such as the initial Atomic Time (AT) generated locally in the U.K. and U.S., decoupled from the rotation of the Earth. The initial coordination was agreed through the CCIR in 1962 as “Coordinated Universal Time” [3, 4, 5]. The broadcast time signals from 1961 to 1972 attempted to maintain UTC to within 0.1 s of UT2 by both frequency offsets and sub-second steps. Close agreement was considered necessary because celestial navigation users required access to rotational time with an uncertainty of less than one second [3]. International Atomic Time (TAI) was recommended by the International Astronomical Union (IAU) in 1967, the International Union of Radio Science (URSI) in 1969 and the International Radio Consultative Committee (CCIR) of the ITU in 1970. The 14th General Conference on Weights and Measures (CGPM) approved the establishment of TAI in 1971 as the coordinate time scale whose unit interval is the Second of the International System of Units (SI) as realized on the rotating geoid [6].

## 5. COORDINATED UNIVERSAL TIME (UTC)

The present UTC system was defined in 1972 [3] and specified UTC = TAI + n seconds, where n is an integer number of seconds known as Leap Seconds and adjustments of the predicted differences of UT1 – UTC < 0.9 seconds, and DUT1 = UT1-UTC [1, 3]. It is in effect a “stepped” atomic time scale. The rate of UTC is determined by TAI so that the basic time interval is the SI second. One second steps, either positive or negative, are then applied to maintain the difference with UT1 within 0.9 seconds. Producing UTC this way is a compromise in providing both the SI second and an approximation to UT1 for celestial navigators to access by radio transmissions. Among the astronomical time scales only UT1 is actively maintained by the International Earth Rotation and Reference Service (IERS) as a difference value (UT1- UTC). The International Bureau of Weights and Measures (Bureau International des Poids et Mesures (BIPM)) assumed responsibility for maintaining TAI and consequently UTC, from the BIH in 1988. International Atomic Time (TAI) is the primary metrologic time scale from which all the other time scales are derived, in particular the relativistic time scales for scientific and astronomical references [7]. Terrestrial Time (TT) is the relativistic coordinate time scale derived from TAI as the fundamental time scale with the SI second as the scale unit on the Earth's rotating geoid [8]. UTC is derived from TAI as a compromise approximation of Universal Time (UT1).

## 6. THE QUESTION OF UTC

From issues raised within the ITU-R and a letter from the Director of the BIPM on behalf of the CCTF, a new question, ITU-R 236/7 (2000) "The Future of the UTC Timescale", was established by ITU-R WP7A. The question considering the future of UTC was considered to possibly have a significant impact on synchronization of communications networks, navigation systems and time distribution performance. With this potential impact and a need to focus, a Special Rapporteur Group (SRG) was formed to specifically address the future of UTC and related issues. Announced by letter from the ITU-R Radiocommunication Bureau on 8 Jan 2001, it invited participation and outlined the plan of action. It was distributed to the BIPM, CCTF, International Committee for Weights and Measures (CIPM), Committee on Space Research (COSPAR), IAU, International Civil Aviation Organization (ICAO), International Council of Scientific Unions (ICSU), International Maritime Organization (IMO), International Union for Geodesy and Geophysics (IUGG), International Union of Pure and Applied Physics (IUPAP), International Union for Radio Science (URSI), and World Metrological Organization (WMO). As a result participants from the CCTF, IAU and IUGG joined the SRG.

Coordination and technical exchange meetings were held to gather data on UTC utilization, to analyze usage, and to examine alternative approaches to reduce or eliminate any operational impact of UTC adjustments. Meetings were held in conjunction with international conferences dealing with time and frequency as well as special presentations to the Institute of Navigation and the Civil GPS Interface Committee [6, 10, 11]. Several bodies in the international community conducted surveys and information fact-finding independently from the SRG but the results did not provide any clear resolution [10]. The early efforts did not identify clearly defined user group(s) using UTC time information nor a consensual opinion on future utilization. Consequently, the SRG organized a special colloquium on the future of UTC for deliberating and exploring possible recommendations with representative organizations and contributing parties. At the Colloquium, representatives in the areas of International Timekeeping, Navigation, Earth Rotation, Telecommunications and Internet Timing were invited to deliver presentations pertinent to the issues and to engage in discussion [12].

Some members of the astronomical community have expressed great concern over any change to the current system. These concerns appear to stem from the use of UTC in lieu of UT1 in various embedded software. Similarly, the astrodynamic community concerned with the determination of orbital parameters of artificial satellites and other celestial bodies utilize UTC as an approximation of the Earth's Rotation Angle in much the same way for the same purpose. It is unclear how much or how little of this problem exists in currently operating systems.

The other concern expressed was the divergence between a continuous time scale and solar time producing an increasing error that may be an issue in "civil" timekeeping. The magnitude of the divergence has been estimated on the average as a few seconds over three years accumulating to an error of approximately one hour in the year 2600, as shown in Figure 7 [12]. One hour was considered appropriate it corresponds to daylight saving time adjustments in "civil" timekeeping.

## 7. ALTERNATIVES TO MODIFYING UTC

Several alternatives have been investigated concerning UTC. Some of the more significant ones are briefly discussed below.

Creation of another time scale, to be known as International Time (TI), was suggested to be the continuous time scale that would be a continuation of UTC only under a new name. Creation of a new name was not recommended. The use of TAI was suggested since it is an existing continuous time scale. Although UTC uses the rate of TAI, it is not disseminated. TAI is primarily maintained as a metrologic time scale the means of dissemination would need to be made available and standardized. Of the defined time scales, in fact only UTC is maintained and distributed for international timekeeping purposes.

A suggestion was make to simply adopt "GPS Time" as the official international time scale rather than creating another time scale or revising UTC since "GPS Time" is a continuous time and readily available. GPS has also become the primary method for time dissemination and would seem a logical alternative. However, "GPS Time" is fundamentally an internal system synchronization time. Its purpose is to maintain the elements of GPS precisely synchronized among themselves for precise navigation. The internal determination, possible frequent adjustments and constant steering are suitable for system use, but not inherently suitable to reproduce fundamental metrological standards, such as the SI second. Consequently, GPS Time is not suitable as an international standard for radio-communication purposes.

Serious consideration was given to a contribution proposing the maximum tolerance of DUT1, the difference between UT1 and UTC, be increased to one hour. This alternative was based on a similar concept of daylight saving time. This modification of standard time used by nations that is determined by national civil authority appeared to satisfy all civil requirements and concerns.

## 8. SUMMARY

The decision within the ITU-R to adopt a continuous time scale is still under consideration. A revision to this recommendation would occur at a World Radio Conference since the UTC definition is incorporated by reference into the Radio Regulations and therefore has treaty status. Within the formal ITU-R procedures the effective date of the revision would be determined at the World Radio Conference.

To change the realization of UTC and forfeit its close agreement with UT1 would make it available to the many applications where a continuous time reference is required. The timekeeping elements within a given system could be configured to provide a realization of UTC within the system. In those cases were possible, the system internal timekeeping might also directly contribute to the formation of UTC. Such an approach would internalize the international standard rather than using it as an external "steering" standard. Different systems could become inherently synchronized and thereby fundamentally compatible. A precise and accurate international time would no longer have to be external.

## 9. ACKNOWLEDGEMENTS

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