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Talking about leap second of UTC at 2020

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Abstract

A resolution about continuing Coordinate Universal Time (UTC) is drafted by Commission A of URSI. When soliciting advices before submitting the resolution to ITU-R, China Commit of URSI delivered an opposition comment. This opposition comment raised highly concern and a further debate upon whether the leap second should be added into UTC. Here, the issue of the UTC's leap second and time continuity is revealed, the views of supportive and oppositive are introduced, the initial and final drafts of statement by URSI are compared.

1 Introduction

UTC is the basis for civil time today. To achieve an coordinated universal time worldwide, when drafting and revising those time rules, an approximate agreement should be met among international organizations before introducing to governments. Standard frequencies and time signals could be disseminated to local areas when its time keeping standard is synchronized with UTC broadcast by BIPM and the local time zone shift is added[1]. In 2000, a debate about whether to add leap second afterward was raised by ITU-R[2]. In ITU conference 2008, 2009 and 2011, China had submitted written comments and oral speech expressing the opinion of keeping current UTC definition unchanged with leap second added. In the 2015 World Radio communication Conference (WRC−15), China voted for the decision of not adding leap second of UTC supporting the majority of participating countries[3]. However, leap second is still added to UTC till now.Since 1999 when ITU-R soliciting comments about leap second of UTC, Commission A of URSI has been an active participant. URSI provides a platform for scientists to freely expressing their opinions. In 2014, the draft of "keeping UTC consecutive without adding leap second" was agreed and this decision supported the adoption of resolution 655 in ITU WRC-15. Yet this resolution was not carried out.

2 Focus on time continuity

The issue about leap second is time continuity. One argument about leap second is that it makes time intervals uneven thus discontinuous[4]. We should think about this opinion from different perspectives.

TAI , adopting SI second as base unit, is a continuous time coordinate. And the metric of time axis are even without regards of relativity effect.Why do we prefer UTC to TAI? UTC is based on UT1, this 24-hour time standard concept and time regulation is deeply rooted among people. The unit and its conversion rule is more adaptable to nature cycles. The time the earth self rotating once is a day, the time the earth revolving around the sun once is a year. 60 is the multiple of 2, 3, 4, 5, 6, 10, 12, 15, 20, and 30. 1 minute has 60seconds. And the six decimal conversion is often used in uniform circular motion or constant periodic motion. It is more convenient for communication following those traditional timing regulations.

For astronomers, continuous time coordinates are adopted. To avoid the influence of leap year or leap month which makes time intervals uneven, Julian Day is introduced as the metric of time. Julian day is used in the Julian date (JD) system of time measurement, presenting the interval of time in days and fractions of a day since January 1, 4713 BC Greenwich noon. Because the starting point or reference epoch is so long ago, numbers in the Julian day can be quite large and cumbersome.

Physically, time is continuous. Globe navigation systems (GNSS) such as Beidou, GPS, adopt TAI second as base unit of time measurement which is continuous. They broadcast the deviation between GNSS time and UTC. GNSS's receiver calculate local UTC time from messages. The issue of discontinuity is not a concern in navigation systems.

The logic regulations and unit conversion rule make time intervals uneven resulting its discontinuity. The cause of time continuity should trace back to the differentiation of time in different coordinates while adopting the same base unit. Time and space are coexisted. Thus the definition of time should be confined to a specific space.

To facilitate astronomical observation and navigation, Earth-centered inertial (ECI) is introduced. It is an inertial coordinate which does not rotate with respect to the earth. ECI coordinate frames have their origins at the center of mass of Earth. And the time at the origin is called geocentric coordinate time (TCG). Time in this coordinate will be influenced by relativity effect except the origin and the infinite point, resulting in different ticking time. The geoid surface, which is an imaginary sea level surface, is defined as reference where the relativity effect is constant. TCG differs from TAI by a fixed speed's offset.

And SI second is the base unit of time in inertial coordinate system.

Another coordinate is non-inertial coordinate which is fixed to the earth ground and does rotate with respect to the earth. Universal Time (UT) is defined by observing sun's motion with the earth rotation axis as reference. So UT is a time in non-inertial coordinate. Time units such as second, minute, hour, day, month and year, and time units conversion are confined to this non-inertial coordinate, conforming periodic change and circle motion.

The second as base unit of time in the two coordinates system has the same value at the starting point of TAI but is different in essence. They have different definitions and should be confined to different space. Since the SI second was adopted, the concept of second defined in UT1 in non-inertial coordinate is introduced to inertial coordinate. Although it is no longer related with the earth self-rotation, time units including minute, hour, day, month and year are still used. Here comes the paradox that SI second in inertial coordinate is incompatible with time units in non-inertial coordinate. Just like repairing a machine changing only its driving gear without changing the rest ones, resulting in mismatch.

The simplest way to solve this problem is adding leap second. In inertial coordinate, adding leap second makes a minute with 61 seconds. The misuse of time unit raise the debate about discontinuity and non-linearity. Cause time units except for SI second were just literally introduced to inertial coordinate from non-inertial coordinate.

In non-inertial coordinate, leap second corrects the partial periodic difference of SI second in inertial coordinate in the earth self-rotation. Just like leap year and leap month, leap second corrects the partial periodic difference of the cycle it takes for the earth to orbit around the sun, which is 365.2425 days. And this regulation matches the periodic motion. In Theory of space metrology[5], "time in different coordinates is not synchronized". Argues about leap second lead to different conclusions in different coordinates.

3 First draft resolution of Commission A

To raise another voting about leap second at ITU-R and CCTF, Chairmen of URSI-Com A, Yasuhiro Koyama drafted URSI resolution for continuous UTC and solicited comments from members and officials of other Commissions. Chairmen of URSI-Com A China initiated an online discussion. 19 experts from different organizations including China National Institute of Metrology (NIM), National Time Service Center (NTSC), Beijing Satelite Navigation Center, BIRMM, BOIMT, and so on.

After a hot discussion among 19 experts, Two opinions were formed about UTC continuity. In view of majority experts, Com A China support the proposal that keep UTC as it is with leap second added and submitted the proposal to Chinese Insititute of Electronics (CIE). Wujian , chairmen of URSI China commitee of CIE, Taoran, Vice chairmen, Lin Runhua, secretary general, organized an online meeting and formed official opinions, as below:

"Leap second is needed in UTC. |UTC-UT1|<0.9s should be kept still with leap second inserted, till we find another method to deal with the problem of UT1 lost from standard time. So far, some experts, institutes and departments in China can not give an accurate or comprehensive evaluation of potential negative effects deleting leap second would bring about. Considering this situation, they suggest that it is not a good time to talk about this topic. They insisted that UT1 and UTC be disseminated with synchronization, since UT1 is still important for their control and measurement systems and softwares."

Since the deadline of soliciting comments on March 1, only one opposition comment was received from china. Chairmen Koyama attached great importance to this opposition comment since URSI is the only platform for radio science experts to express their opinions to ITU-R and CCTF. Therefore, an ad-hoc drafting group was initiated and members including Liu Min from BOIMT, Patrizia Tavella from BIPM, Demetrios Matsakis, former minister of USNO , Masterclock, USA . Deputies from USA, France, India, China, Japan, Israel, Italy and Mexico attended. And two experts, Tianchu Li, National Institute of Metrology, China and Carsten Rieck, Research Institutes of Sweden, Sweden joined as observers.

Citations and references should follow IEEE standards (as used by the *Radio Science Bulletin*). Citations can be of the form [1, 2] as is appropriate to the sentence, with the reference format illustrated at the end of this template.

4 Main opinions of experts in China

4.1 Opinions of those supporting canceling leap second

1) Leap second leads to non-linearity. Time intervals are uneven with leap second. Leap second poses a great challenge for precise measurement in astrology. For example, if UTC is adopted in pulsar observation coordinate, leap second might lead to its periodic flick. And leap second will bring trouble for computing software. Thus, uneven time intervals leads to non-linearity in measurement.

2) Unforeseeable future problem of leap second. The IERS provides information of Earth orientation, its website publishes data whether leap second is needed in the coming 6 months. It is possible to make approximate prediction of the number of leap seconds in the coming

30 years as long as we know rules of the tides and seasonal changes. Yet, just like the prediction of earthquake and hurricanes, it is hard to make precise measurement.

3) Difficulty for synchronization when adding leap second. Every country has its GMT time zone, and leap second is added on an agreed time point. For example, leap second is added at 7:59:59 to7:59:60 by NTSC. Since the time lag from dissemination to subscribers, there is great difficulty for synchronization. Then, a 1 second difference exists between those with clocks adjusted and those without. For those self-operated equipment such as submarine, aeroplane and satellite, it poses a potential danger.

4.2 opinions of those suggesting keeping leap second

1) Irreplaceability of UTC coordination. The word 'coordination' has two meanings. First, UTC is a time agreement achieved among industries and countries, an agreement commonly accepted. Secondly, UTC is a resolution to make up the difference between the earth rotation period and TAI. With the earth rotation slows down, the difference between our standard time and UT1 would be greater and greater without lap second added. The difference between UTC and UT1 would be accumulated to 1 hour 5000 years later. Thus, UTC's coordination is irreplaceable.

2) Conformity to people's daily life time. Time regulations were initially made according to the solar motion. Time tells us the position of the sun. without leap second, it would be hard for us to know the relation between time and astrology. Leap second has little effect for our daily life. The earth satellite navigation system is different from UTC. For example, leap second is not added in Beidou time(BDT). The difference between BDT and UTC is reported only for reference.

3) No substitute resolution right now. UTC is a common agreed standard time. So, a common agreement about not adding leap second should be achieved. Without this common agreement, it might pose severe consequences when some countries adopt it while others don't.

4) Dependency on IERS of UT1 users. Without information of the relationship between UTC and the earth rotation, we would rely on IERS. Fields including measurement of the earth reference coordinate such as the tracing software of astronomical telescope in the field of observation of celestial bodies, the control time of satellite launching or orbit changing, the GEO orbit maintaining, and some coordinated transfer algorithm and observation antenna angle scanning, and other research activities.

5 Voice from UT1's user

1) We knew that the scale interval on time coordinate axis of current UTC, such as minute, hour, day, and month and year, was not even. And the leap second inserted was hard to forecast accurately. The leap second of UTC was impossible to change simultaneously. These shortcomings bring some trouble to users who need a continuous time axis. But now this problem can be solved conveniently by current time dissemination technology, such as internet and satellite.

2) On the other hand, if UTC become continuous without leap second, it will bring another problem to users. UTC was already an agreement and was widely used as standard time, when user could get conveniently from UTC broadcast signal. There are two kinds of important messages included in the dissemination of UTC, the first message is the globe synchronized time and SI second, the second message is the information of earth oriental information (EOI), as UT1.

3) If UTC become continuous without leap second, then the information of UT1 will be lost from dissemination signal of UTC. The users who need UT1, can only turn to website such as WWW.iers.org[6,7]. How much load capacity could the website endure, and how to deal with the situation once website was blocked or broken down? It had no test reports. The hardware and software that had already relied on the dissemination signal of UTC must cost a large amount of money to get the information of UT1. The susceptible industry involved control and measurement related to earth rotation, for example, the automatic follow-up tracing software of astronomical telescope in the field of observation of celestial bodies, the control time of satellite launching or orbit changing, the GEO orbit maintaining, and some coordinated transfer algorithm and observation antenna angle scanning.

4) The globe navigation satellite system(GNSS), such as GPS, BDS, GLONASS and GALILEO, give users their GNSS time and the deviation from UTC in the broadcast text. If UTC is continuous without leap second, then the deviation value become a constant number, the information of UT1 will be also lost from broadcast text. Users who need UT1 will have difficulty to get access.

5) If no more leap second is inserted in UTC, which coordination will the time service system choose for dissemination? UTC or UT1? If the time service system considers the need of both users, they must research and develop new technology to disseminate continuous time and earth rotation time UT1 respectively. Or they have to deal with the problem of disseminating the information of UT1, then to discuss the topic of UTC continuity. Before we are fully prepared, it is better to keep the current state of UTC.

Anyhow, the problem of UTC and leap second may be not simply taken for granted that the continuous time is a more scientific standard time. Considering the significance of UT1 and earth rotation parameters, since

there is no good plan to solve those problems above yet, we decide to keep UTC the current state.

6 Final resolution of URSI-Commission A

After 19 days online discussion of ad-hoc, a compromised and common agreement was achieved.

The final resolution outcomes several changes. UTC is changed into reference time, avoiding disagreement with the definition of coordinated time. Concerns of the UT1 subscribers are expressed. Information of difference between UT1 and UTC is included in satellite navigation dissemination and network dissemination signals, which should be attached special focus for satellite navigation designers. Partial contents of draft list as below:

Resolves for URSI to make the following statements:

A) All GNSS are requested to consider broadcasting UT1 - UTC to a precision of a millisecond or better, within the constraints of their funding availability and development latencies. In addition, systems providing UT1 - UTC over the internet need to be hardened against cyber-attacks and should be supplemented with additional secondary sources that would meet the needs of users who only require knowledge of UT1 - UTC on the yearly basis;

B)Radio scientists of the International Union of Radio Science (URSI) have identified various risks caused by the adjustment of leap seconds on UTC that are not predictable over the long term. It was also found that a unique and continuous reference time scale is essential for the scientific research and the related activities in Radio Science. They also concluded that many of the technological concerns associated with the need of adapting systems and software can be solved, and that the challenge is justified compared to the scientific and operational benefits of a continuous reference time scale. Therefore, URSI's position is to withdraw the present limitation on the maximum magnitude of UT1 - UTC after a suitable period of public notice provided that real time UT1 - UTC dissemination is achieved and no fatal problem is identified by 2023.

7 Conclusion

Leap second in UTC is a topic in the international science community for more than 20 years. Deputies of China had expressed their opinions in ITU and CGPM supporting the majority for not keeping leap second in UTC. However, more and more schoolars realized the indispensable relationship between space and time and took a new review of its pros and cons. This time, a different suggestion was presented.

This year, when most of us are locked down during the Cov-19 pandemic, we had an online discussion with a wide variety of science organizations. Thanks for the development of the internet, this discussion was quite transparent and efficient. China was the only one submitting an opposition comment and URSI paid highly importance. The final resolution is a compromised result with Chinese experts' opinions taken into account. And this resolution expressed concerns of UT1 users.

8 References

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