UTC WORLDWIDE ADJUSTMENT

by

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It is the purpose of this paper to provide one more opportunity to remind you of the coming changeovers, to give you some of the reasons and details, to solicit questions, and to find out if you anticipate any problems.

To review the situation, it has become evident during the last couple of years, to those responsible for time-keeping, that one could not continue to allow the possibility of frequency changes every year. The old UTC system approximated UT 2, the astronomical mean solar time, by slight frequency changes in multiples of 50 parts in 10^{10}. If the system were not to be changed this coming January, we would now have to make one step of 100 milliseconds on 1 November, the first of this month. I am positive we would have had to announce a change in the frequency offset from 300 to 400 parts in 10^{10} because we have observed a continual retardation of the earth. I am telling you this in order to make you feel easier about the difficulties of the coming transition. What we are doing is taking this opportunity to make a last change, unless some of our successors again change their minds. I always have to admit this possibility because requirements do change. Still, I think it is going to be a good system. All timing systems will be on standard frequency without offset. This means that we will have to increase our frequency by 300 parts in 10^{10} on 1 January 1972. Approximate synchronization with universal time will be kept by introducing a leap second whenever it is necessary. At the present rate, that will become necessary for the first time at or before the end of next June. When we approach midnight of June 30, we will count 23 hours, 59 minutes, 50 seconds, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60. At the next second (61) it will be midnight and the beginning of the next month. The change will always be introduced as the last thing in the month. It is the intent of the Bureau International de L'Heure (BIH) to announce these steps well in advance. It is absolutely necessary that every nation conform to this, and it is anticipated that each will.

It is the intent to make these steps at the beginning of July and at the end of the year, when necessary. This will happen, on the average, once per year, but it may not be possible at all times to adhere to the dates because there is also an obligation to keep within a maximum tolerance of .7 seconds. This is considered an absolute upper limit and the intent is really to keep as much as possible within one-half second of universal time. Many users require universal time to a greater precision than this tolerance. The correction, the difference between the time signal and universal time, will refer you directly to UT 1 and not to UT 2 any more, because UT 1 is what the observer needs. It will be available by every means of communication; it will certainly be published in advance; it will be listed on our Time Service circulars, Bulletin #7; it will be broadcast by WWV, by WWVH, by every standard frequency station, and by every time signal. It was intended that the form in which this broadcast is made be standardized. Unfortunately, due to largely unforeseen difficulties, there will be at least three different formats in existence. Probably the most widely used will be the standard CCIR format in which the first seconds of every minute are marked by doubling. The number of marked seconds is counted. This gives the correction, in multiples of one-tenth of a second, which is to be applied to the time signal. If it is a minus correction, the marking will start at second 9 and continue through as many of the following seconds as necessary. This format will be applied on most of the standard frequency stations (standard in the sense that they operate on the standard frequencies designated for standard frequency dissemination; that is, 2-1/2, 5, 10, 15, 20 and 25 megahertz). It will also be used on CHU, Canada, on its several frequencies.

The CCIR format will definitely not be used on two time services: The Russian time service and the U.S. Navy time service. We intend to issue an addendum to the Time Service Announcement, Series 1, which gives all the time signals transmitted globally, and the exact format of the codes used[1]. The Russian code will be slightly different than the CCIR code because they intend to provide greater precision than one-tenth of a second. Their intent is to give multiples of 20 milliseconds, because that kind of precision is necessary for modern automatic celestial systems and geodetic operations.

The time service of the United States Navy is in a similar predicament. However, we have preferred, in the face of many boundary conditions and additional points of view, to use the alternative method allowed by the CCIR format which is to transmit the information in Morse.[2] This is possible because up to now there has been a gap between seconds 55 and 60 of every minute. This gap will be filled with an "A" and the Morse digit for "add" and an "S" with the Morse digit to "subtract." This is necessary because we have been notified by several elements of the U.S. Government that they are still thinking about a precision greater than one-tenth of a second. These requirements have to do with celestial navigation and the need to know the rotational position of the earth.

There has been an additional complication in the code which should be mentioned. That is the coming introduction of frequency shift keying (FSK) time signals. The Naval time signals are bound by the fact that on VLF stations it is impossible to provide voice code. One cannot announce the second or the minute or the time of day; one has to provide for a code and since the beginning of the Naval time signals (going back to the station here in Arlington), a so-called American code has been used for this purpose. This code is

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1. T.S.A. Ser 2 #14.

2. This is also done by the French time signals.

discussed in Time Service Announcements, Series #2. The American code gives a minute indication, and it consists of straight CW keying; high frequency stations and VLF stations are keyed from the same programming clock.

The advent of frequency shift keying has forced the Naval Research Lab, under Mr. Stone, to develop a FSK time signal format. The difficulty, technically, is due to the fact that a VLF antenna has a very narrow bandwidth. In the interest of efficiency, a VLF antenna has to be tuned to the carrier in the case of CW keying and to the center (between the "Mark" and "Space" frequency) in the case of FSK keying. This tuning is done between the two keying modes but it is very inconvenient for the station to shift the tuning before each time signal. In view of this, NRL put an experimental service on the station at Northwest Cape, Australia in February; FSK time signals are available on this station. I hear from NELC that these time signals can be picked up across the Pacific with a resolution of the order of ten microseconds. CW keying comes on/off with one megawatt of power radiated suddenly. The antenna must start ringing first, and after the signal is removed the antenna continues to ring. Therefore, it is clear that the true beginning of the signal cannot be recognized with great precision, and one millisecond is about what one could get. However, if keying is done by shifting the frequency, it is possible to resolve the transition from one frequency to the other with much greater precision, because the antenna is always under power. This provides the possibility of increasing the resolution to a degree which will allow cycle identification and, therefore, a more precise timing which is the additional benefit to be had from switching to FSK timing.

These changes, however, have put additional constraints on the selection of the time signal format. The NRL and the Naval Communications Command have undertaken a long series of audio tests. They used a number of receivers as phase track receivers and communication receivers and eliminated those formats which would not have been able to convey reliably the time tick information. At any rate, the ΔUT code will be available on most standard frequency transmissions.

At the moment of the changeover we will also make a small time step; we will retard all clocks by 107,600 microseconds. This number, incidentally is slightly different from the one announced by the BIH. The reason is that, at the moment, the Naval Observatory has accumulated a difference of roughly 150 microseconds against UTC as kept by the BIH. Since we incorporate these 150 microseconds, and have selected a round number to make it easy for operators at the stations, and since the time step will be a delay, we will accomplish another thing. We will have an epoch (the fraction of seconds only) in the new improved UTC which will be very close to International Atomic Time as kept by the BIH. The BIH in Paris uses the information from all major timing centers and produces a composite clock time scale known as International Atomic Time (IAT). The stepped form, or the adjusted form of this, is known as Universal Coordinated Time (UTC), and UTC will always differ from IAT in an exact number of seconds. Therefore, there will be two international time scales: one which will not suffer adjustments, the other which will be stepped exactly one second. It is clear that the major time services, and certainly the Naval Observatory, will attempt to anticipate the BIH international time scales (UTC) to as great a precision <u>and uniformity</u> as possible. This anticipation is necessary because IAT is not available in real time; it is available one month after the fact in the form of correction bulletins which are published by the BIH and distributed by the Naval Observatory in this country. However, this cannot be completely implemented in January; we will have to wait another half year or year. In the meantime, it is anticipated that some decisions will be reached jointly between the BIH and the contributing time services as to the necessary very small frequency changes. We intend to coordinate frequencies to within one part in 10^{13} so that we will stay together within very narrow tolerances. We have an excellent example of what can be accomplished in coordination in that which has been going on between the National Bureau of Standards and the Naval Observatory since October 1968. Since that year we have been together with a sigma of 2.5 microseconds. At the moment we are apart two sigmas.

In closing I come back to the possible applications. It is clear that electronic systems which refer to this coordinated time scale will be "on time" automatically. By participating in this time step and the frequency change, they will be reproducing and anticipating very closely the international coordinated time and/or the International Atomic Time. Some of these systems, for example Loran-C, should not be stepped, since there is no need to do so. Next June, when a step in our wall clocks will be made, the step will be done on paper in the Loran system because the new time-of-coincidence tables will go only to June, and in the July table of coincidences they will be shifted one second. Therefore, any operator tracking a Loran-C station will be synchronized and only has to set his wall clock. He does not have to set the receiver because the paper relationship, the time-of-coincidence tables, will reflect that change of the wall clock. It is, in my opinion, the simplest possible procedure, and it will do justice to the requirements of both time-keeping operations, astronomical or navigational and electronic on the other side.

This will also be the procedure to be followed by Omega. It will be a very attractive one because Omega will automatically be on International Atomic Time since the difference will be exactly ten seconds on 1 January; if we make the step adjustment of 107,600 microseconds, we will have the system very closely on International Atomic Time. This is important because the concept of that system is to have it operated as an international system, and it should be on an international time scale as precisely as possible.

Some confusion caused by the changes is inevitable; the greatest confusion and difficulty I see is in those stations which have to tune a crystal oscillator because a change of 300 parts in 10^{10} will be a serious interference with the standard operation of a crystal clock. It will affect the Transit system and Timation. Mr. Easton's satellite clock is not going to like that either, I'm afraid, but let's hope for the best; let's be prepared for it and if you see any difficulty or any other requirement, then please inform the Naval Observatory. We will try our best to assist in the changeover and to accomplish it as smoothly as possible. Many additional clock trips have been scheduled to provide the necessary additional service and confidence in the new system for those users who require high precision time.