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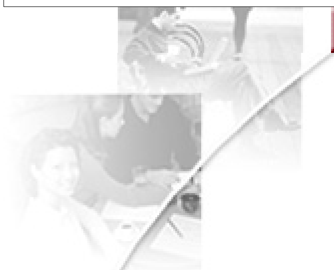

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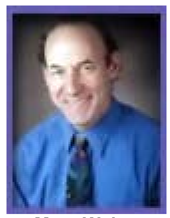
UTC, GPS Timing and Synchronization in Telecommunications

by visiting professor
Marc A. Weiss, Ph.D.
NIST, Boulder, CO



Marc Weiss
bio

Abstract
We review UTC as the timing reference for international telecommunications systems. UTC is most readily available and widely used in telecommunications by means of the Global Positioning System, GPS. There is an immediate need for telecommunications professionals to present requirements to the agencies developing the next generation of GPS called GPSIII. Since GPSIII is designed to last next 30 years, there is a current opportunity to enable telecommunications systems to access increased timing accuracy and stability. Read more...

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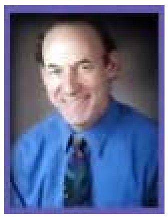

UTC, GPS Timing and Synchronization in Telecommunications

by Marc A. Weiss, Ph.D.
NIST, Boulder, CO

At the very outset I want to make an appeal for input from the telecommunications industry into requirements for GPSIII. The next generation of GPS, called GPSIII, is currently being designed. The new system, which is to last about 30 years, is being designed to meet both military and civilian requirements, whereas the current system was designed for military use only, with civilian use as an afterthought. Since GPS is the major source of timing for telecommunications systems, we have a window of opportunity to influence the future accuracy of timing for telecom. Requirements documented now could become realities without significant additional cost, whereas later they may be very expensive, or even impossible, to achieve.

Timing accuracies and stabilities for GPSIII will probably not be degraded from current levels. However, they may not be increased unless requirements for such improved timing are expressed. Although the GPSIII design process may continue in some form for years, the design specifications that will be written into the initial contract will probably be finalized in the fall of 2001. Hence it is imperative to provide input soon.

T1X1, the body that writes telecommunications standards associated with synchronization (as described in Sync 202), has decided to write a liaison letter to the agencies responsible for GPSIII specification. Any relationship that can be documented in some form between improved timing and an improved telecommunication service should be submitted. While it may turn out that such a service can be improved and marketed without improved GPS timing, there is no penalty for having better timing available. In addition, accuracy of timing available from GPS is related to the quality of the oscillator used. Existing timing levels might become available with less expensive oscillators if GPS timing signals were improved.

Thus we see two types of studies that could be significant:

1. relating specific improved services to GPS timing accuracy
2. relating decreased cost of existing services to GPS timing accuracy

Anyone who wants to contribute should contact either T1X1.3 leadership (**http://web.archive.org/web/20011023033033/http://www.t1.org/t1x1/_x13-off.htm**) or myself.

Let's go on with a discussion of timing and synchronization in telecom. These disciplines represent a field of science and engineering that is core to a wide range of technology, not just telecommunications. Whereas most of technology depends either directly or indirectly on time and frequency metrology, awareness and understanding of this field remains obscure. Often timing within systems is transparent when they are working, becoming visible, and painfully visible, only when they fail. A timing failure often brings down entire systems. I'm speaking generally here, though I know the focus of this talk is on sync in telecom. However, I'd like to start with a bigger picture.

Timing and synchronization are critical in many electronic systems, from telecommunications to household appliances to medical technology to combustion engines. We've all heard the expression, "timing is everything." It certainly seems that this is true. Metrology is the science of standards and measurements that support trade. Without standards and careful measurements, components produced in different places might not fit together, or might not be interoperable. By international agreement, scientists have established a set of basic units for metrology to support technological advance and commerce: the second, the kilogram, etc. The International Bureau of Weights and Measures, located just outside Paris France, has formalized these units into the International System of Units. Acronyms for these are usually with reference to the French words Bureau International des Poids et Mesures (BIPM) for the International Bureau of Weights and Measures, and le Système International d'Unités (SI) for the International System of Units. See **http://web.archive.org/web/20011023033033/http://www.bipm.fr/**.

The realization of the second is the most accurate measurement we make, thanks to the brilliant work of a number of physicists. The 1989 Nobel Prize in physics celebrates some of the discoveries that are core to atomic clocks. See **http://web.archive.org/web/20011023033033/http://www.nobel.se/physics/laureates/1989/index.html**. Technology based on the 1997 award for laser cooling, **http://web.archive.org/web/20011023033033/http://www.nobel.se/physics/laureates/1997**, has already produced frequency standards with accuracies of almost 1 part in 1015 for realizing the SI second. Because the second can be determined with such high accuracy, other units are often defined in terms of it. For example, the meter is defined as the distance light travels in a certain amount of time; and the volt and the ohm are measured in terms of the Josephson effect and the quantum Hall effect, respectively, both of which relate the unit to frequency. For more information about these units see the BIPM web site above.

Because of ever-present noise, all clocks walk off from each other in time, in principle, without bound. This is because all clocks are based on a physical system that produces frequency. Time is measured by counting up cycles of the frequency. Since all measurements of frequency contain some white noise, this integrates to a random walk of time error.

To establish an international standard of time we have picked one clock as the correct time. This "clock", a paper clock created by the BIPM, is a weighted average of the most stable clocks in the world, which is then steered in rate to the world's most accurate primary frequency standards. This is International Atomic Time, denoted as TAI. Leap seconds are applied once or twice per year to TAI to produce Universal Coordinated Time, abbreviated as UTC. Leap seconds keep atomic time within one second of Earth's period of rotation. The clocks providing stability to TAI are typically commercial cesium beam clocks or hydrogen masers. The primary frequency standards that provide accuracy to TAI are specially built in a few national labs. They are amazing devices based on the best physics we have, specially designed so that all known sources of inaccuracy can be characterized. One such clock is the cesium fountain clock at the National Institute of Standards and Technology (NIST) in Boulder, Colorado, U.S.A., where I work. This is denoted as NIST-F1.

UTC is the time and frequency standard used for all of telecom. It is perhaps ironic that UTC exists perfectly only after the fact. Each national lab produces its own signal that is its prediction of UTC. Since data must be collected from around the world and then processed and disseminated by the BIPM, we find out from the BIPM how far our predictions were off from UTC about one month later through a BIPM publication called "Circular T". We then steer our UTC to maintain our best prediction, using our local clocks for stability between updates of Circular T. The version of UTC predicted at NIST is denoted UTC (NIST). The U.S. Naval Observatory produces its own version called UTC(USNO). These two time-scales tend to stay within about 10 ns of each other. Currently, UTC is most readily available from GPS by means of a specially designed timing receiver (see Sync 203 for telecom sync reference application). This version of UTC is currently steered to UTC(USNO). There is some effort to develop UTC from GPS into its own independent prediction, UTC (GPS).

NIST provides a legal source of time and frequency in the U.S., and has the added responsibility of providing the best possible realization of the SI second for the U.S. NIST-F1 is currently one of the three most accurate frequency standards in the world. Legal traceability of time and frequency can be obtained from NIST through a number of services. NIST also co-sponsors with T1X1 an annual Workshop on Synchronization in Telecommunications Systems. Information about this workshop, NIST-F1, dissemination services, and other activities of the Time and Frequency Division can be obtained from http://web.archive.org/web/20011023033033/http://www.bldrdoc.gov/timefreq.

Biography of Marc Weiss

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Biographical Sketch

Marc A. Weiss, Ph.D.
NIST, Boulder, CO

Marc Weiss received his B.S. degree from Valparaiso University, Valparaiso, Indiana in 1973. He received his M.S. degree in Mathematics in 1975, and his Ph.D. in Mathematical Physics in 1981, both from the University of Colorado, Boulder, Colorado.

Dr. Weiss has worked at the National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards, NBS) in Boulder Colorado since 1978. He wrote the firmware for the NBS/GPS Time Transfer System for which he received the Applied Research Award of the NBS in 1983, along with the other principals. This receiver is still used in timing laboratories throughout the world for the generation of International Atomic Time through GPS common view time transfer. He also designed and wrote the firmware for the NIST Ionospheric Measurement System, a system that uses GPS signals in a codeless mode to measure the ionospheric delay. Dr. Weiss has been active in studying and developing time transfer systems especially using the Global Positioning System, for applications such as the generation of International Atomic Time. He also has led the NIST contract with the GPS program office for support of their clocks and timing systems.

In addition Dr. Weiss has specialized in new time scale algorithms, and in synchronization in telecommunications systems. He has worked on problems with Relativity as they relate to GPS and to primary frequency standards. He has spearheaded an annual Workshop on Synchronization in Telecommunications Systems, which is now co? sponsored each year by NIST and T1X1, the telecommunications synchronization standards committee.