GNSS Timescale Description

GPS

Definition of System

1. **System timescale: GPS Time**

2. **Generation of system timescale:**
   Clock ensemble of monitor station frequency standards and GPS satellite clocks.

3. **Is system timescale steered to a reference UTC timescale?**
   Yes

   a. **To which reference timescale:** UTC(USNO)

   b. **Whole second offset from reference timescale?**
      Yes, 15 seconds ahead of UTC as of 07/2010, with changes corresponding to the addition/subtraction of leap seconds

   c. **Maximum offset (modulo 1s) from reference timescale?**
      1 microsecond, typically within 10 nanoseconds

4. **Corrections to convert from satellite to system timescale?**
   Yes. **If yes:**

   a. **Type of corrections given; include statement on relativistic corrections**
      Quadratic coefficients broadcast as part of the GPS navigation message. The expression for relativistic correction is given in IS-GPS-200. This expression accounts for 1^{st} order deviations in eccentricity of individual GPS orbits from the mean orbital elements.

   b. **Specified accuracy of corrections to system timescale**
      part of the overall GPS system specification of user range error which is expressed as a combination of satellite position error and satellite clock error: 6 meter for legacy GPS. Typical errors are much better than this specification.

   c. **Location of corrections in broadcast messages**
      Subframe 1 of the legacy GPS navigation message.

d. **Equations to correct satellite timescale to system timescale**

a_f0 + a_f1(t-t_oc) + a_f2(t-t_oc)^2 + delta_t_r

$$a_{f0} + a_{f1}(t - t_{oc}) + a_{f2}(t - t_{oc})^2 + \Delta t_r$$

With: a_f0, a_f1, a_f2 = Quadratic coefficients
t = GPS system time
t_oc = Time of clock data
delta_t_r = Delta time due to relativistic correction

delta_t_r = F e sqrt(A) sin(E_k)

$$\Delta t_r = F e \sqrt{A} \sin(E_k)$$

With: F = -2 sqrt(mu) / c^2 = constant
mu = value of Earth's Universal gravitational parameters
c = Speed of Light
e = Eccentricity
A = Semi-major axis
E_k = Eccentric anomaly

5. **Corrections to convert from system to reference UTC timescale? If yes:**

   a. **Type of corrections given**

   Linear coefficients and leap second terms

   b. **Specified accuracy of corrections to reference timescale**

   40 nanoseconds (95 %), but typically within 10 nanoseconds. This is the accuracy of the UTC(USNO) offset data in the broadcast navigation message portion of the SPS SIS which relates GPS time (as maintained by the Control Segment) to UTC (as maintained by the U.S. Naval Observatory).

   c. **Location of corrections in broadcast messages**

   Subframe 4, page 18

   d. **Equations to correct system timescale to reference timescale**

   delta_t_utc = delta_t_LS + A_0 + A_1 (t_E - t_ot + 604800(WN-WN_t))

   With: delta_t_LS = delta time due to leap seconds
   A_0, A_1 = linear coefficients
   t_E = GPS time as estimated by the user

t_ot = Reference time for UTC data
WN = current week number
WN_t = UTC reference week number

6. **Specified stability of system timescale**
   Not specified

7. **Specified stability of reference timescale**
   UTC(USNO) stability of $3x10^{-15}$ per day

8. **Specified stability of satellite clocks**
   Not published, stability depends on block of satellite

9. **Availability of System to GNSS Time Offset (GGTO)**
   GPS plans to broadcast a GGTO correction as part of the modernized navigation messages.

   a. **Systems for which corrections are given?**
      Up to 7 GNSS systems

   b. **Type of GGTO corrections given**
      Quadratic coefficients

   c. **Stated accuracy of GGTO correction, if available**
      GPS has a stated goal of 5 ns (95 %) for a GPS to Galileo Time Offset. Accuracy of GGTO corrections to other systems will be highly dependent on each system's time scales predictability.

   d. **Location of corrections in broadcast messages**
      As specified in IS-GPS-200D, IS-GPS-705 and IS-GPS-800

   e. **Equations used for GGTO message**
      Similar to 4d without relativistic correction

Describe the details of the system, i.e. locations of system and reference timescale clocks, generation of timescales, and other details.
The GPS Master Control Station is located in Schriever AFB, Colorado, USA and GPS Time is computed as part of the overall clock and orbit estimation process. GPS operates 6 monitor stations regional distributed around the world in addition to using 6 monitoring stations operated by NGA. Each reference station receiver is referenced to a Cesium atomic clock. At two reference stations Hydrogen MASER clocks are used. These clocks

and the satellite clocks are ensembled to make GPS Time.

The oscillator frequencies onboard the GPS satellites have been offset from their nominal values in order to account for special and general relativistic effects with respect to ground-based observers so that the received frequencies at the Earth's surface are consistent with terrestrial time (e.g., UTC), assuming mean nominal GPS orbital elements.

Describe how the timescale transfers from the reference timescale to the system timescale and finally to the satellites. Include the nominal rate of SV updates.

USNO monitors the offset of GPS time from UTC(USNO) and reports this data to GPS Operations for use in timescale steering and UTC broadcast corrections. Satellites are nominally updated at least once per day.

If any other pertinent details exist concerning the generation and realization of system and/or reference time, include them as well.

GPS Time is realized by simultaneous L1 P(Y) and L2 P(Y) pseudorange observations used in a linear combination to remove the 1st order ionospheric propagation delay, according to IS-GPS-200. Users of other GPS signals must account for inter-signal biases to obtain the broadcast GPS Time consistently.