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 Message-Id: <200108150210.WAA28796@maia.usno.navy.mil>
 Subject: [GPST] a more stable IGS time scale
 To: jimr@maia.usno.navy.mil
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In-Reply-To: <200107251748.NAA26774@maia.usno.navy.mil>; from "Jim Ray" at Jul 25, 2001 1:48 pm
 X-Mailer: Elm [revision: 212.5]
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Dear Colleagues,

As you know, the IGS now distributes clock products for both satellites and tracking receivers, tabulated at 5-minute intervals and distributed in .clk RINEX-format daily files. Together with the .sp3 orbit files, these products provide users with sufficient information to determine consistent coordinates and clock values for an isolated GPS receiver at 5-minute intervals with an accuracy at the 5-cm level or so.

However, because the underlying time scale for the IGS combined clocks is based on a linear alignment to broadcast GPS time for each day separately, the day-to-day stability of the IGS clocks is very poor. Examples for the ALGO and USNO receiver clocks (both using external H-maser frequency standards) can be viewed at

<http://maia.usno.navy.mil/gpst/igs-comb/1087/plots/ALGO.1087.res.ps>
<http://maia.usno.navy.mil/gpst/igs-comb/1087/plots/USNO.1087.res.ps>
 where the very similar behavior of both reflects the common-mode effect of the time scale. This is a direct consequence of the limited stability of GPS time itself, which is illustrated at daily intervals in the plot
<http://maia.usno.navy.mil/gpst/igs-comb/utc-gps.circt.ps>
 showing the differences between UTC and GPS time as published by the the BIPM in its monthly Circular T. At 1 d intervals, the Allan deviation is about 2 parts in 10¹⁴. The ending of SA on 02 May 2000 has not improved the performance of GPS time at these intervals.

A longstanding goal of the IGS is to improve the day-to-day stability of its clock products while providing an underlying time scale linked as closely as possible to UTC. This is a primary objective of the IGS/BIPM Pilot Project in close cooperation with the BIPM. The next step, agreed

to at the IGS Workshop at USNO in September 2000, is for the IGS to realize an improved internal time scale. The idea is to use the current IGS clock products to form a new reference frequency scale from a weighted ensemble of the stable frequency standards available in the IGS network. Eventually, it is expected that this stabler IGS time scale will be traceable directly to UTC through the data of calibrated GPS receiver links at timing laboratories (the first of which should be available in the near future).

Ken Senior (USNO/TS, senior.ken@usno.navy.mil) has developed a new internally realized IGS time scale with the following main features:

- * uses an integrated frequency scale formed from an ensemble of the IGS frequency standards
- * contributing clocks are dynamically & objectively weighted
- * deterministic models for clock rates & drifts (aging)
- * can include stochastic noise processes (currently not used)
- * robust detection of outliers & phase/frequency breaks
- * external steering enabled (could use calibrated receiver data)
- * Kalman filter package with modular program structure
- * written in Matlab (C/C++ source code available)
- * inputs/outputs use .clk RINEX format

The time scale is loosely steered to broadcast GPS time, with a time constant longer than a month. Results indicate that the new time scale is stable to about 1 part in 10^{15} at 1 d, better than that of any individual receiver clock. Note that the differential relationship between any pair of clocks is unchanged from the official IGS products, so the overall consistency is also unchanged. For a detailed description of Ken's algorithm, please refer to the preprint by K. Senior, P. Koppang, D. Matsakis, and J. Ray, "Developing an IGS time scale", Proc. 2001 IEEE International Frequency Control Symposium, in press 2001, at <http://maia.usno.navy.mil/gpst/refs/senior-fcs01.pdf>

Ken has generated re-referenced .clk files and plots (time domain and Allan deviation) starting with week 1086 (29 Oct 2000), which you are invited to examine. They are available at

<http://clockdev.usno.navy.mil/igst/final/> or
<ftp://clockdev.usno.navy.mil/igst/final/>

Note that quadratic trends are removed for plotting purposes and only every 3rd point is shown. The clock labelled "GPST" is the realization of the current IGS time scale compared to the new scale; it is not an observed clock. The GPST values have been removed from the current IGS clocks to produce the new re-referenced clocks.

Please send any comments, suggestions, or questions to Ken at . We plan to discuss these new clocks at the upcoming IGS Workshop in Ottawa in October.

Best regards,
 --Jim