Long Term Time Stability of Conventional GPS Receivers

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***Abstract*— The most important feature of GPS-receivers in time keeping is long-term phase stability and reliability. MIKES and Nokia have studied in cooperation the performance of medium price commercial GPS receivers both in the short term and long-term sense. By comparing time differences of the receivers, both short term and long-term stability can be evaluated assuming that all receivers do not drift into the same direction.**

A long term stability seems to be from < 1 ns/yr to about 10 ns/yr. Due to operational interrupts unexpected transient phase changes occur in some receivers. The magnitude of these permanent jumps varies from 10 ns to 50 ns. The older receivers show a diurnal phase variation of 10..20 ns.

Temperature effects seem to be small though the ambient temperature can vary from –20 °C to +30 °C.

I. Introduction

Currently most time-keeping laboratories rely just on GPS-time since the availability of the signal from the other positioning system, GLONASS, is not very high. The GPS system time is properly supervised and controlled but delays of receivers vary.

Laboratories should have several GPS-receivers from different manufacturers. When time differences are monitored, it is possible to find out irregularities.

In this paper we have compared our GPS-receiver data since January 1997 with atomic clocks as a "flywheel".

The measured GPS data were recorded every ten minutes and the diurnal measurements were averaged over 24 hours to resolve phase jumps or irregularities at nanosecond level. Time (phase) differences between all the receivers were computed pair-wisely. The long-term drifts of our receivers were estimated and phase jumps in certain receiver types were detected.

II. RECEIVERS STUDIED

For long term stability studies we have three Navstar (later Navsymm) XR5, type A120-001G2, which were purchased between Apr/1994...Apr/1996.

Two Motorola Remote GPS, type GCPRP12103 receivers were purchased in Oct/1998.

A geodetic receiver LEGACY-E was purchased in May20/03.

Navstars were replaced with Fastrax IT03-S in Oct/2008.

III. MEASUREMENT SYSTEM

The automatic measuring system of MIKES records the phase differences of all clocks and receivers. As a master clock there is an active maser Kvartz CH1-75A.

All measurements were made by the basic sampling rate of 10 minutes. These values were used to calculate two-hour averages and the diurnal averages. These averages were used to compute time differences pair-wisely between desired frequency standards as a function of MJD (Modified Julian Date).

IV. RESULTS

The oldest receiver studied in this paper (model XR5, known as "GPS1" in our system) worked continuously for ten years with only one small phase jump at MJD 52739 due to service. It was in the beginning a long term reference. Most of long term differences are calculated against it. Fig. 1 shows the time difference between GPS1 and GPS2 which was also a XR5 receiver.

After being rebooted the GPS2 usually lost the former phase which appears as permanent phase jumps, see Fig 1. The third XR5 behaved similarly. GPS3 (Motorola) seems to be quite similar to GPS4 in the beginning but later phase jumps of even ± 100 ns were observed. GPS4 (Motorola) had only one phase jump during 10 years of continuous operation. Its long term drift was about 10 ns/yr. In addition, there has been an annual variation about 20 ns pp (Fig. 2). This

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phenomenon seems to correlate better with outdoor humidity than with temperature.

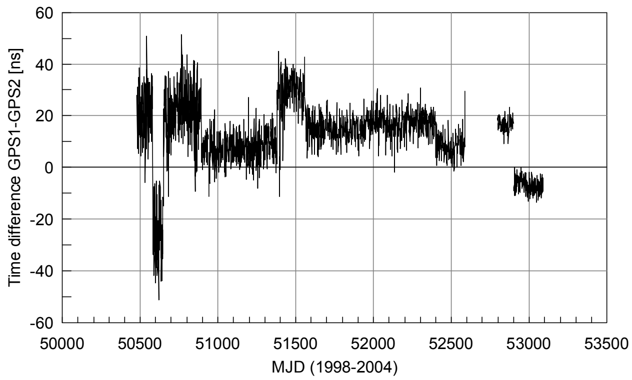

Fig 1. Time difference between XR5 receivers GPS1 and GPS2.

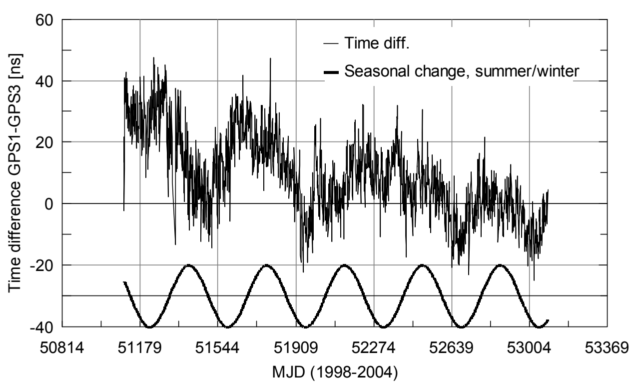

Fig 2. Time difference between XR5 (GPS1) ja Motorola GPS receiver (GPS4).

Fastrax GPSs have been in use for about 6 months. No significant drifts (les than 1 ns) have been observed. A power supply failure caused a 60 ns phase shift. Later we tested this receiver by “chopping” the power off for one minute every 4 hours. The results (Fig. 3) pointed out three phase modes, roughly 30 ns apart.

V. CONCLUSIONS

Phase jumps are common in GPS receivers. Our first GPS receiver (Kinemetrics-DC, 1988), 2-channel receiver, could have 1 ms jumps, equivalent to PRN code length.

In new receivers correlation peak is detected using several correlators, which have different offsets from the "true" value. The offsets are multiples of clock cycle, e.g. N·30 ns. The width of the peak is 1000 ns. Due to noise the detection of correlation peak may slip to control of a "wrong" correlator, leading to phase jumps.

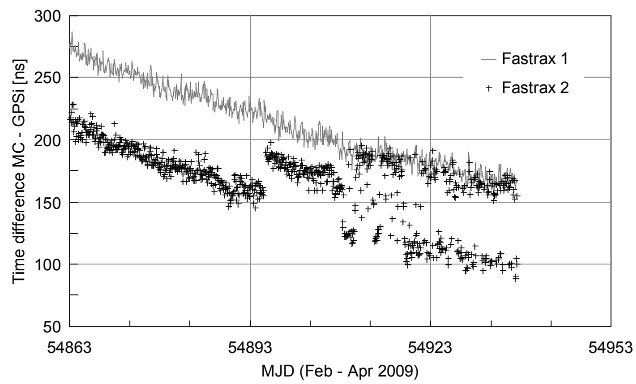

Fig 3. Time difference between two Fastrax GPS receivers

In the case of the GPS2 receiver (XR5), some unknown software problems were met because the tracking was lost, typically once per year. Rebooting of the GPS2 receiver caused usually a phase jump (Fig. 1). At first, a couple of 50 ns phase jumps and later, some 15...25 ns jumps were detected. At MJD 52587, the GPS2 receiver "died" and it was replaced with a similar receiver, denoted by GPS2b. It was observed to have the same features in performance and the detected phase jumps were alike in respect of the original GPS2 receiver, referring also to software problems in the more recent Navstar units.

When operated over five years, the GPS3 receiver (Motorola) has performed 5 phase jumps due to the PPS driver. The amplitude of the PPS driver was high enough but the rise time was slow, around 500 ns. This caused changes into delay(s) as a function of the changes in the loading impedance. Because natural explanations to all phase jumps were found, it was concluded that the GPS3 receiver is fit to behave this way under the conditions in question (Fig. 2).

No significant correlation between the time difference behaviour and seasonal temperature effects was found. Instead, correlation between phase variations and humidity seems somewhat more significant.

GPS4 appears to be quite similar to GPS3. It performed two phase jumps but recovered automatically by itself within few days.

Based on the results, the conclusion is that the drift of the Navstar XR5 receivers is much smaller than the drift of the Motorola receivers. It seems that Fastrax is a good successor to XR5. Its noise and diurnal variations are less than 50 % compared to the XR5.

The oldest receiver studied in this paper, GPS1 (Navstar XR5) operated continuously for ten years with only one small phase jump. Two other XR5 receivers both operated for about five years.