19th Symposium IMEKO TC 4 Symposium and 17th IWADC Workshop
Advances in Instrumentation and Sensors Interoperability
July 18-19, 2013, Barcelona, Spain

Influence of GPS Measurements Quality to NTP Time-Keeping

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***Abstract*-T**he Metrological laboratory for angle and length calibration (ML160) uses a geodetic class double-frequency GPS receiver as a time standard. Time correction terms are delivered to laboratory computers via Network Time Protocol (NTP). We tested NTP parameters within the intranet environment with the respect to the quality of GPS measurements. The 24 hours experiment showed that the characteristics of time delivered to NTP clients is influenced by the quality of GPS data received by our Stratum 1. We suggested methods for improving the reliability of GPS disciplined time corrections.

I. Introduction

Time and frequency standards supply us with three basic types of information: date and time-of-day, for marking specific time events; time interval, to precisely measure the periods between two events, and frequency, to measure the rate at which something happens [10].

Our laboratory, ML160, state special requirements for time-keeping. It is accredited by the Serbian Accreditation body. Among the wide scope of surveying equipment, we also issue the certificates of calibration for GPS receivers. One of the characteristics we test is the short-term stability of GPS clocks. As a laboratory standard (which is a secondary standard in the Serbian standard hierarchy chain) we use a geodetic class double-frequency GPS receiver Trimble NetRS. We synchronize our laboratory computers' clocks by NTP corrections, where NetRS acts as a Stratum 1 NTP server. The issue of the clock synchronization is a common issue for all GPS measurement techniques. A position of GPS receiver is calculated using a complicated mathematical model, including the clock parameters estimation, both on the satellites and the receivers [11].

This research aims to analyze the quality of the synchronization in an Local Area Network (LAN) environment.

II. Background and methods

NTP is widely used in LAN and WAN environments for clock synchronization. NTP servers deliver time correction terms to NTP cliens throughout the network. The accuracy of the synchronization depends on the characteristics of the time of packets travel and the accuracy of the time source itself. The NTP server provides a data packet that includes a 64-bit timestamp containing the time in UTC seconds since January 1, 1900 with a resolution of 200 picoseconds, which can provide accuracy of 1 to 50 ms [2]. If an NTP client software runs continuously, it permanently gets periodic updates from the server.

Atomic clocks generally provide a much more accurate frequency than can be generated by any physical device such as a pendulum or quartz crystal oscillator. An atomic clock uses as its reference the oscillation of an electromagnetic signal associated with a quantum transition between two energy levels in an atom [1]. However, transferring time from the atomic clock to a computer implies calculation of signal travel time. If the computer is disciplined across WAN, the synchronization quality may be affected by the quality of the Internet traffic. GPS is often used as the stratum 1 in NTP environments, due to its availability to provide absolute UTC time marks [5]. This all is applied to the stationary receivers. When the receiver or the antenna is moving, the measurements are constantly changing and the self survey fix can no longer be relied upon to generate low phase error to the time mark. In fact the more quickly the receiver moves in space the greater the error would be, and the acceleration is most critical [8].

Cumulative GPS phase measurements follow the smooth curve. Due to physical obstacles or interference with certain radio-sources, certain jumps occur in the curve, which are known as cycle slips. Each cycle slip affects the accuracy and reliability of the phase measurement by introducing a new unknown in the mathematical model of an autonomous or a relative position of a surveyed point. The cycle-slips resolved in real-time by the GPS receiver's firmware, or during the post-processing, using appropriate mathematical models and software.

Here the method of wide-laning is used. Wide-lane is a linear combination of the raw phase measurements on both frequencies, which eliminates the ionospheric delay. Bias fixing (cycle slip resolving) refers to constraining the phase biases to integer values and effectively removing the biases as parameters from the solution. This method calculates the cumulative probability that all the fixed biases (wide-lane and ionosphere free) have the correct value and to subsequently fix another bias only if the cumulative probability stays greater than 99% [3]. By using this algorithm, over 99% of the station-satellite passes required no further analyst intervention, while almost all of the remaining 1% had incorrectly determined integer discontinuities due to rapid variations in the ionospheric phase delay [4].

In our work, we use GPS Toolkit for the GPS and time data processing. Here, applications DiscFix for GPS raw measurements processing, and ordGen for clock parameters estimation are used [6].

III. Experiment and results

The device under test (DUT) is a quartz clock of a laboratory computer, used for time-keeping purposes. It runs under FreeBSD 7.4-RELEASE. operating system. The reference for generating NTP corrections (stratum 1) was our Continuously Operating Reference Stations (CORS) network GPS receiver, dual-frequency Trimble NetRS, with the geodetic class accuracy [12]. NetRS logged the GPS data with the resolution of 1 s, during 24 hours. DUT is situated in the same building with NetRS. Both devices are connected to the institutional LAN, so the experiment lasted without the influence of the Internet.

Prior to the experiment start, we turned off our DUT, in order to test the time required for achieving the standard NTP synchronization features. After turning the DUT on, we started the *ntpq* utility with *peers* command started in 1 s intervals. We logged the raw output of the ntpq into a plain ASCII file. On the other side, using the remote capability, we started a new static 24-hours GPS session with 1 s interval registration at our reference GPS receiver (NetRS).

The measuring session lasted for 24 hours. After the measurements were completed, we processed obtained data. From the NTP log file, we extracted *delay*, *offset*, and *jitter*. parameters from the logged data. The result was a three column ASCII file, each one representing one of the delay, offset, and jitter parameters, expressed in ms..

GPS measurements were logged in Binary Receiver Independent Exchange (BINEX) format [9]. After the completion of the measuring session, we used the propriety software to convert the logged data into Receiver Independent Exchange (RINEX) format, in order to process it with the third party software. BINEX is a superset of RINEX. It is a binary format, used for different sets of data (broadcast ephemerides data, events, meteorological data, and observation data). Than the RINEX file is processed to cycle slips detection, which resulted in 64 found cycle slips, 2 per time mark. The cycle slips occur in the phase measurements, when the receivers lost the lock to a satellite. Cumulative phase is a smooth curve, if there is no cycle slips. Fig. 1 represents tracking for the satellite G16 on both frequencies.

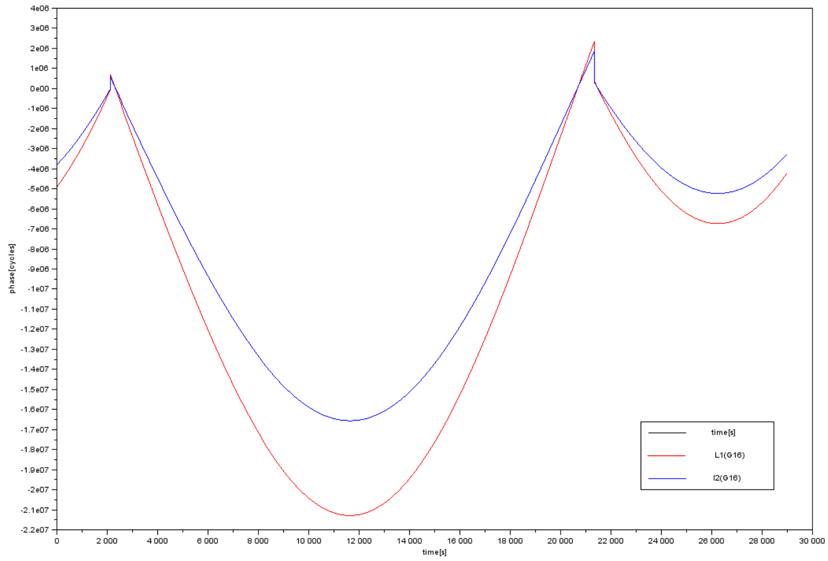

Figure 1: Graphical representation of NTP tracking with detected cycle slips

It means that each cycle slip occurred on both two frequencies, L1 and L2. We created another ASCII file, with the same number of time epochs as in NTP log file, joining to each time mark 0 or 1. Zero means "The measurement for this epoch is O.K.", and 1 means "Here occurred a cycle slip".

We generated the clock estimates using the GPSTk Observed Range Deviation (ORD) tools [6,7]. The raw measurements, obtained by the RINEX file, are processed in order to allow the clock parameters estimation. After parsing the data, those data points that do not fall within a 5σ of the data set are replaced with an interpolated value based on the data falling on either side of the outlier. A graph of the calculated overlapping Allan deviation is showed in Fig. 2.

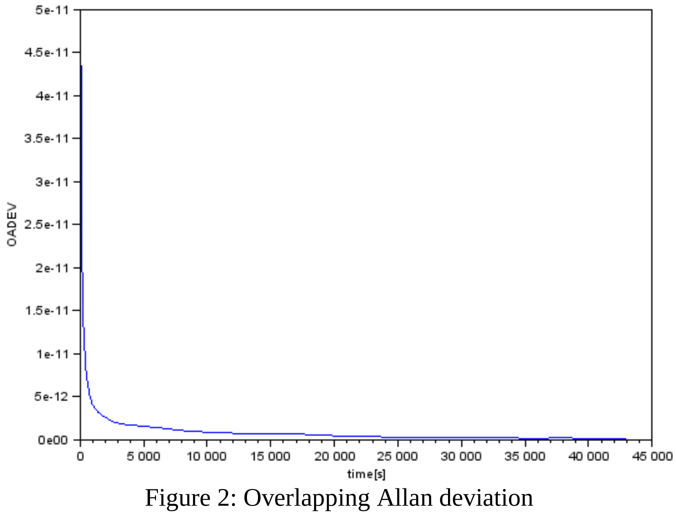

Figure 2: Overlapping Allan deviation

After pairing two files (cycle slip and NTP), we obtained the base for correlation calculation between extreme NTP tracking parameters and the cycle slips. Fig. 3 shows the results of NTP tracking (delay, offset, and jitter in line form) and the cycle slips (black pluses).

During the first 2.5 h of the experiment, five times the clock estimating parameters become zero. This indicates the break in continuous receiving of the NTP corrections, although the experiment was held in a controlled, close environment. There were, also, seven cycle slips during that time, but no correlation between them and the received corrections exist.

Around the 7th hour of the experiment, three cycle slips occurred, which corresponds with the greater changes in offset and jitter. Regarding other cycle slips, it can not be proved that they caused the changes in the smoothness of the received corrections.

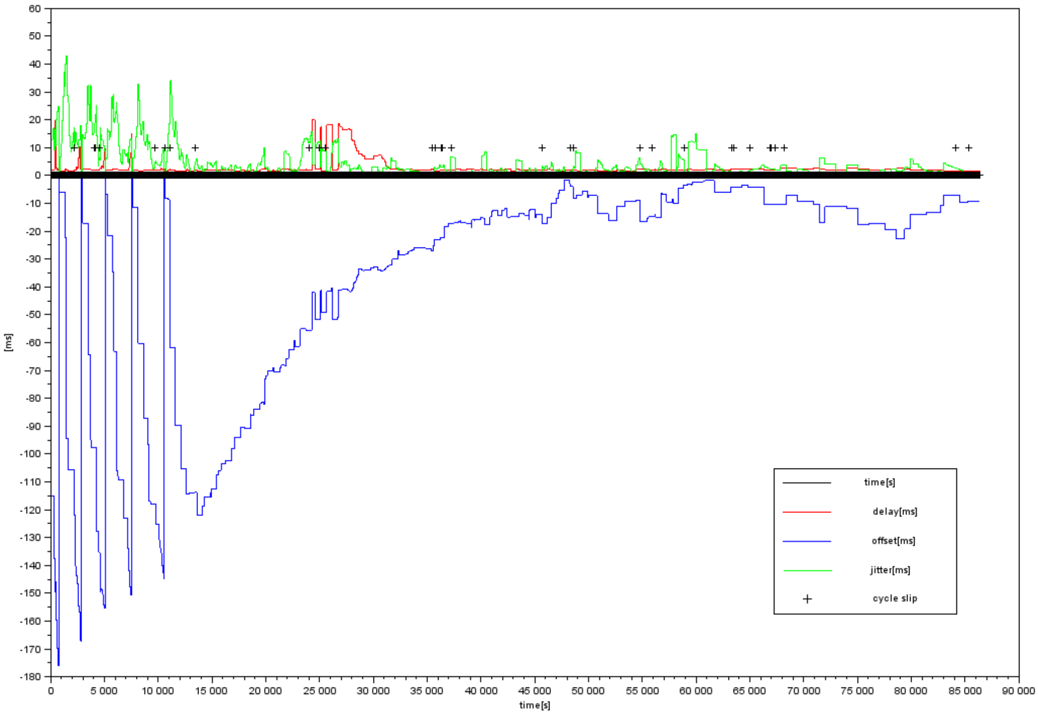

Figure 3: Graphical representation of NTP tracking with detected cycle slips

IV. Conclusions

From our experiment, we can conclude that cycle-slips in GPS measurements can influence the accuracy of time correction terms delivered to network clocks. When using the GPS receiver as the NTP stratum 1, one should pay a strong attention to the location of the GPS antenna, in order to avoid any disturbances or obstacles that could invoke the cycle-slip. Still, the features the LAN also play a significant role in the NTP configuration. Those two influences cannot be separated, but rather considered jointly.

When these requirements are met, the accuracy in order of parts of milliseconds can be expected in the LAN. Extension to WAN does not meet these criteria, due to the unpredictable speed of network transport.

References

[1] Allan, D. W. , Ashby, N., Hodge, C. C.: *The Science of Timekeeping*, Hewlett Packard Application Note 1289; 1997.

[2] Behrendt K, Fodero, K., “The Perfect Time: An Examination of Time Synchronization Techniques”, In Transmission and Distribution Conference and Exposition, 2010 IEEE PES”, April, 19-22, 2010., New Orleans LA, pp. 1-8, 2010.

[3] Blewitt, G., “Carrier Phase Ambiguity Resolution for the Global Positioning System Applied to Geodetic Baselines up to 2000 km”, Journal of Geophysical Research, vol. 94, No. 88, pp. 10,.187-10,203, 1989.

[4] Blewitt, G. et al., “An Automated Editing Algorithm for GPS Data”, Geophysical Research Letters, vol. 17, no. 3, pp. 199-202, 1990.

[5] Carta, A. et al., “GPS and IEEE 1588 Synchronization for the Measurement of Synchrophasors in Electric Power Systems”, Computer Standards & Interfaces no 33, pp. 176-181., 2011.

[6] Craddock, T. et al, “The GPS Toolkit: Open Source Clock Tools”, In Proceedings of the 40th Annual Precise

Timing and Time Interval (PTTI) Meeting, December 01-04, 2008., Reston, VA, pp 275-274., 2008.
[7] Gaussiran, T. et al., “An Open Source Toolkit for GPS Processing, Total Electron Content Effects, Measurements and Modelling”, In Proceedings of the International Beacon Symposium 2004. October 18-22. 2004., Trieste, Italy. 2004.
[8] Hightower, P., *Motion Effects on GPS Receiver Time Accuracy*, Instrumentation Technology Systems, Northridge, CA, 2008.
[9] Jong, C.D. de, Marel, H. van der, “Proposal for a Binary Receiver Independent Exchange Format”, Phys. Chem. Earth (A), Vol. 26, No. 6-8, pp.551-554, 2001.
[10] Lombardi, M., *NIST Time and Frequency Services*, NIST Special Publication 432, NIST, 2002..
[11] Schildknecht, T., Dudle, G., “Time and Frequency Transfer: High Precision Using GPS Phase Measurements”, GPS World, Feb. 2000, pp. 48-52, 2000
[12] Trimble: *NetRS GPS Receiver - User Guide*, Trimble Navigation Limited, 2004.