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New developments for GNSS precise positioning and timing

Michael Schulz[1], Jürgen Rüffer[1]
[1] ALLSAT GmbH, Sokelantstr. 5, 30165 Hannover, Germany
michael.schulz@allsat.de

Abstract:
The latest developments in the GNSS precise positioning and timing receivers from JAVAD GNSS include the option to replace the classical TCXO (Temperature Compensated Crystal Oscillator) by an OCXO (Oven Controlled Crystal Oscillator). This internal OCXO delivers an unmachted short term frequency stability 2x10-12 (@1sec) and 5x10-12 (@10sec). The position and timing signals measured using this OCXO will have great advantages, especially for flight test measurements with high dynamics or ionosphere scintillation measurements both requiring high update rates for raw measurement and positioning (up to 200Hz supported).

For the long term frequency stability, the latest JAVAD GNSS receivers have the ability to precisely synchronize the internal receiver clock with external 1 PPS signal without any additional equipment. In this mode the receiver uses the external frequency as the reference, but the time offset between 1 PPS and 10 MHz signal is measured inside the receiver and can be recorded. All the observations are performed in the epoch defined by an incoming 1 PPS signal. Receiver synchronizes its internal time scale to input 1 PPS signal with accuracy less or equal 0.4 ns, without any external time interval counter. This is the optimal solution for network timing or to synchronize FTI.

Key words: GNSS, time synchronization, OCXO, FTI, JAVAD GNSS

Introduction

To achieve the highest accuracy and precision in PNT applications, the most essential hardware part of the GNSS receiver is the internal oscillator. The stability of the internal reference frequency delivered by an OXCO oscillator is the key factor to measure short term effects like ionosphere scintillations and TEC, which require sampling rates up to 200Hz. Also for high dynamic applications like flight tests or autonomous navigation in the automotive industry, the short term frequency stability is essential for delivering precise trajectories.

For the long term frequency stability, i.e. essential for time synchronization of FTI, the highly stable PPS or NTP output signals require the ability to precisely synchronize the internal receiver clock with atomic satellite time without any additional equipment.

Highest stability of reference frequency [1]

The latest developments in the GNSS precise positioning and timing receivers from JAVAD GNSS include the option to replace the classical TCXO (Temperature Compensated Crystal Oscillator) by an OCXO (Oven Controlled Crystal Oscillator). This internal OCXO delivers an unmachted short term frequency stability 2x10-12 (@1sec) and 5x10-12 (@10sec).

The OCXO oscillator can be installed as an option in the receiver DeltaS-3S to provide the highest stability of the reference frequency. No special configuration efforts from the end user are needed. The comparison between two receivers one with the OCXO and one with a conventional TCXO is shown below.

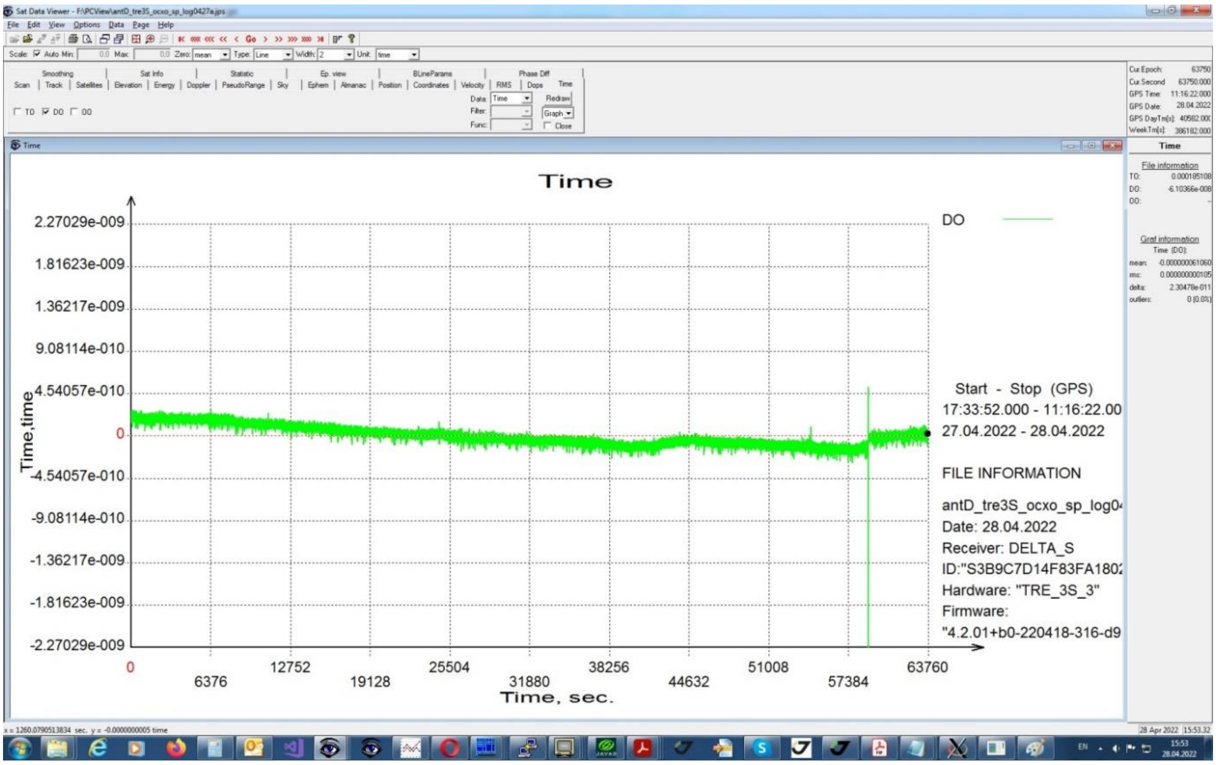

Fig.1. GNSS Receiver with new OCXO (offset of reference frequency from nominal value)

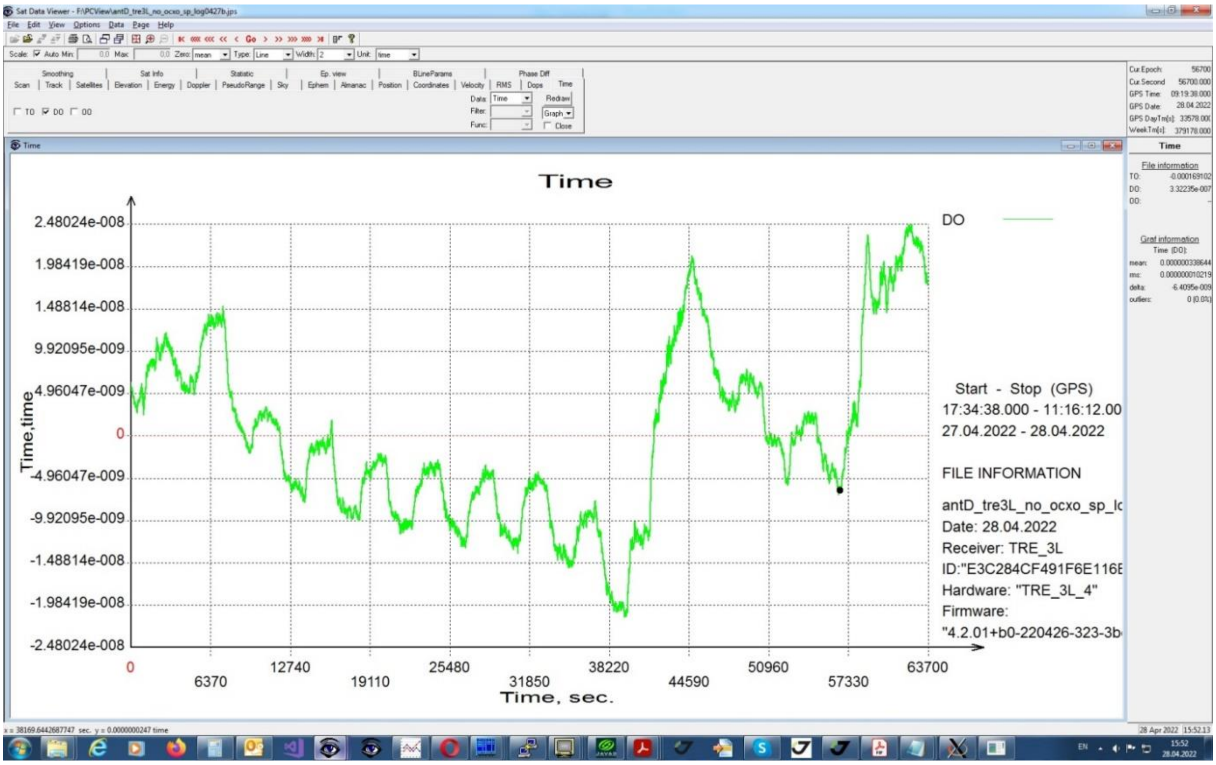

Fig.2. GNSS Receiver with standard TCXO (offset of reference frequency from nominal value) at the same place at the same time connected to the same antenna

The two charts cleary show temperature fluctuations affecting the precision of the reference frequency of the standard TCXO (Fig. 2), whereas the new OXCO (Fig. 1) controls temperature by its internal oven shows significantly more stable frequency. It can be noted that even small temperature changes, e.g. from the operation of the air conditioner, as well as from the morning airing of the room, are clearly visible.

High stability of reference frequency can be used in different applications such as timing applications or applications that need low noise measurements for example the GNSS antenna phase-center calibration or Ionosphere Scintillation monitoring and Total Electronic Content (TEC) computation.

TEC is computed using iono-free combinations of range measurements refined by corresponding phase measurements. Since the measurements inside the receiver have hardware biases the calibration of measurements needs to takes place before the computation of TEC. Calibration is performed at the time of minimum ionospheric activity using an analytical model of the ionosphere.

There is special command to activate calibration:

%%set,/par/raw/tec/calib/mode,on

TEC values in TECu units are outputted for all tracked satellites by special JPS message [te]:

Struct SatVTEC {nSats+1} {F4 VTEC[nSats];U1 cs;};

Raw data from all existing GNSS in JPS format can be logged with up to 200Hz either into internal receiver memory or to a file on the PC. The free JPS-File Analyzer software can be used to visualize the VTEC measurements. JPS-File Analyzer decodes raw JPS-data, presents them in charts and tables, and calculates their statistics. Processed data are presented on the panels organized as a tree.

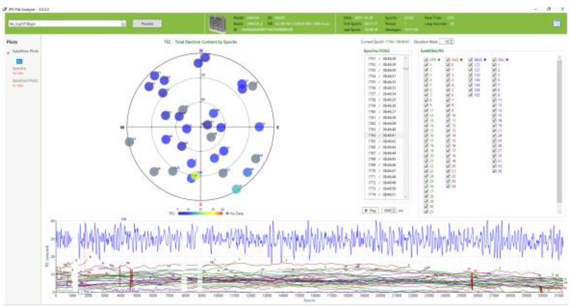

Fig.3. TEC graphs. All satellites are selected.

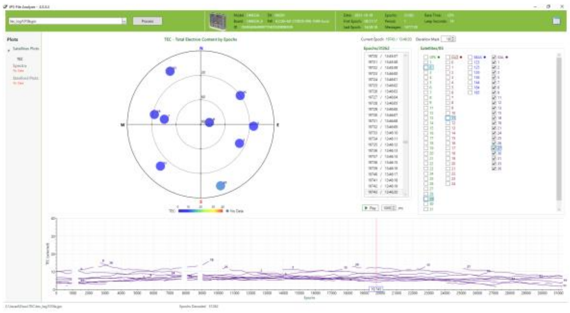

Fig.5. TEC graphs. Galileo only satellites are selected.

TEC panel contains a 2D graph in axes epochs-TEC. Y-values represent Total Electron Content calculated for a satellite. The sky plot shows the position of the satellites for the current epoch. Each satellite is displayed by the circle colored according to the TEC value from blue to red. The smallest values are blue, biggest -red, gray – value is unavailable.

JAVAD Receiver for Time Transfer (Timing receiver) [2]

For the long term frequency stability, the latest JAVAD GNSS receivers have the ability to precisely synchronize the internal receiver clock with external 1 PPS signal without any additional equipment. In this mode the receiver uses the external frequency as the reference, but the time offset between 1 PPS and 10 MHz signal is measured inside the receiver and can be recorded.

Delta(S)-3S receiver is a universal high precision GNSS receiver with an additional "time transfer" feature. It utilizes the unique calibration hardware, which allows to measure (and then compensate in data processing) the delay between the input PPS signal and the internal receiver's time reference. The accuracy of such calibration is about 20 picoseconds. The presence of such a schematic simplifies the overall hardware setup (see Figure 5). There is no need for the so-called "time interval counter", which is usually a rather big and expensive device.

The receiver supports the on-board generation of CGGTTS-V2E files, widely used in the time transfer community. Not only GPS-based data are available. Time transfer may be obtained using any GNSS system, including Galileo and BeiDou.

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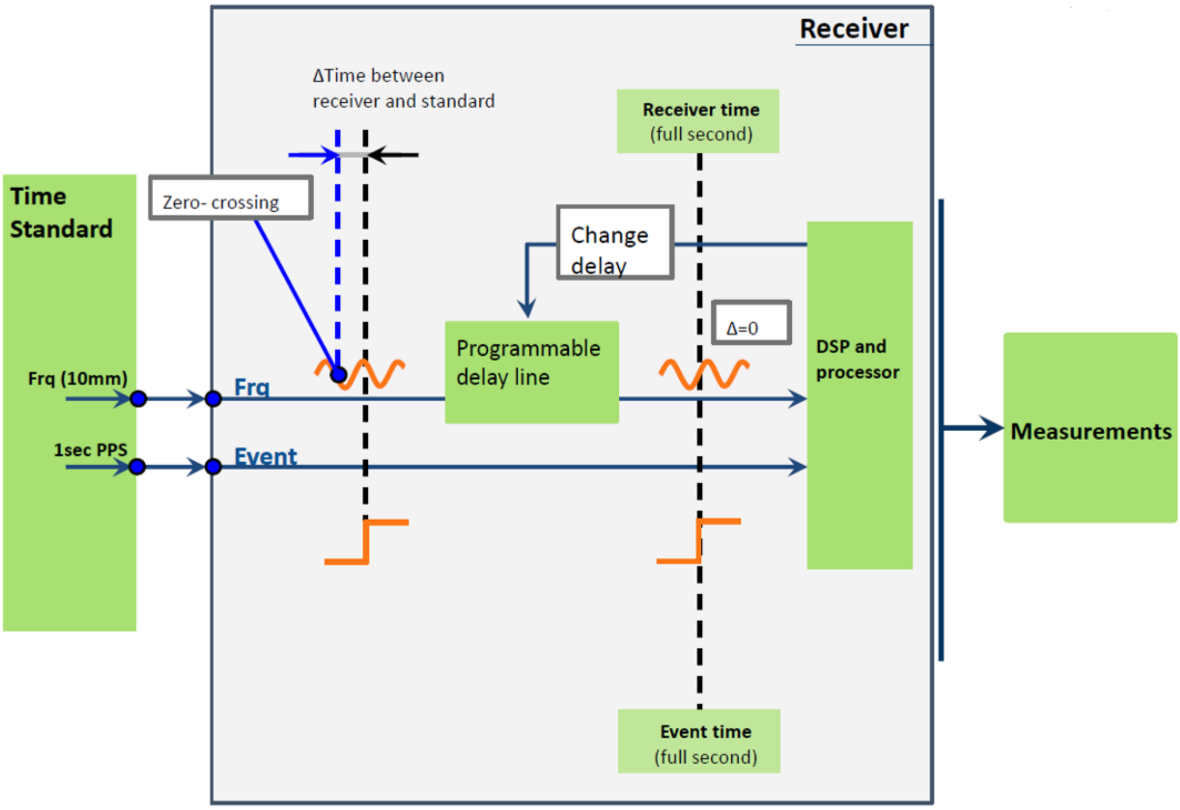

Fig.5. JAVAD Receiver for Time Transfer (Timing receiver)

Conclusion

For GNSS precise positioning and timing applications the position and timing signals measured using an internal this OCXO will have great advantages, especially for flight test measurements with high dynamics or ionosphere scintillation measurements both requiring high update rates for raw measurement and precise position calculation with GNSS receivers.

For the long term frequency stability, the latest JAVAD GNSS receivers have the ability to precisely synchronize the internal receiver clock with external 1 PPS signal without any additional equipment. This is the optimal solution for network timing or to synchronize FTI.

References

[1] V. Zhukov, S. Yudanov, O. Tubalin, Highest stability of reference frequency with OCXO oscillators

[2] V. Zhukov, S. Yudanov, O. Tubalin, JAVAD Receiver for Time Transfer