

CCTF- Technical Exchange meeting of WG TAI and UTC laboratory Collegues
21st Jan 2025

“Low-Cost GNSS Receivers”

Performance of GNSS receiver modules and TIC with UTC(NPLI)



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Low Cost GNSS Timing Receivers

What is expected from a Low-Cost GNSS timing receiver

- Less costly (few 100s of dollars)
- Dual frequency (preferable)
- Should provide data output (formats: Proprietary/Rinex/CGGTTS)
- Must have an option for 1 PPS and 10 MHz input
- Should have an option for 1 PPS output
- Input from at least one Antenna

Purpose

- Reliable time traceability between {UTC & UTC(k)} / {UTC(k) & remote site}
- Small size, Low power consumption
- Easy integration into the system

Our goal

- NPLI- Disciplined Oscillator: To develop remote time traceable system with UTC(NPLI)

A few low cost GNSS Timing receiver chips

Ublox ZET-F9T-10B



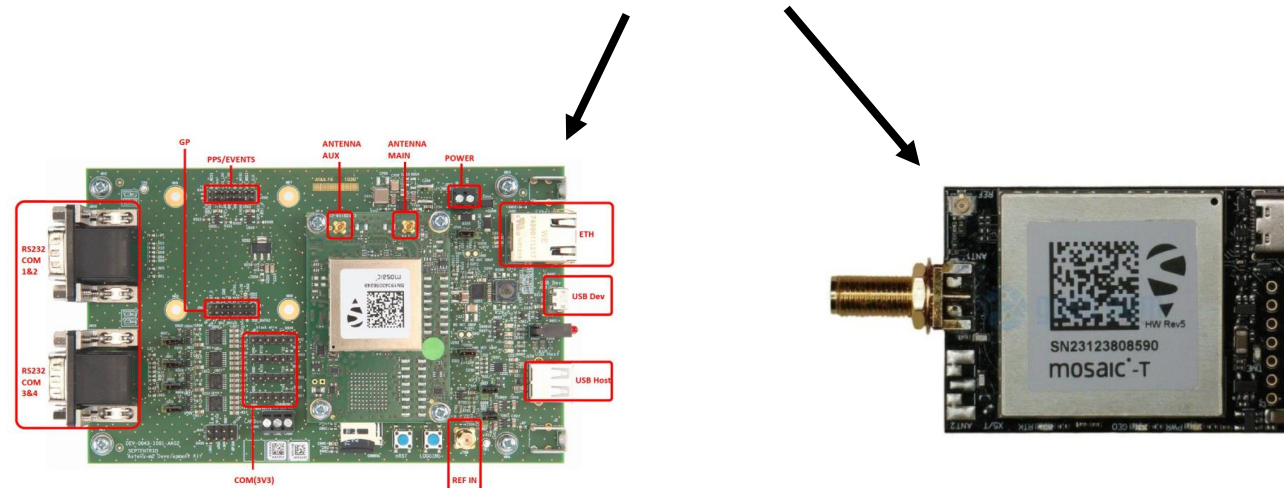
Septentrio Mosaic-T



Sky Traq PX11255-01



NavIC (L5) + GPS (L1)



➤ Ublox ZET-F9T-10B



➤ 184 channel

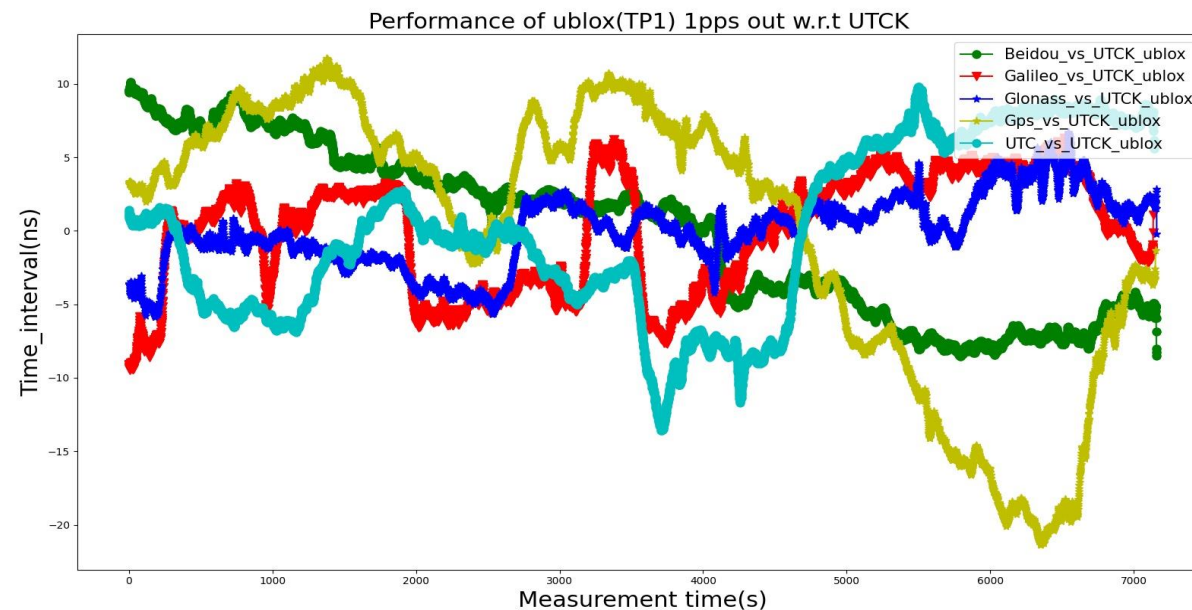
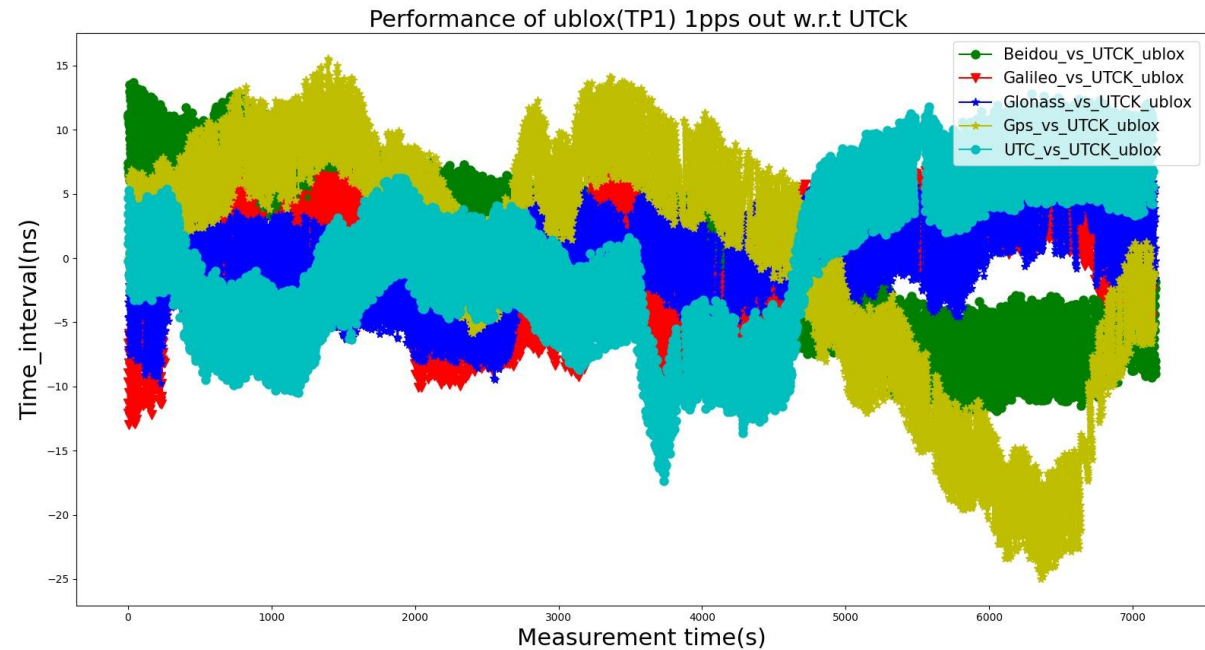
➤ Signals

- GPS L1C/A, L5
- GLO L1OF
- GAL E1B/C, E5a BDS B1I, B1C, B2a
- QZSS L1C/A, L5
- NavIC L5
- SBAS L1C/A

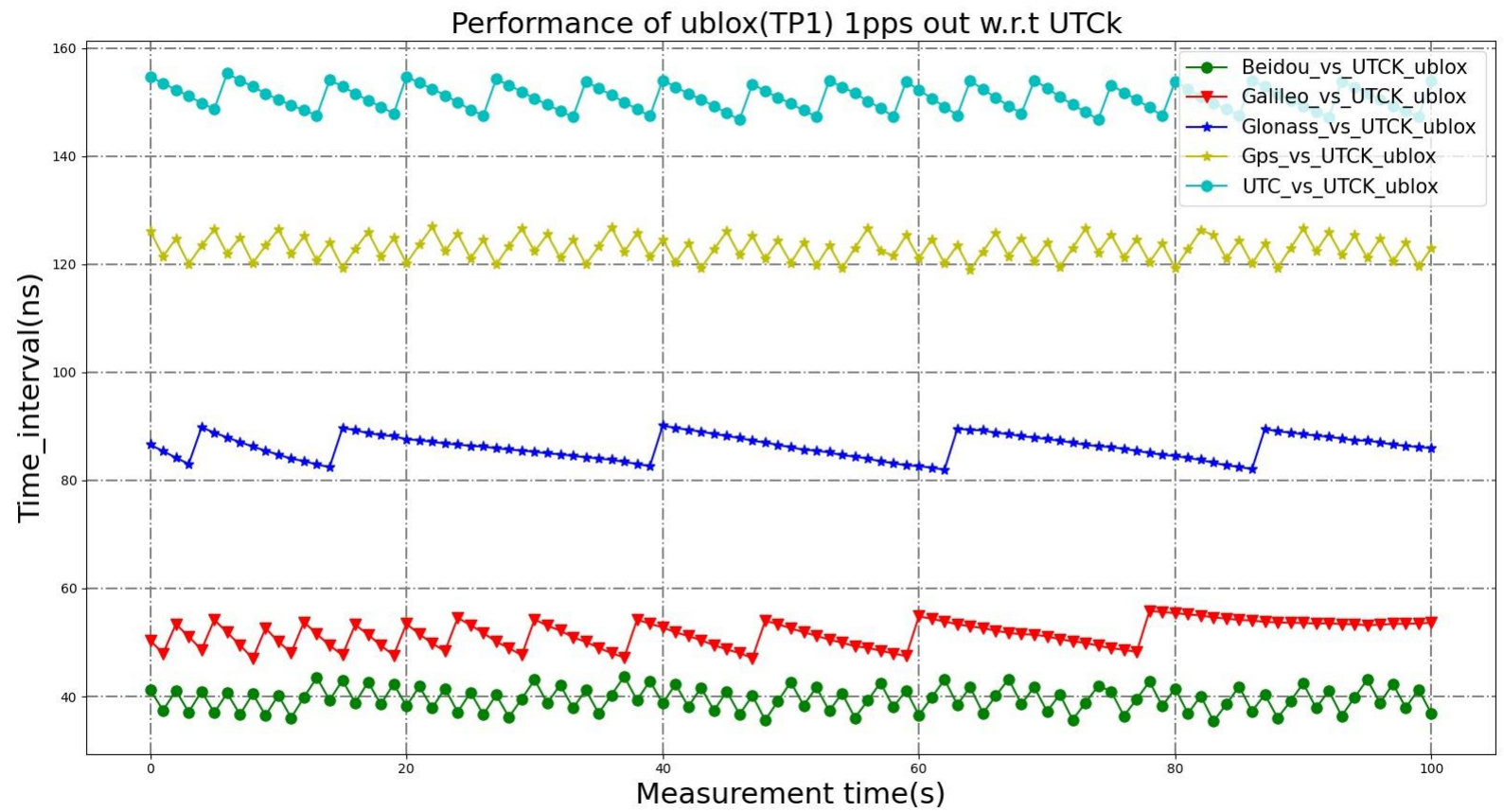
➤ No Option for Input 10 MHz

➤ Output data format

1. NMEA
2. UBX



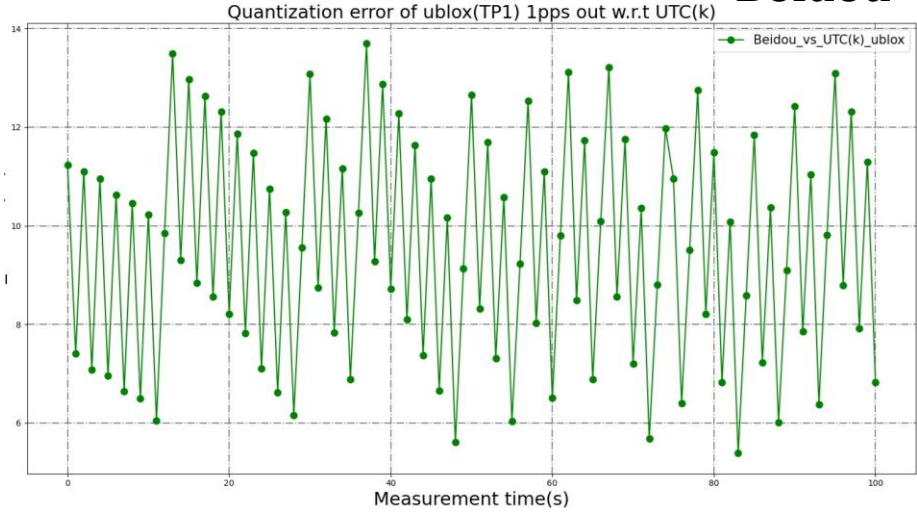
➤ Ublox ZET-F9T-10B



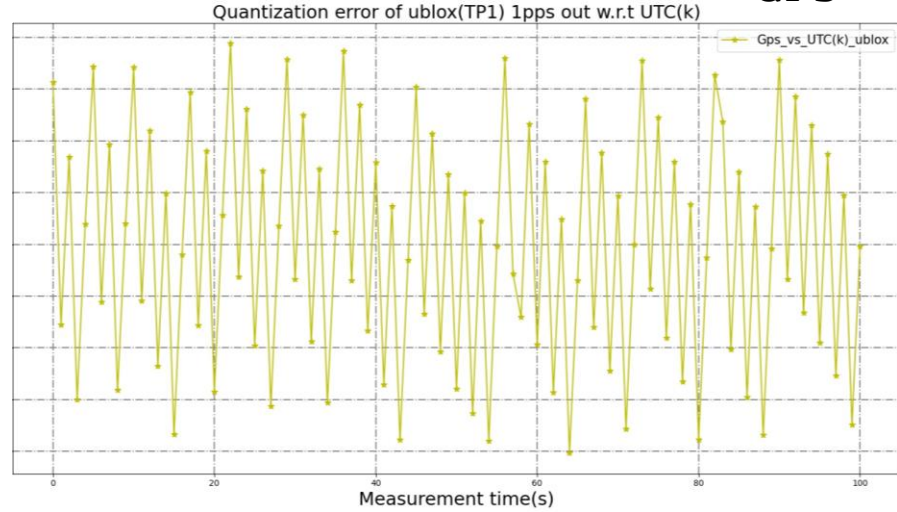
➤ Intentional offset added to observe the quantization error

➤ Ublox ZET-F9T-10B

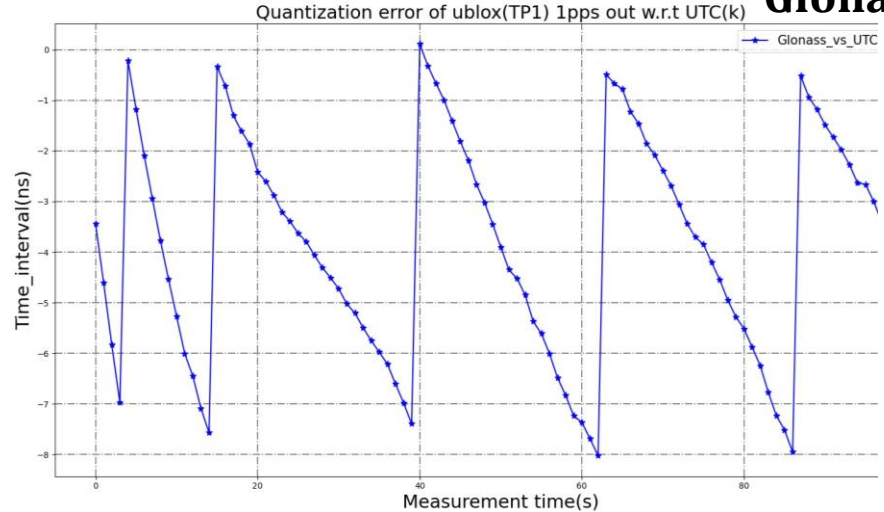
Beidou



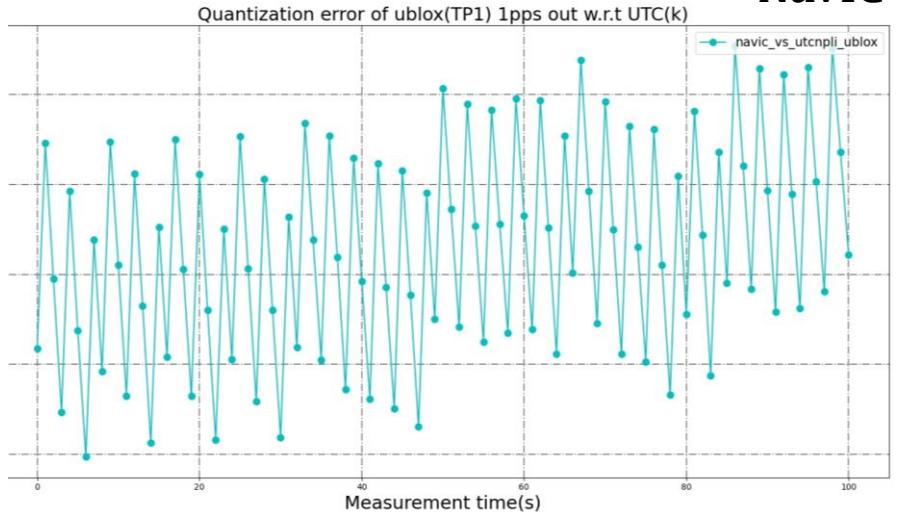
GPS



Glonass

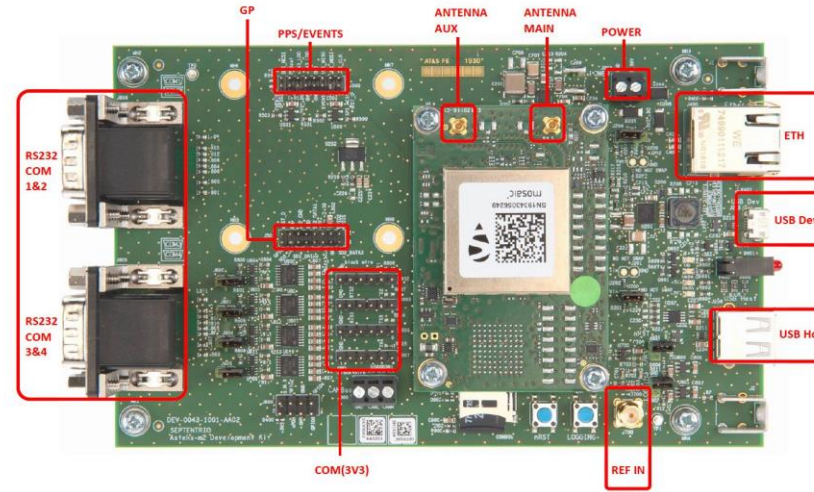


NavIC



- Ublox ZET-F9T-10B
 - Good product with options for external event inputs (1PPS).
 - Can perform Common View among F9T – 10B receivers chips.
 - We tried and failed to convert **Ubx data format** to Rinex or CGGTTS

➤ Septentrio Mosaic-T



➤ 448 channels

➤ Signals

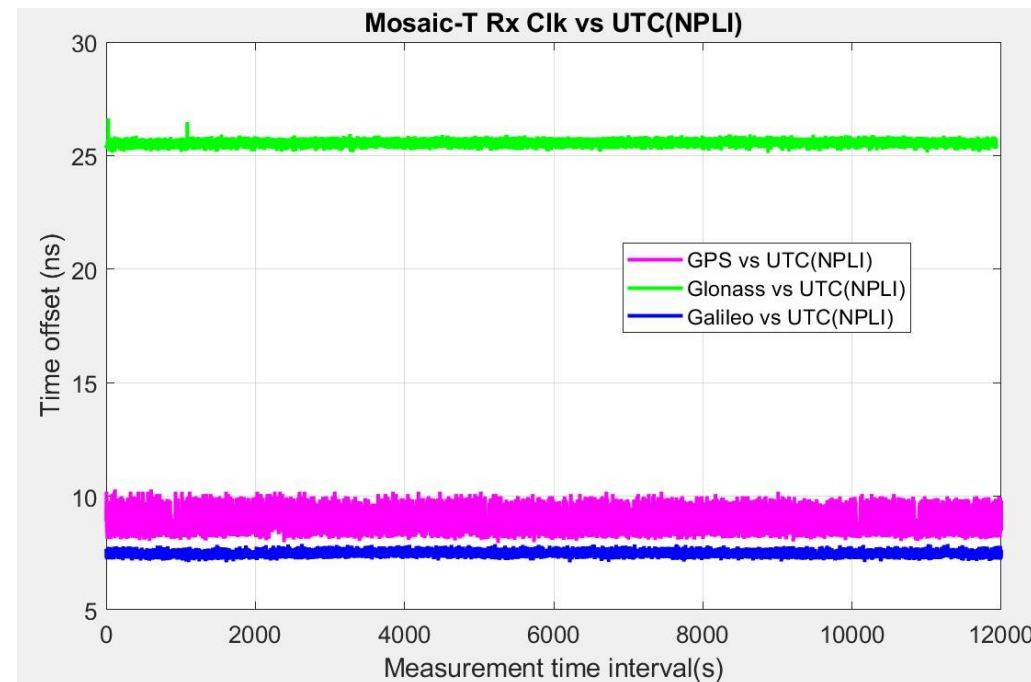
- GPS L1C/A, L1PY, L2C, L2PY, L5
- GLONASS: L1CA, L2CA, L3 CDMA
- GAL E1B/C, E5a, E5b, E5
- BDS B1I, B1C, B2a, B2I, B3
- QZSS L1C/A, L2C, L5
- NavIC L5

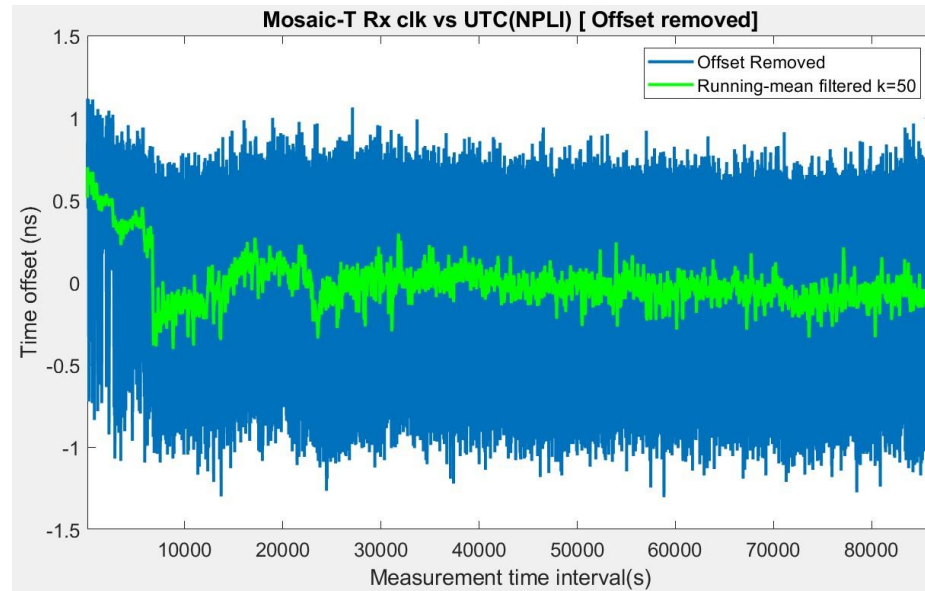
➤ Option for Input 10 MHz

➤ Option for input 1PPS

➤ Output data format

1. NMEA
2. SBF

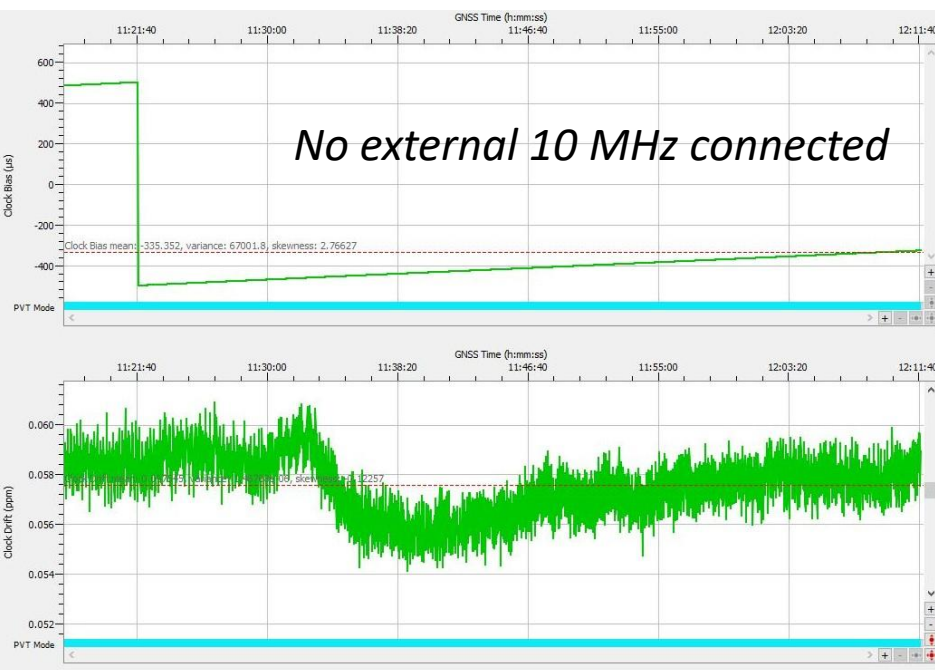




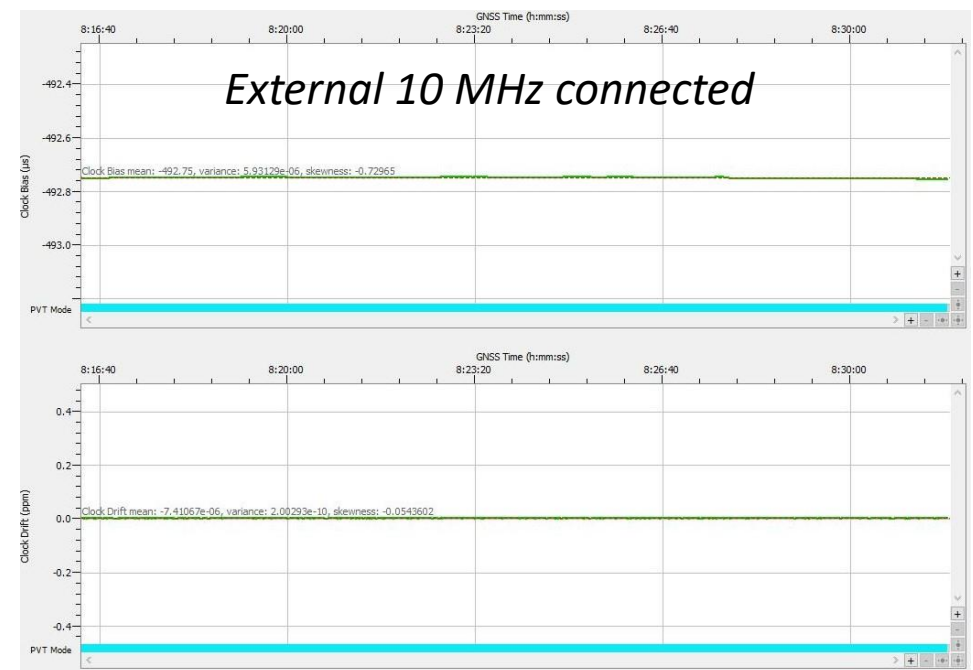
Receiver output
Timing Jitter less than ± 1 ns

Rx Clock bias and drift

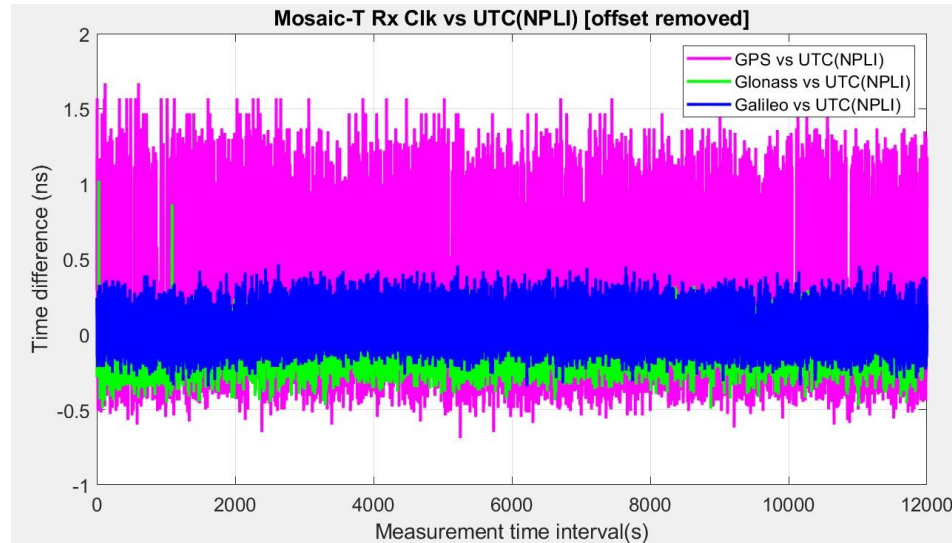
Rx Clock bias and drift



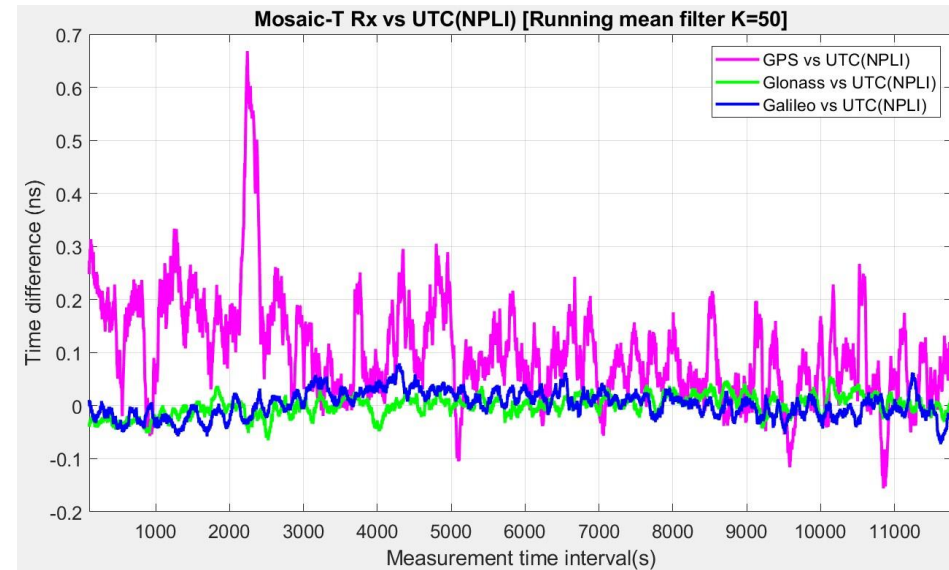
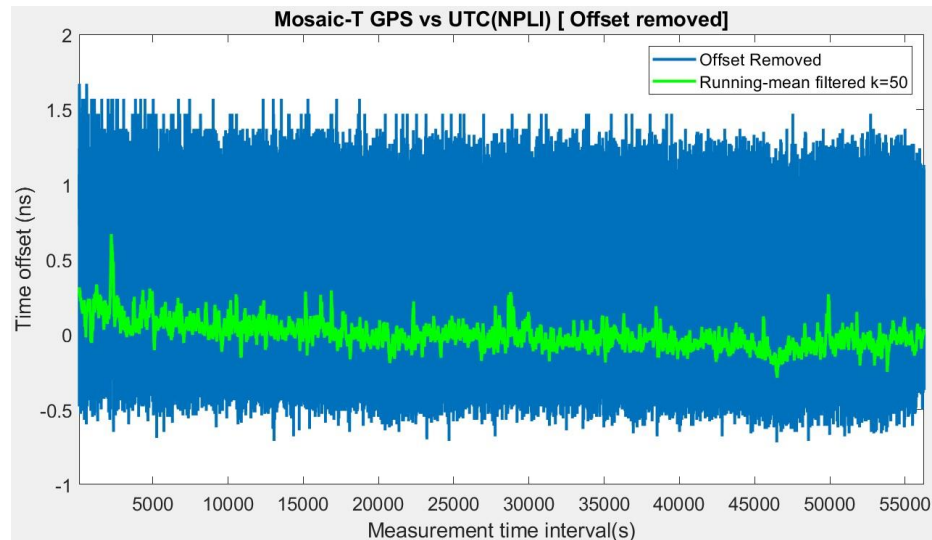
No external 10 MHz connected



External 10 MHz connected



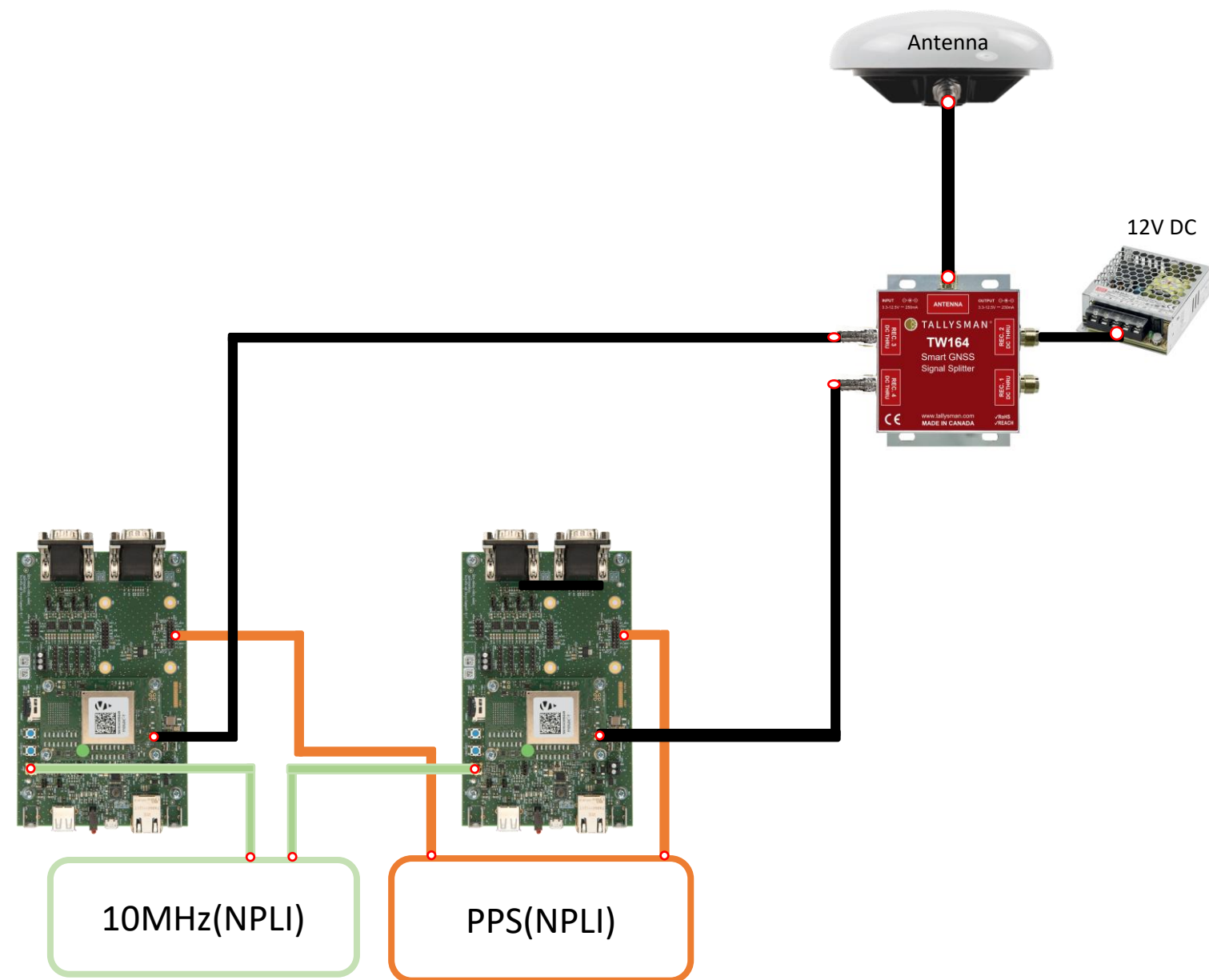
GPS, Glonass and Galileo
output Timing Jitter less than ± 1 ns



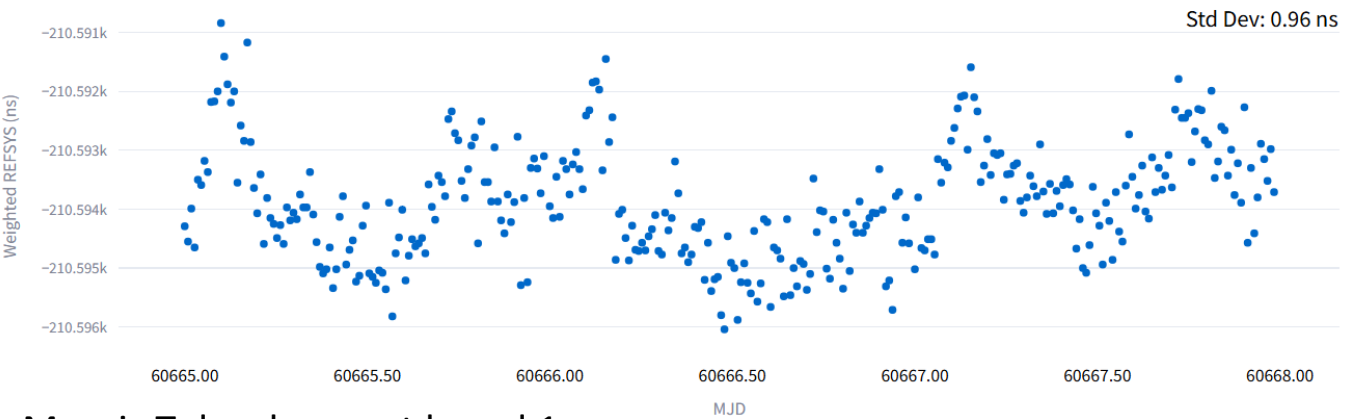
Common View Time Transfer:

Common clock configuration at one location

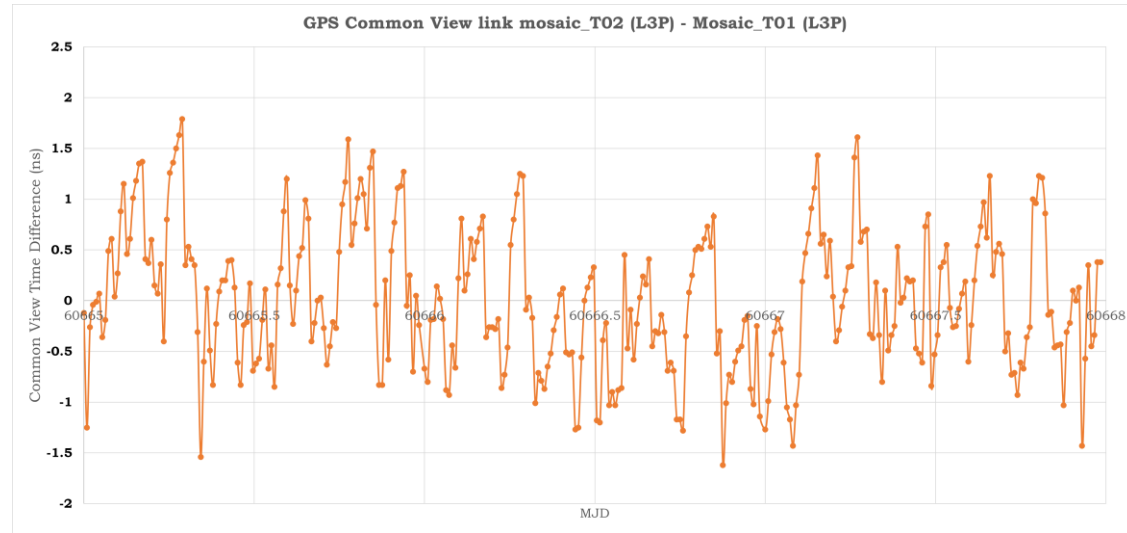
- As we have 45 m antenna cable we power up antenna using a Separate DC source 12V.
- Block the reverse DC voltage supply to other receivers using DC blockers. Allow only RF signals.
- Easy to setup, configure, and generate various formats of data including CGGTTS data files directly session wise (@ 15 minutes).



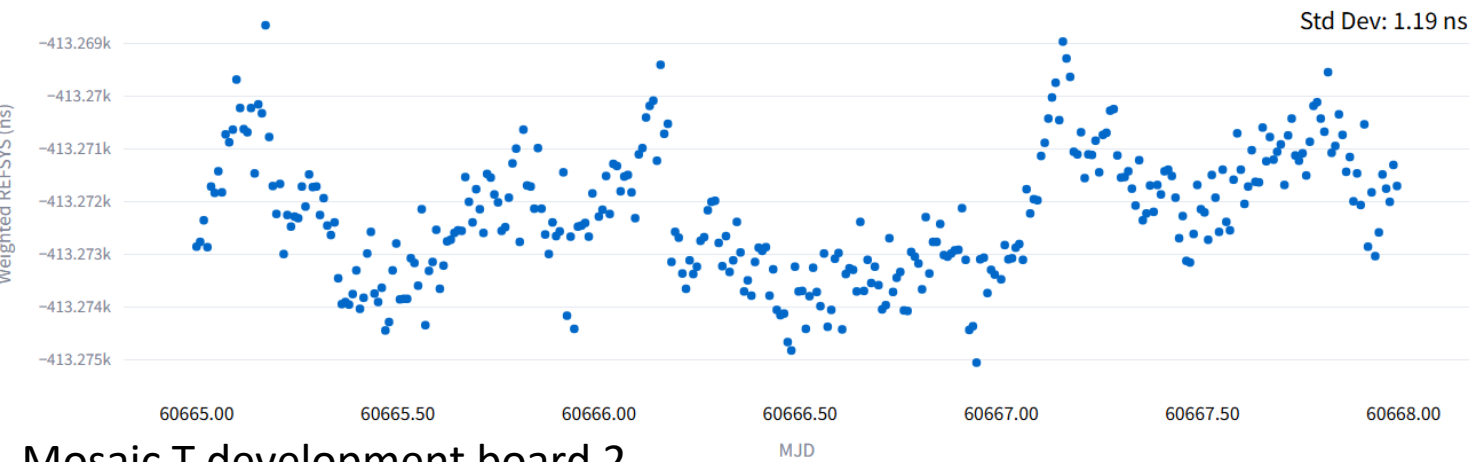
- GPS time at Lab: Moasic_T01 through L3P. (Each point corresponds to Sum of all satellite weighted refsys per epoch)



Mosaic T development board 1



- GPS time at Lab: mosaic_T02 through L3P. (Each point corresponds to Sum of all satellite weighted refsys per epoch)

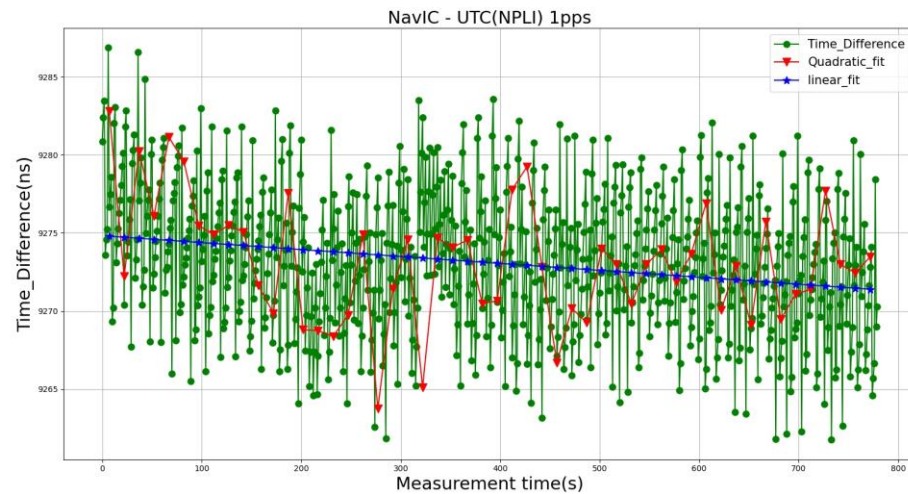
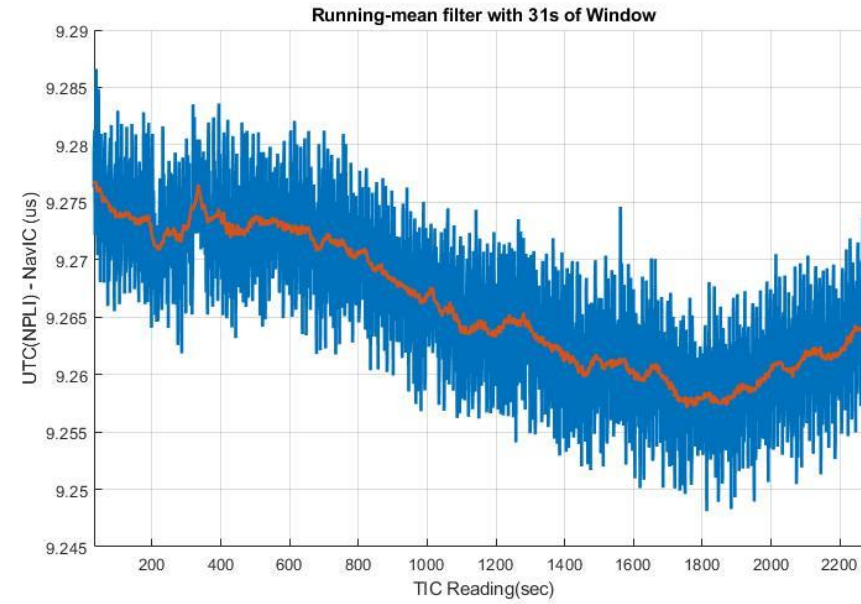


Mosaic T development board 2

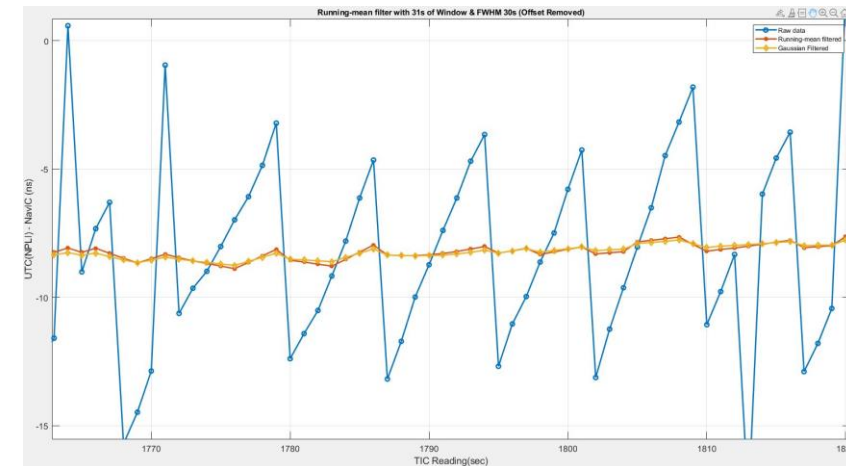
➤ SkyTraq PX11255-01



- GPS L1 C/A
- NavIC L5, GAGAN
- 56 channel
- Raw output



- Quadratic fitting for the time difference

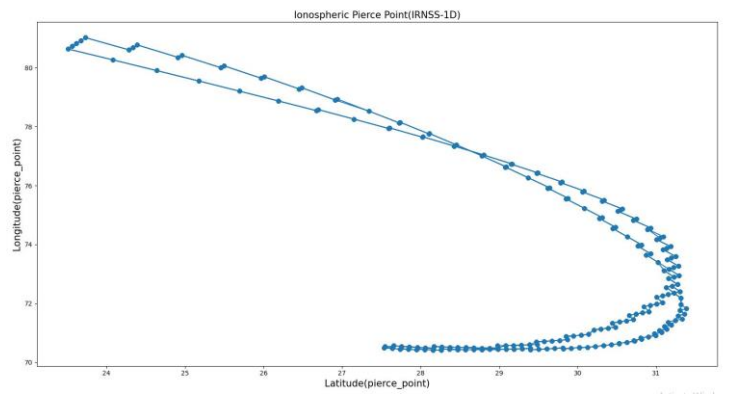
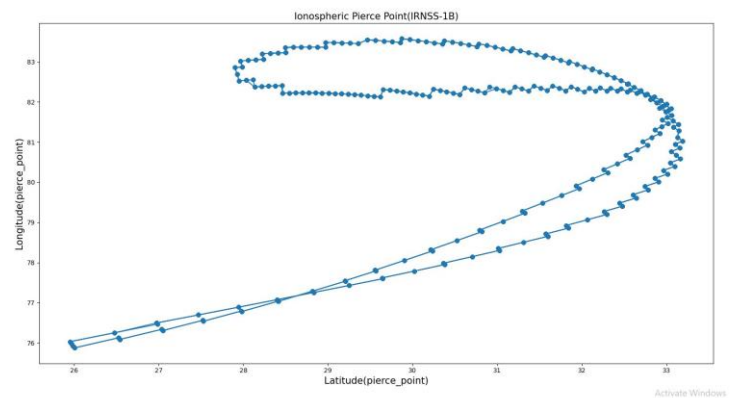
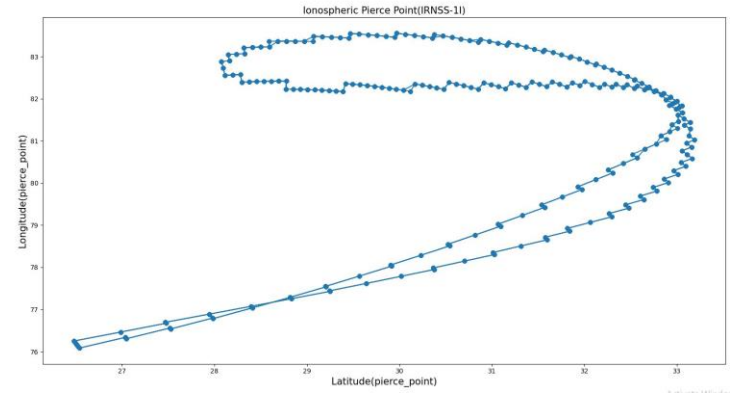


- SAW tooth error 20 ns

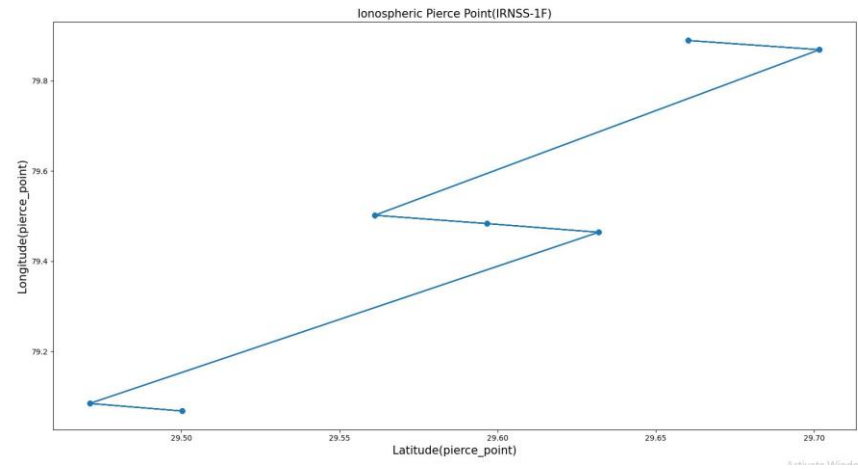
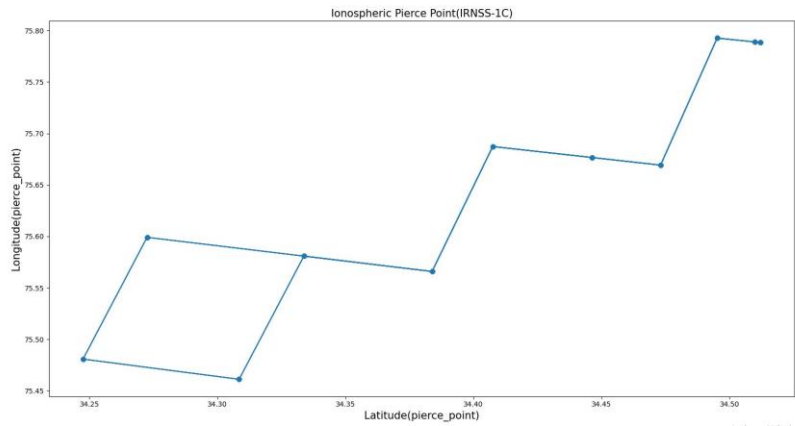
SkyTraq PX11255-01

Ionospheric Pierce Point (IPP) from Grid model of NavIC signal

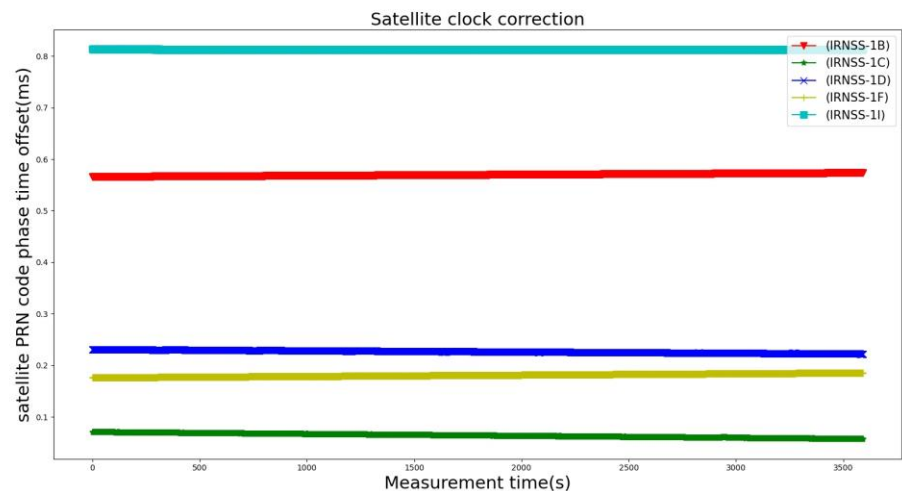
Geo Synchronous satellites



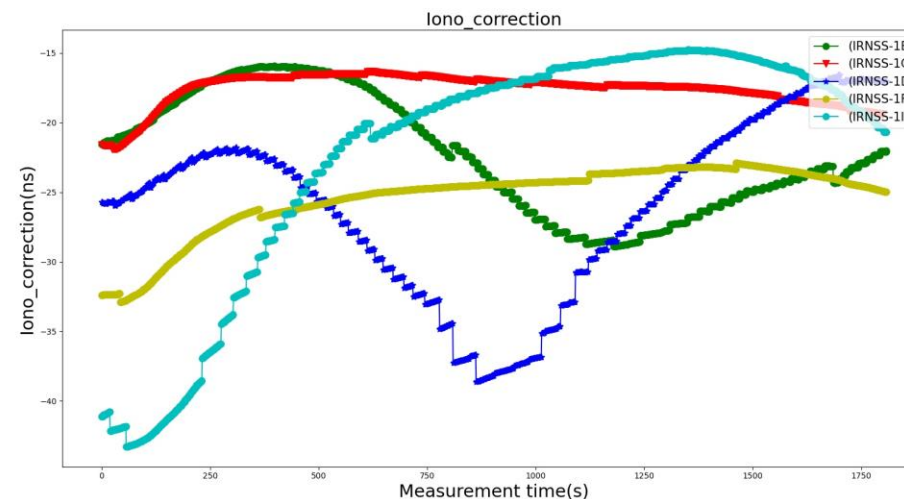
Geo Stationary satellites



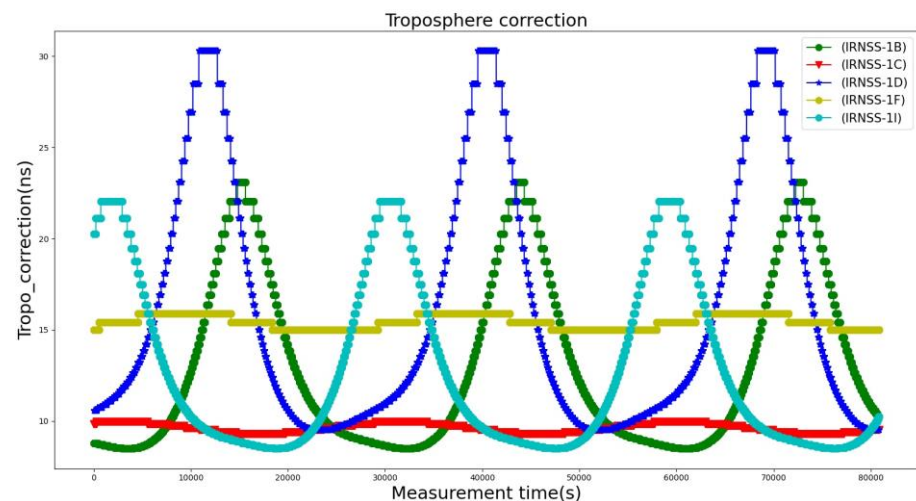
On board satellite Clock corrections



Ionospheric corrections



Tropospheric corrections



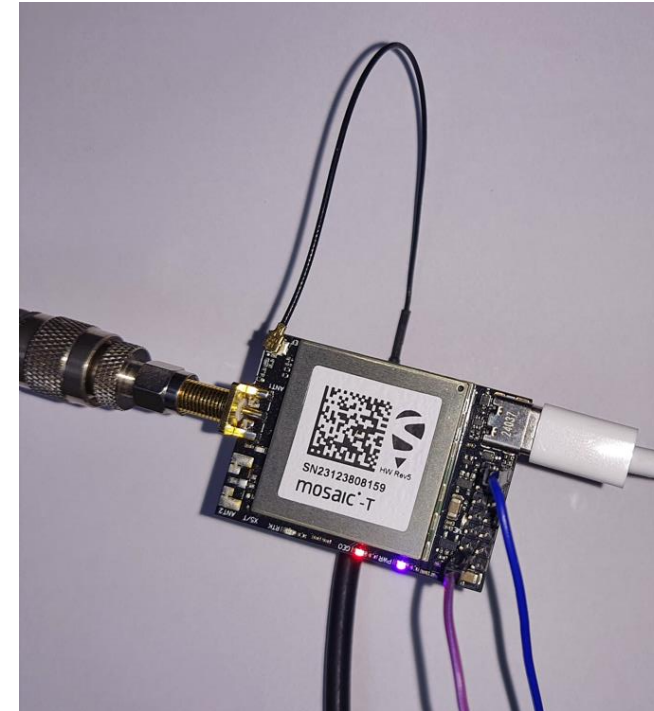
Parameter	Uncertainty
1 pps quantisation error	7.2 ns
On board satellite clock	3.8 μs
Tropospheric effect	6.4 ns
Ionospheric effect	30 ns
Total	3.8 μs

➤ Septentrio Mosaic-T module



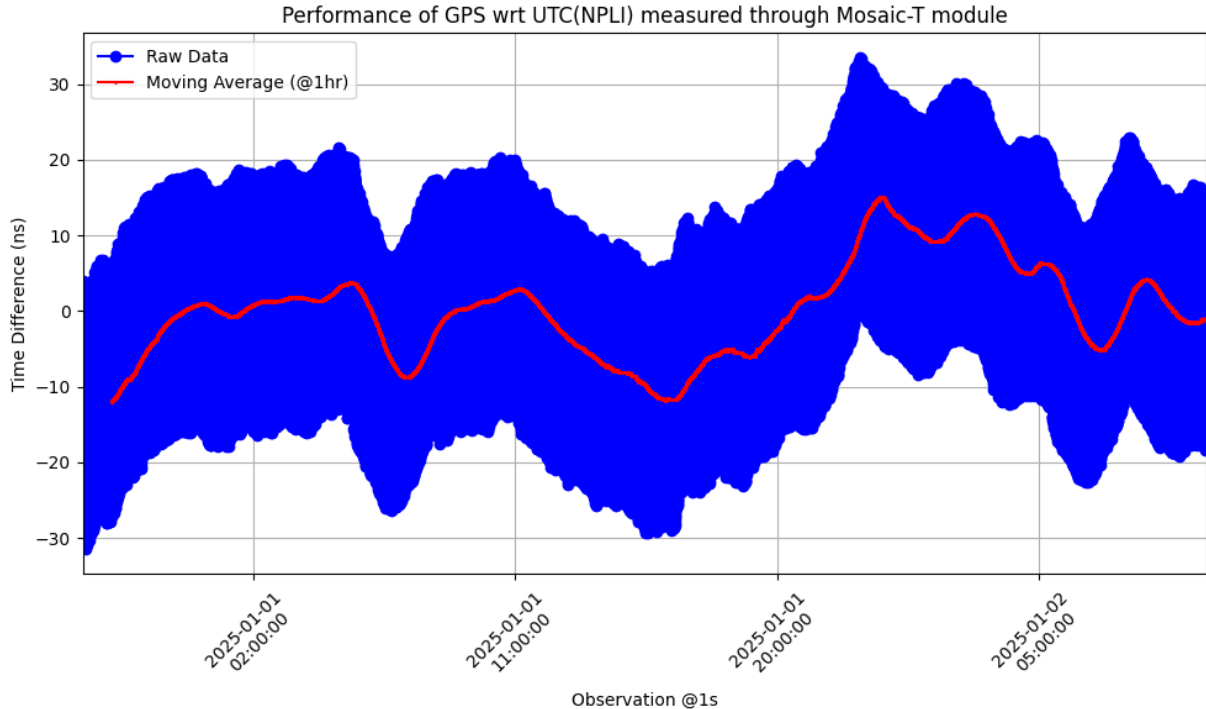
<https://gnss.store/septentrio-gnss-modules/359-358-elt0741.html#/57-connector-sma>

Unit price: 350 euro

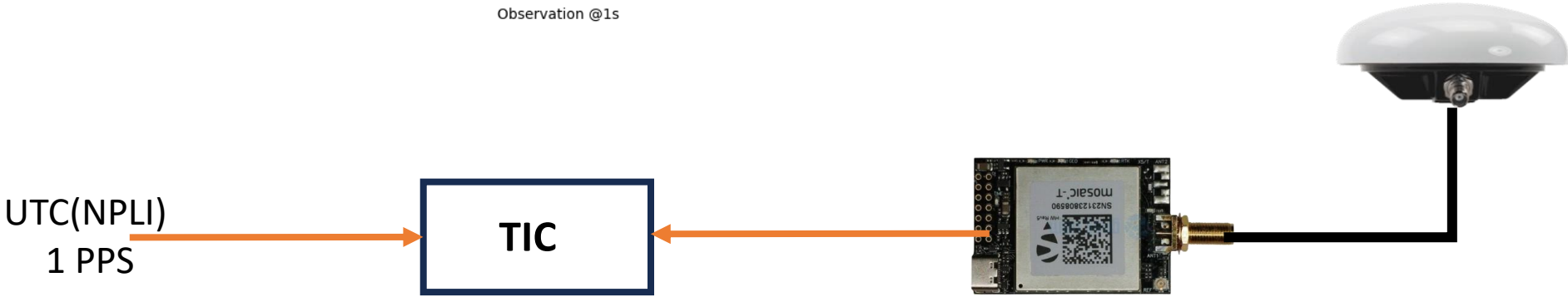
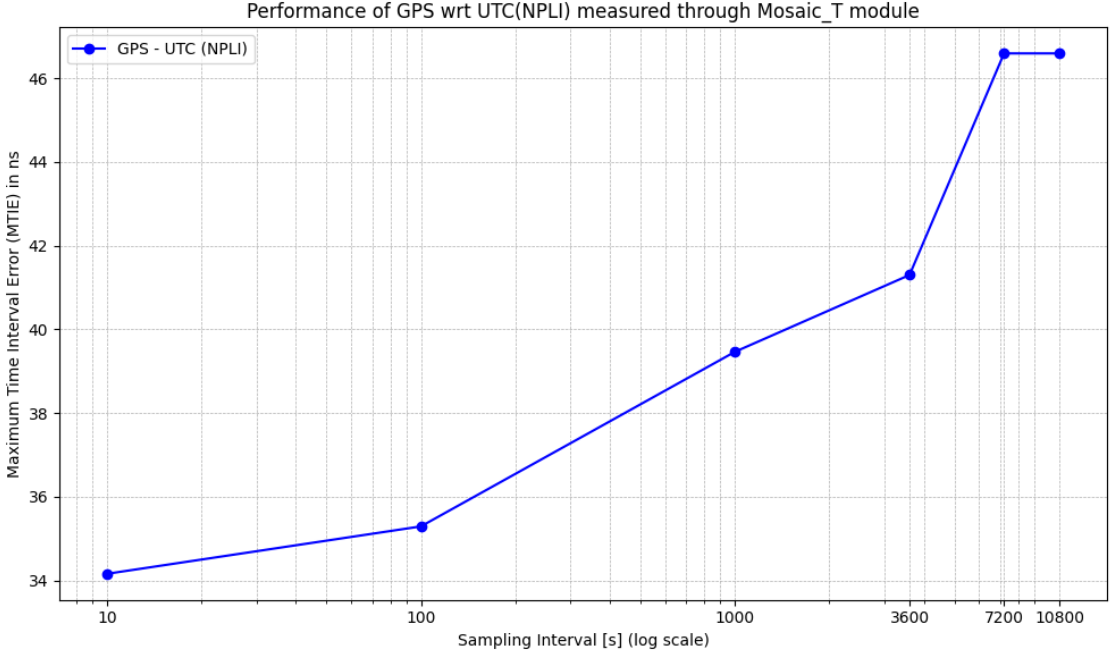


Test setup

GPS output w.r.t UTC(NPLI)



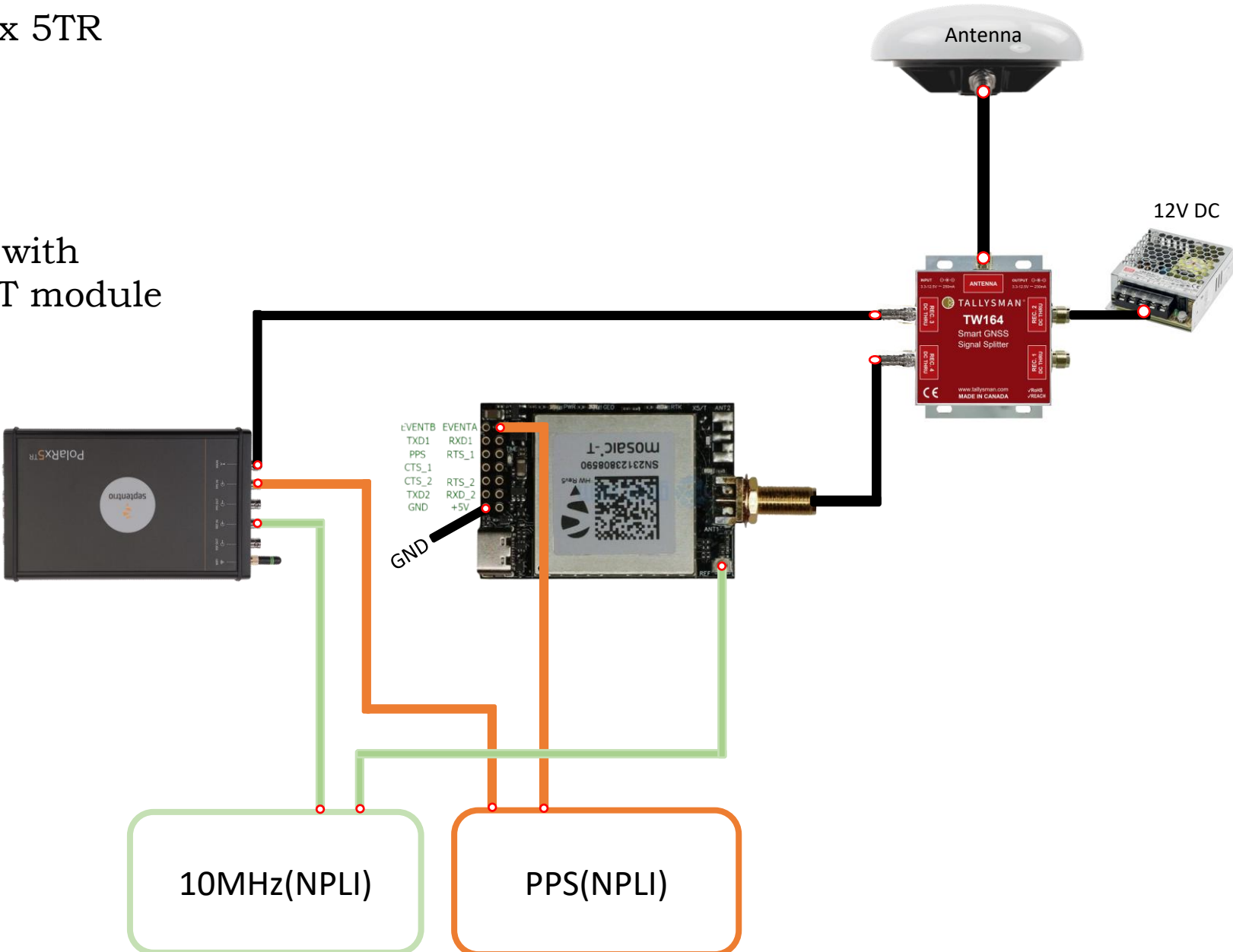
MTIE plot



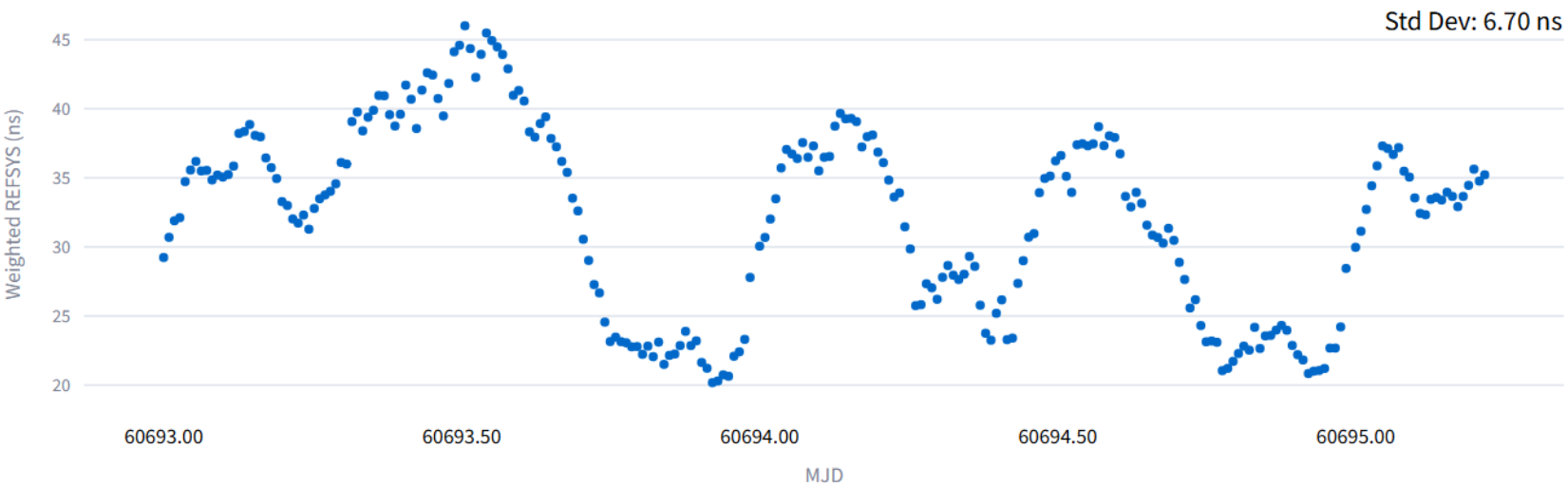
Performance comparison with Polarx 5TR

Observations:

Internal oscillator seems not locked with external input of 10 MHz in mosaic T module

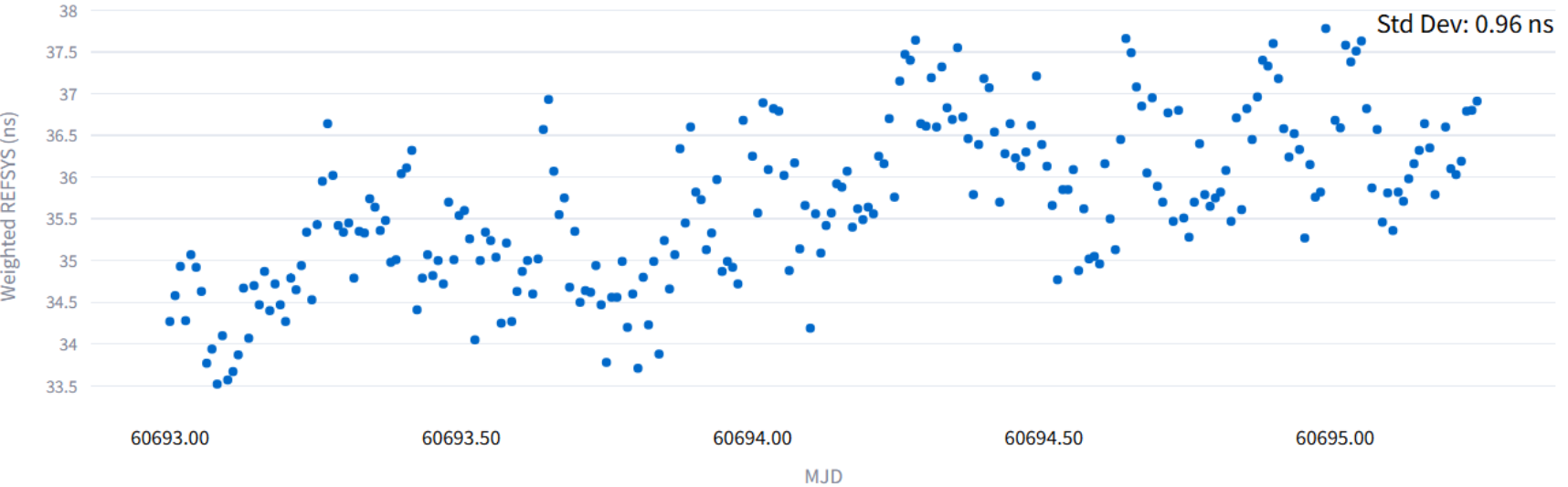


UTC(NPLI) - GPS time at Lab: mosaic_TS through L3P. (Each point corresponds to Sum of all satellite weighted refsys per epoch)



Mosaic T module

- GPS time at Lab: TTLab_5TR1 through L3P. (Each point corresponds to Sum of all satellite weighted refsys per epoch)



Polarx5TR

- Tried using Time to Digital Converters (TDC) for TIM
- Software timestamped Time of Flight Measurement devices

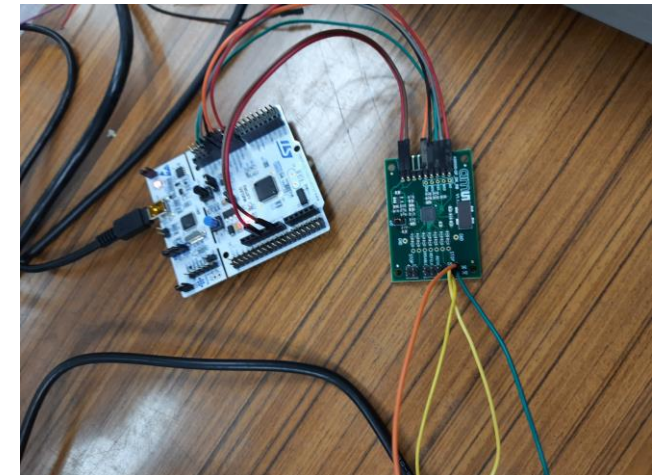
Texas Instruments
TDC7200

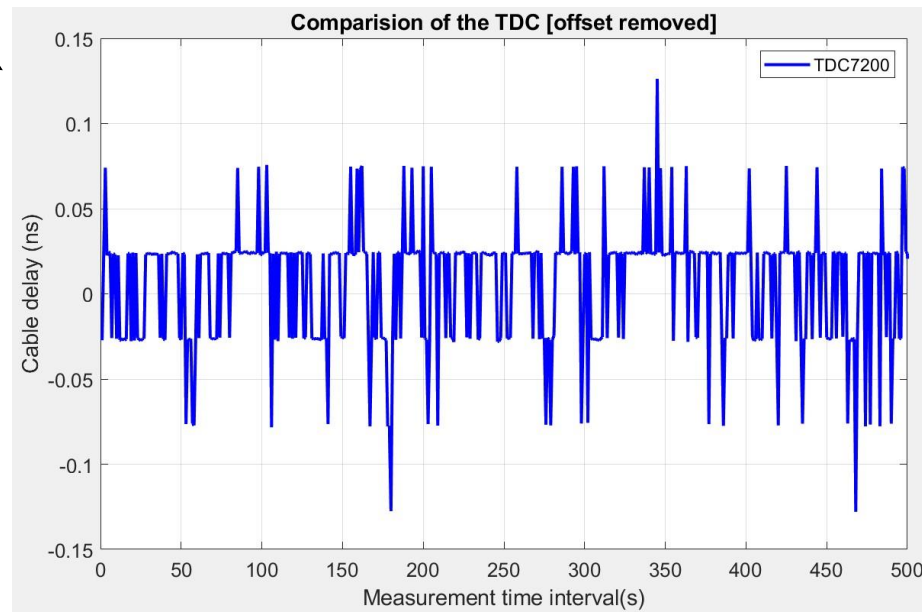
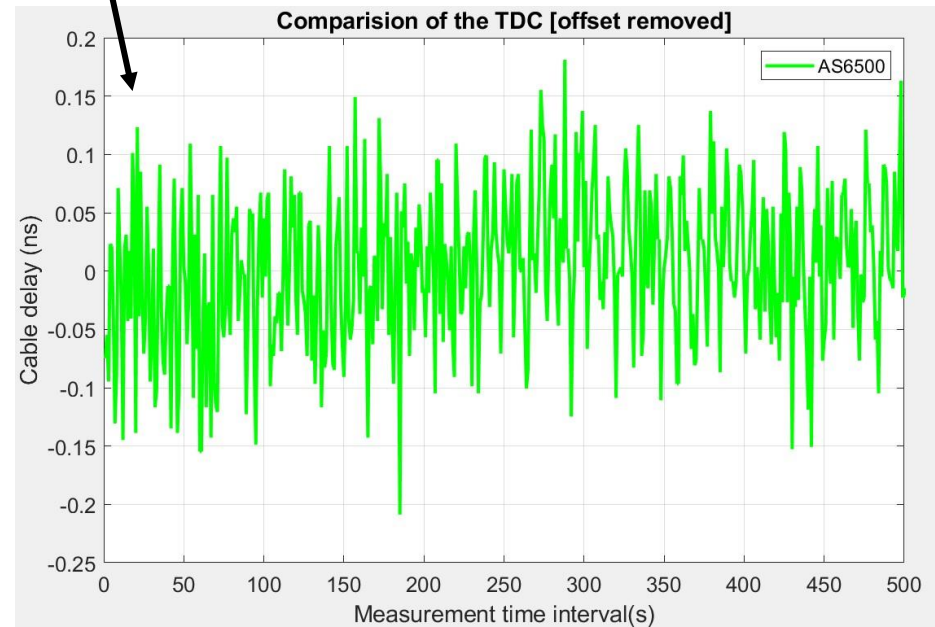
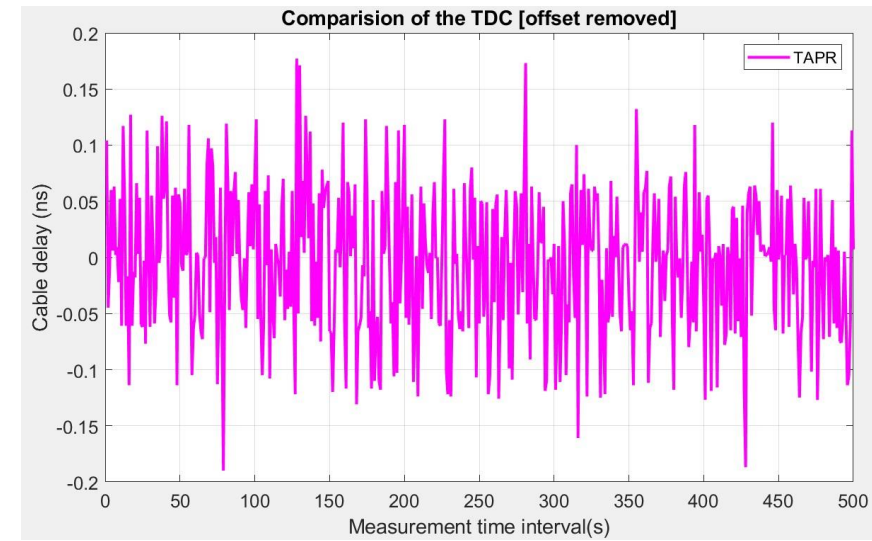
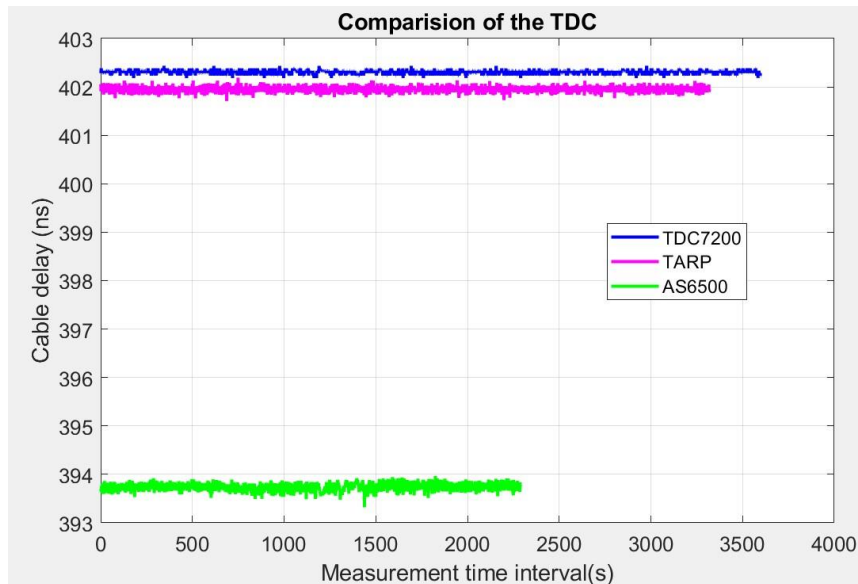


TAPR - TICC
(2 TDC7200 used)

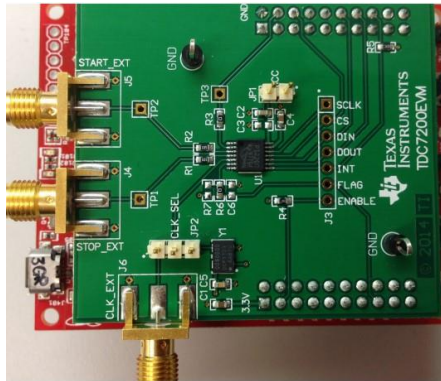


Amu - AS6500

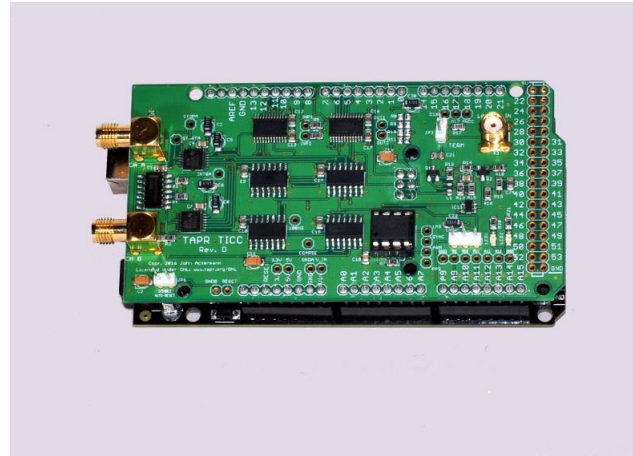




Texas Instruments
TDC7200



TAPR - TICC
(2 TDC7200 used)



Amu – AS6500



	TDC7200	TAPR TICC	AS6500
Range	Mode 1: 12 ns to 500 ns Mode 2: 250 ns to 8 ms	0 to 16 s	4 ns to 6.5 ms
Single shot Resolution	55 ps	60 ps	20 ps
Jitter	± 50 ps	± 50 ps	± 70 ps
Ext Clk Ref In	1 to 16 MHz	1 to 16 MHz	2 to 12.5 MHz

- After trying various receivers, we are currently using Septentrio Mosaic-T for NPLI-DO application
- Easy to use with flexible direct data formats output in BIPM format.
- Low cost 350 Euro

Thank you

