Compact, Low-cost GNSS Hardware: Potentials In Precise Positioning, Ionospheric Probing, Time Transfer And Application Development

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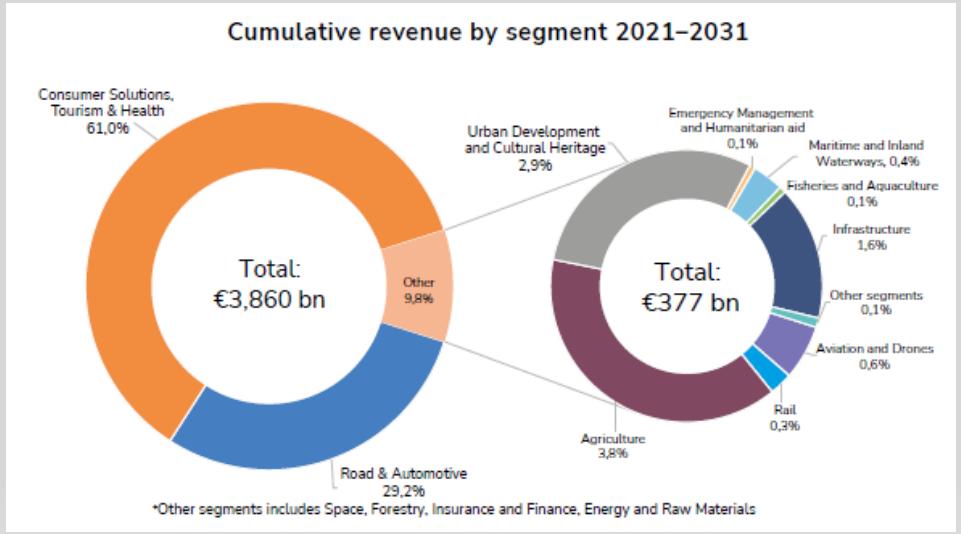
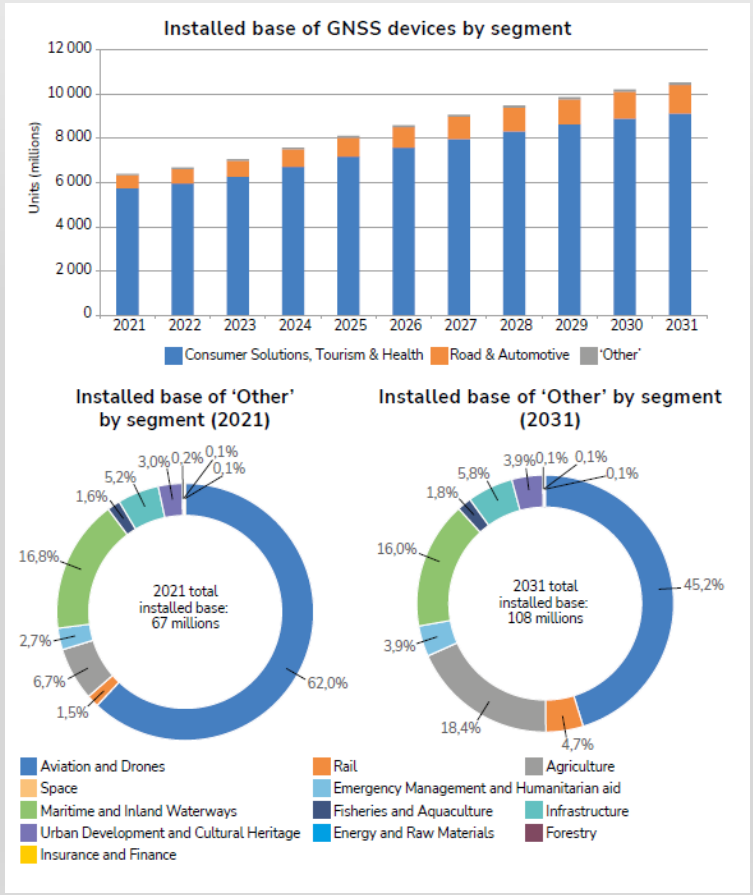
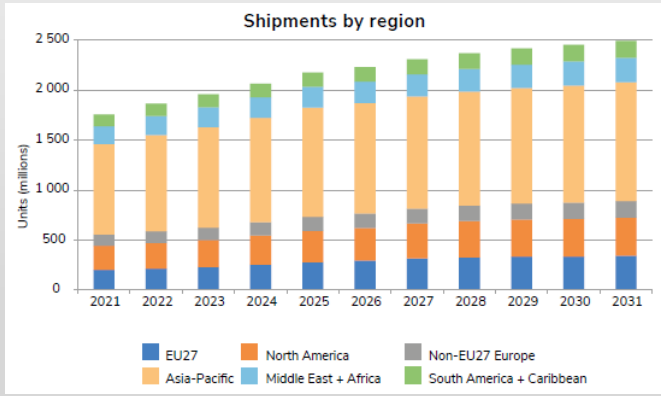
Agenda

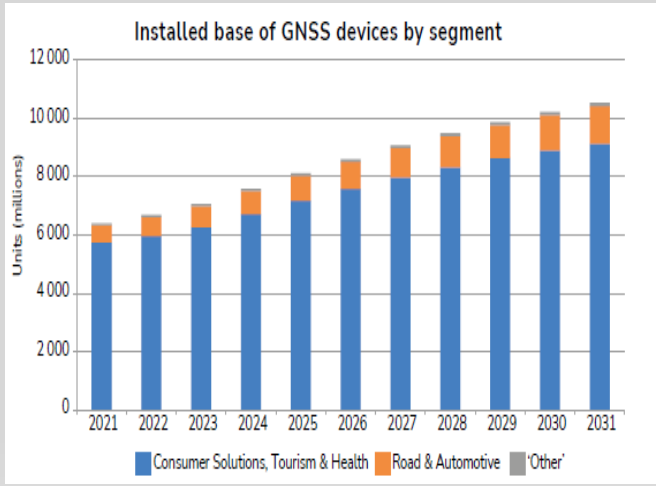
- The Global market potential of GNSS and Current Multi-GNSS Scenario
- The Compact, Low-Cost GNSS Modules
- Use Case: Positioning
- Use Case: Atmospheric Research
- Use Case: Time Transfer
- Application Development Examples
- Final Remarks

The ever-growing GNSS market









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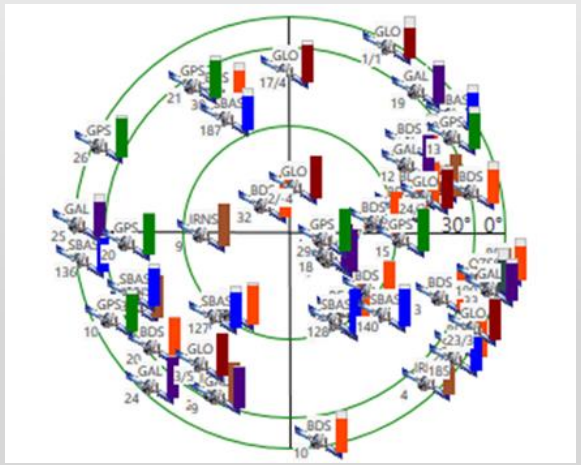
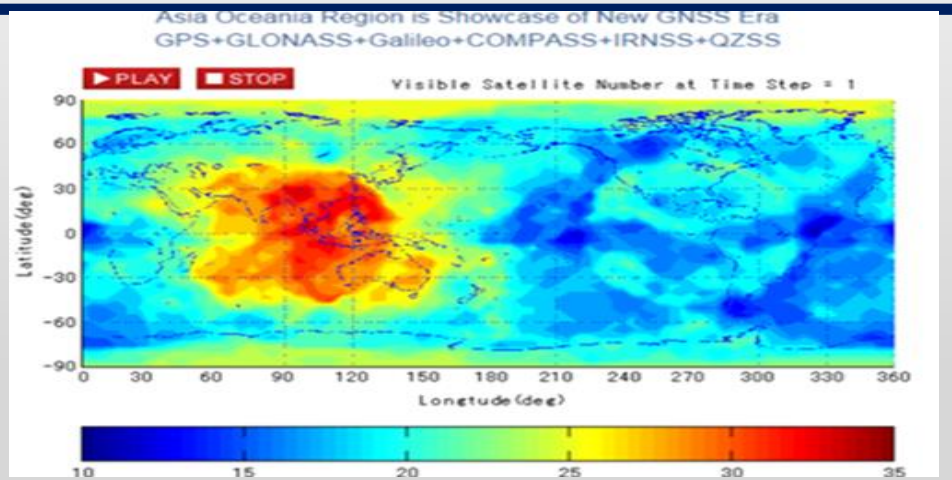
https://www.euspa.europa.eu/2022-market-report

Multi GNSS environment: Advantage Asia



Typical skyplot for Western India
(23 June, 2019: 18:11 hrs IST)
54 satellites in view, 45 used
GNSS receiver screenshot

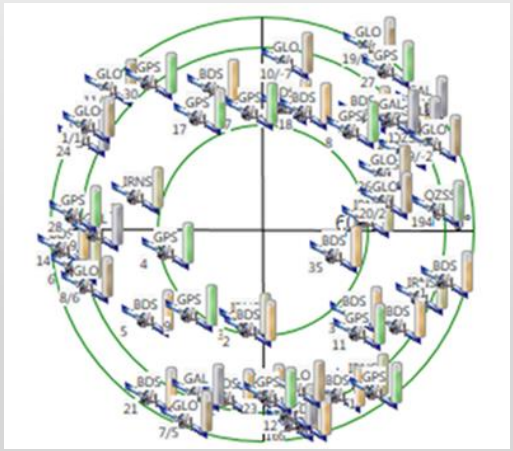
GPS+GLONASS+Galileo+Beidou
+
NavIC+QZSS



Simulated Multi-GNSS visibility
(Multi-GNSS Asia- MGA)

GNSS View App Screenshot

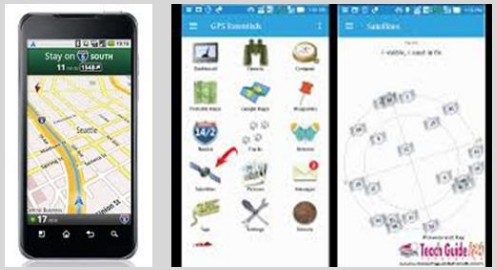
The Asia Oceania Region is the Multi-GNSS signal hotspot

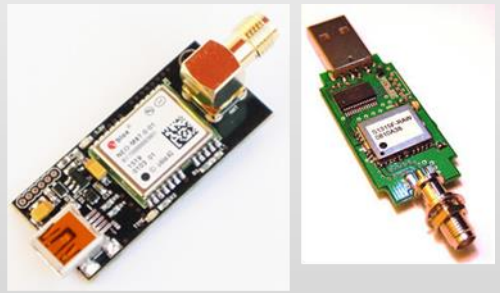


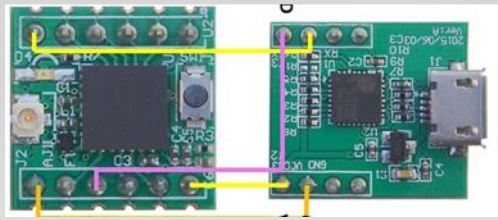
Typical skyplot for Eastern India
(04 March 2019: 15:00 hrs IST)
54 satellites in view
GNSS receiver screenshot

GPS+GLONASS+Galileo+Beidou
+
NavIC+QZSS

GNSS User Segment







Q: How to exploit the full benefits of the situation ?

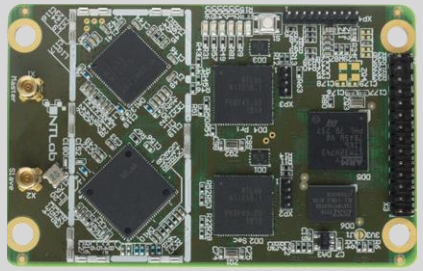
A: GNSS receivers of varying cost, capability and complexity

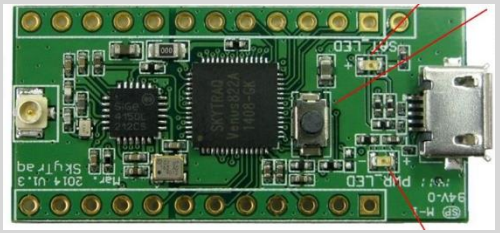
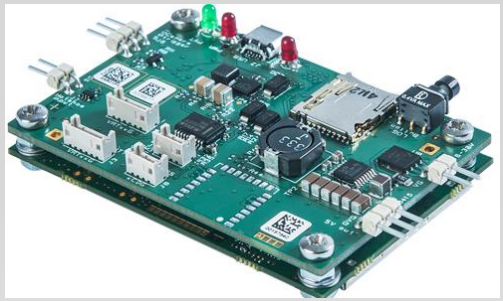
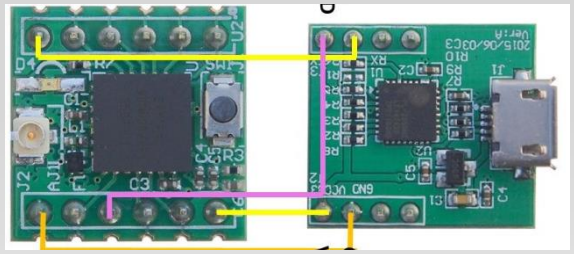
Q: How to cater the need of the mass-market, typically in cost-constrained situations ?

A: Compact, Low-cost, Power-efficient GNSS modules

GNSS Compact, Low-Cost Modules





- **Compact modules are commercially available in the market Compact Low cost Single (CLS) and Compact Low cost Dual (CLD) frequency enabled**

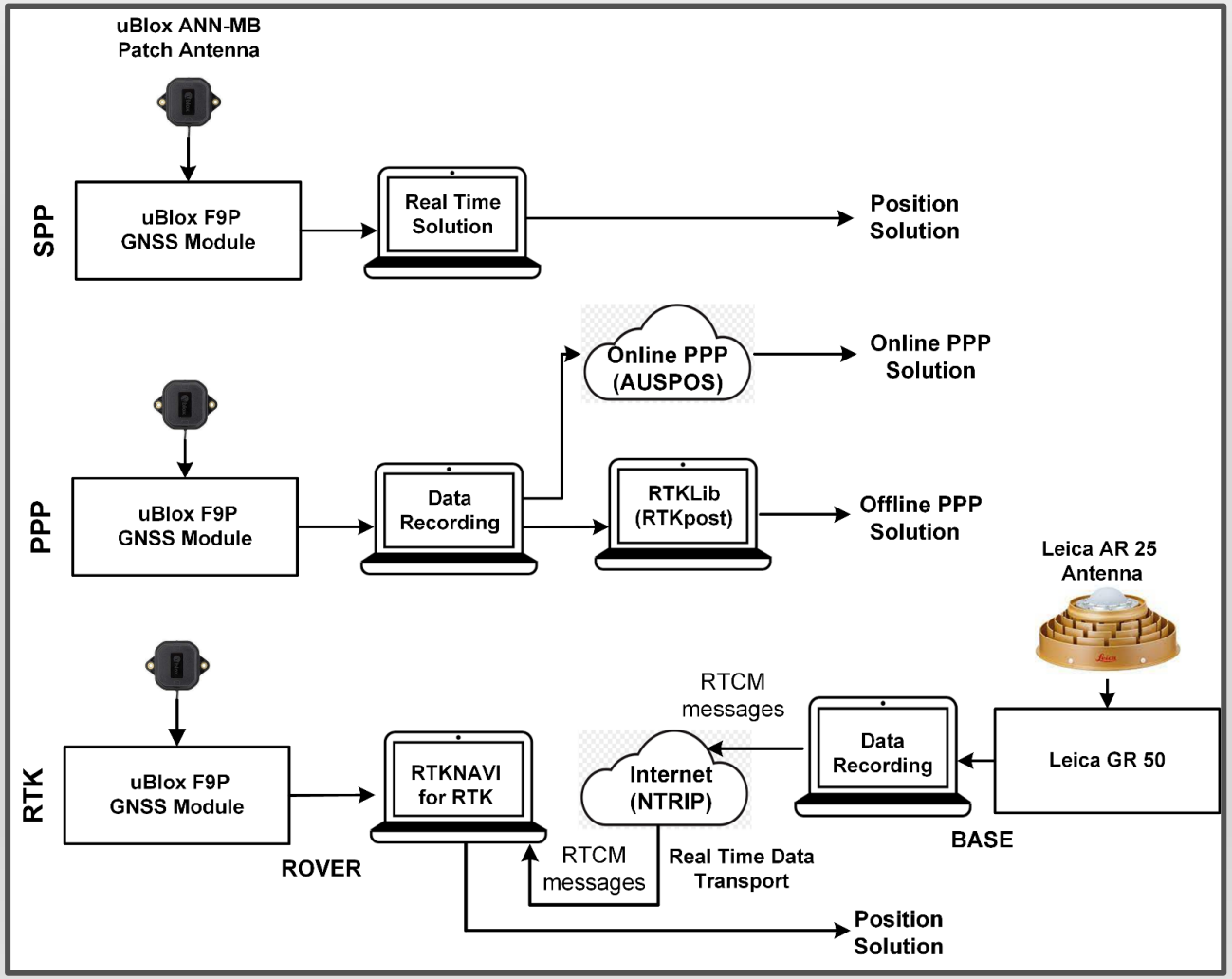
Advantages

- **Low cost : <USD 1000; Compact: <100 grams**
- **Small size, low-power consumption**
- **Can be directly attached to Computers to log data (raw/ NMEA)**
- **Multi-constellation, Multi frequency**
- **Arduino and other Microcontroller Compatibility for data transfer and application**
- **RTK-enabled boards, Carrier phase measurements**

Limitations

- **Needs training in using such modules**

In positioning



- uBlox ZED F9P (F9P) CLD module together with an uBlox ANN commercial patch antenna is used for GNSS SPP, PPP, and as the RTK rover.
- The total cost of the hardware is less than 380 USD and open- source GNSS data processing software (RTKLib) is used in the work.
- For SPP, data from the F9P-patch antenna (placed in an open-sky condition) combination is collected in a computer using the u-center software from uBlox.

SPP and PPP Results (GPS-only)

SPP and PPP performances offered by compact GNSS module (uBlox F9P)			
SPS (m)		2DRMS	2.897
		CEP	1.348
		SEP	2.746
		MRSE	2.988
PPP (m)	Online	Latitude	0.004
		Longitude	0.003
		Altitude	0.010
PPP (m)	Offline	Latitude	0.014
		Longitude	0.013
		Altitude	0.018

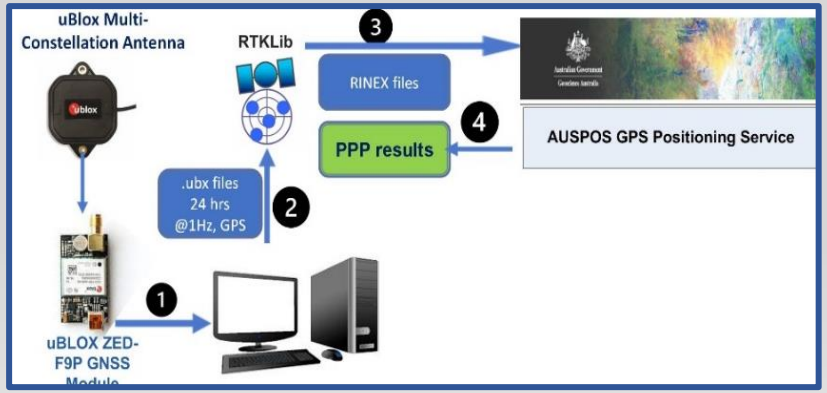
- Performance evaluation of F9P CLD GNSS module used with a commercial patch is conducted for GNSS SPP and PPP
- Table shows the SPP and PPP, (Offline and Online) solution qualities provided by the F9P CLD GNSS module against the same dataset.
- SPP: The 2D and 3D solution accuracy in SPP w.r.t the Reference Coordinate (RC), lies between 2-3m. SPP using CLD GNSS modules is a very convenient and cost-efficient method of real-time geolocation when the offered solution quality is sufficient for the users.
- PPP: Online PPP provides solution accuracy in the order of few mm (95% confidence level) in the horizontal coordinate and in centimeter-level for the vertical coordinate.

PPP using Compact Modules: More results

3.4 Positional Uncertainty (95% C.L.) - Geodetic, ITRF2014

Station	Longitude(East) (m)	Latitude(North) (m)	Ellipsoidal Height(Up) (m)
R000	0.005	0.003	0.010

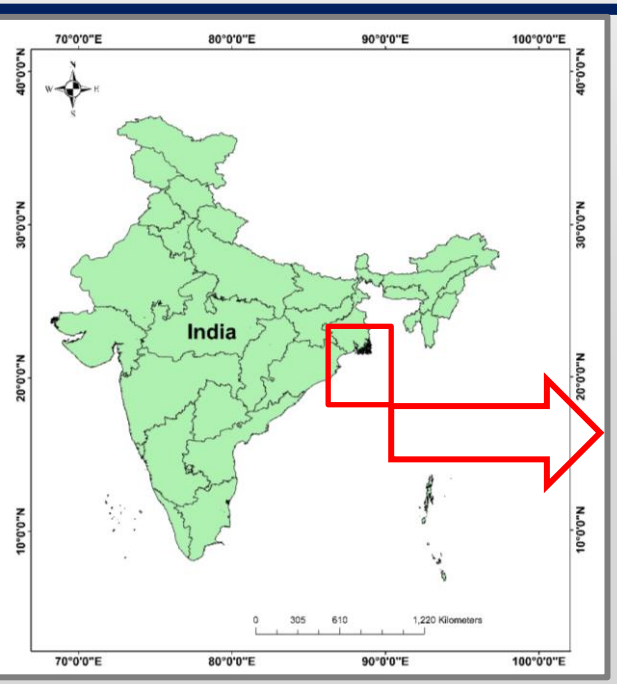
Coordinate	X (m)			Y (m)			Z (m)		
Date	GPS	GLO	GPS+ GLO	GPS	GLO	GPS+ GLO	GPS	GLO	GPS+ GLO
24/04/2021	0.003	0.080	0.003	0.003	0.015	0.003	0.013	0.036	0.012
25/04/2021	0.003	0.013	0.003	0.003	0.025	0.003	0.013	0.059	0.013
26/04/2021	0.004	0.122	0.004	0.004	0.279	0.004	0.018	0.267	0.018

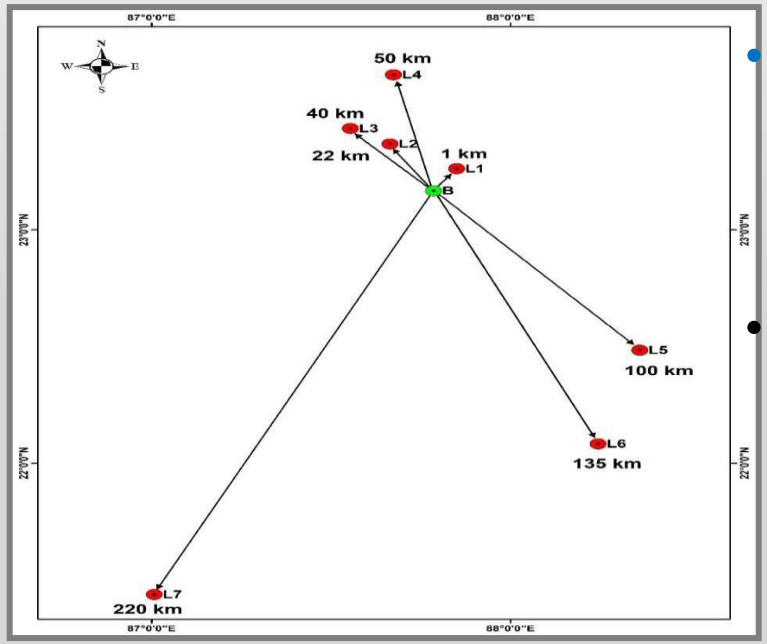


- GPS only, uBLOX F9P, 2021
- Results from AUSPOS online PPP service

- NTLab 104v3, 2021
- Results from NRCAN online PPP service

RTK: Data collection Locations





- The experiment is conducted for multiple short to long baseline length (<220 km) RTK performance evaluation.
- Different RTK Rover Locations at eastern India is shown on the left ; Base Location is marked in green and Rover locations are marked in red.
- Data is collected at each location @1Hz for 1 hour each (3600 epochs) using the GNSS CLD module during June-December 2022.

"Single Baseline Long Distance RTK using CLS GNSS Module and Open-Source Software: A Case Study from India", Somnath Mahato, Mrinal Goswami, Surajit Kundu and Anindya Bose, IETE Journal of Research, April 2023, DoI: https://doi.org/10.1080/03772063.2023.2192424

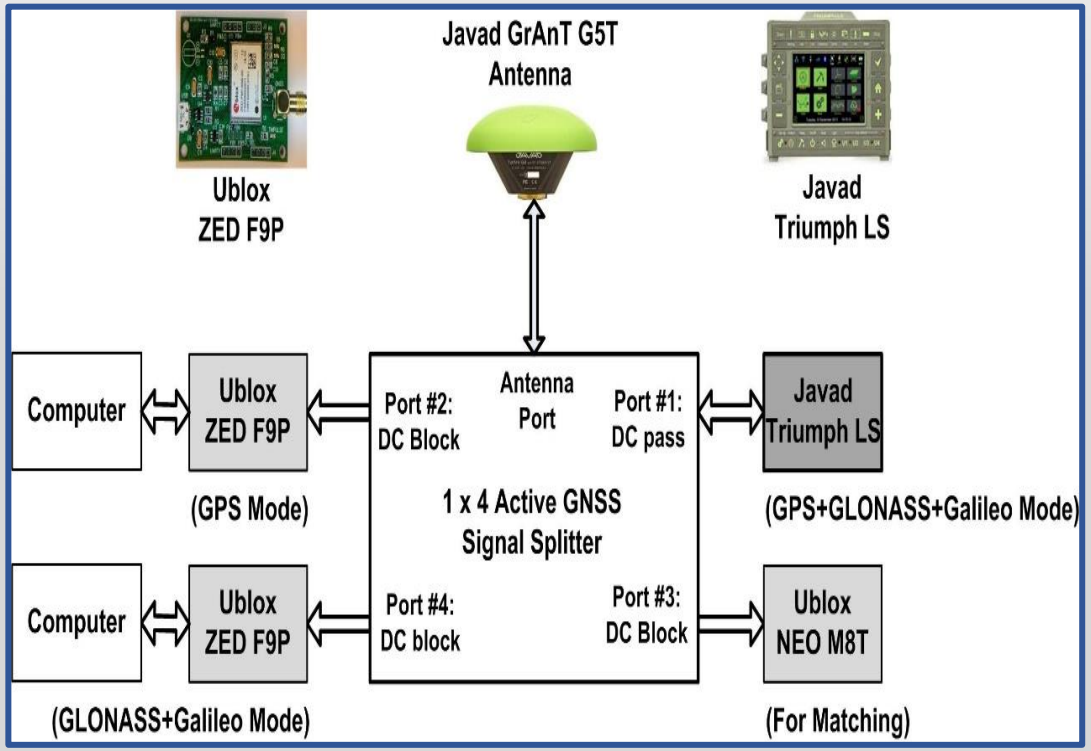
RTK: Results

Short to long-distance RTK performances offered by compact GNSS modules (uBlox F9P) as Rover in GPS mode				
Baseline Distance (km)	Solution precision values (m)			
	2DRMS	CEP	SEP	MRSE
1	0.053	0.087	0.093	0.121
22	0.287	0.254	0.207	0.242
40	0.584	0.523	0.562	0.582
50	0.444	0.417	0.321	0.376
100	0.677	0.628	0.597	0.605
135	0.829	0.81	0.802	0.843
220	0.997	0.968	0.948	0.989

- Table shows the position solution quality provided by the F9P CLD module used as Rovers at different baseline distances.
- Short baseline lengths up to around 50km, solution precision of less than 50 cm both for 2D and 3D is obtained.
- For higher baseline lengths, the solution quality slowly degrades with increasing distance, but even for the baseline distance of more than 200 km, the 2D and 3D precision remains within 1 m in GPS-only operation.

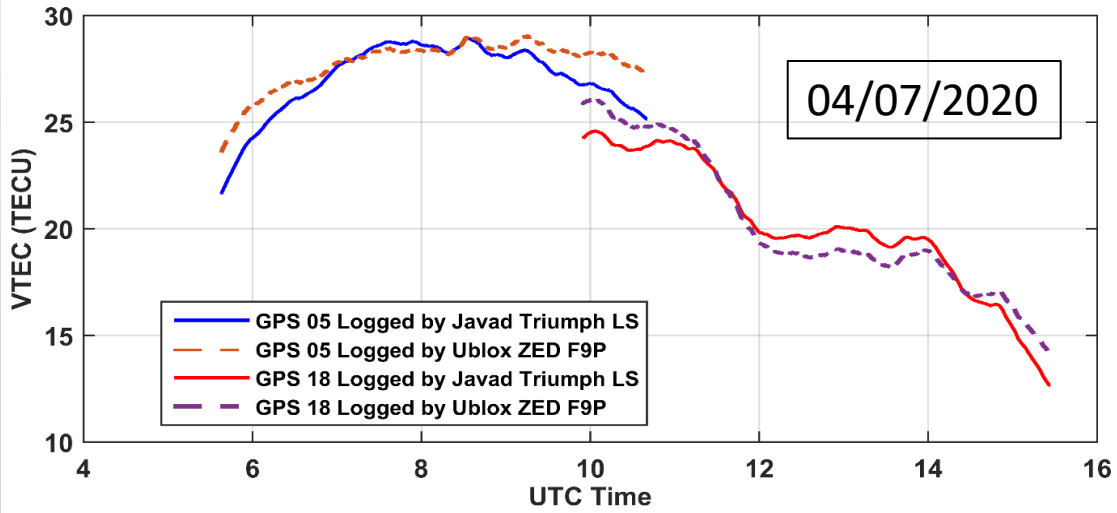
- A single Base is used upto 200+km baseline together with the low-cost module for RTK; real-time sub-meter position solution is achievable reducing the overall infrastructure cost.

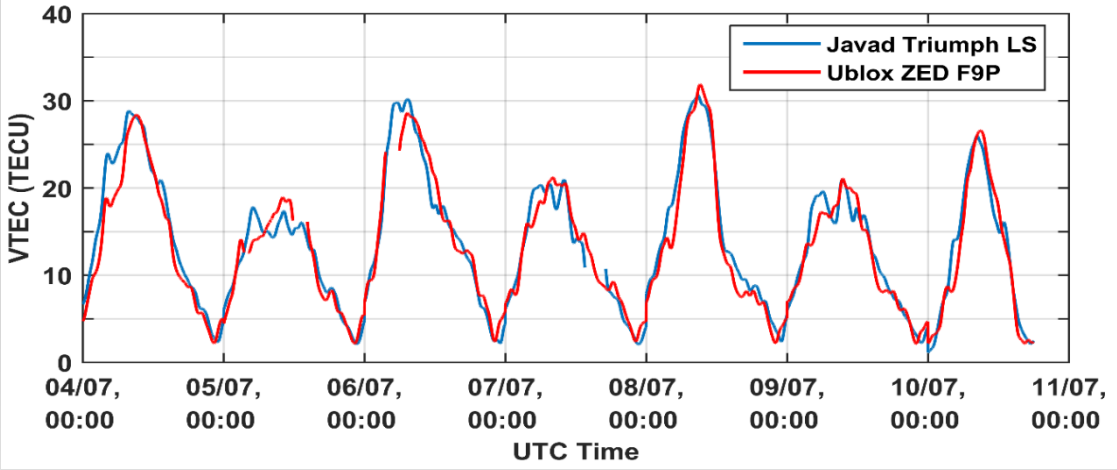
In Ionospheric Studies

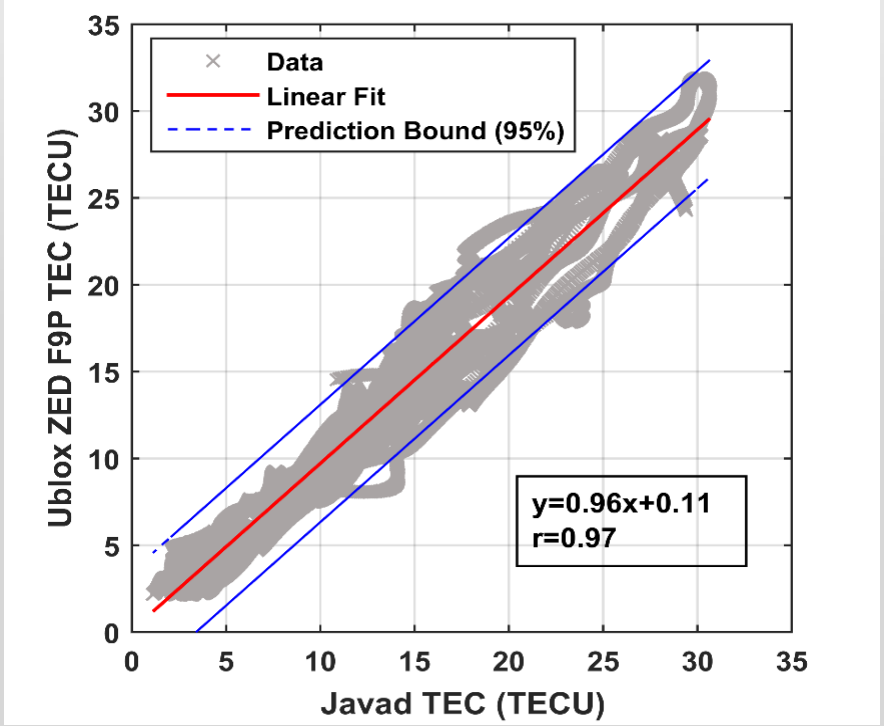


Experimental setup for the comparative study of Ublox ZED F9P and Javad Triumph LS receiver for GNSS-based ionosphere study

GPS TEC Comparison (Geodetic v/s CLD)

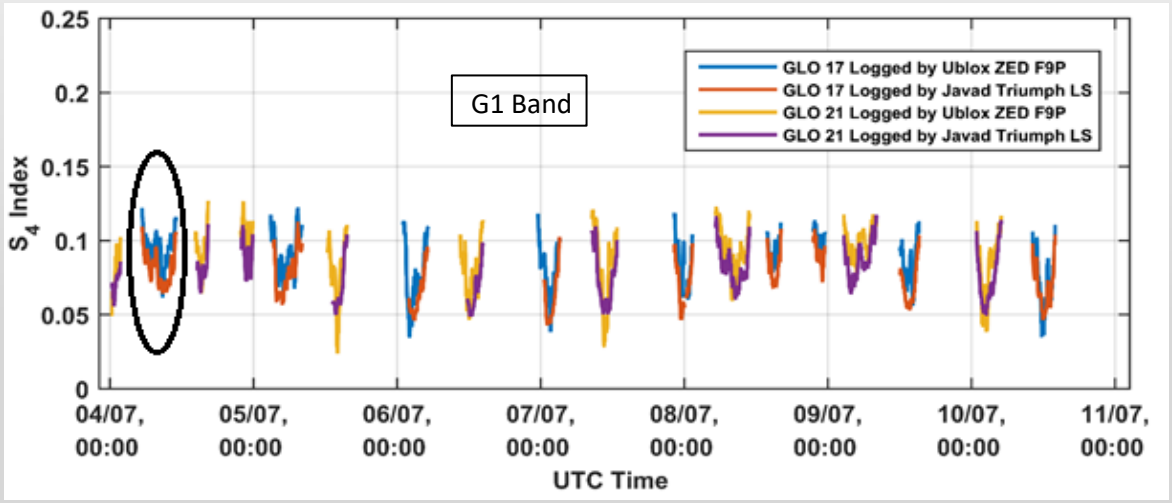


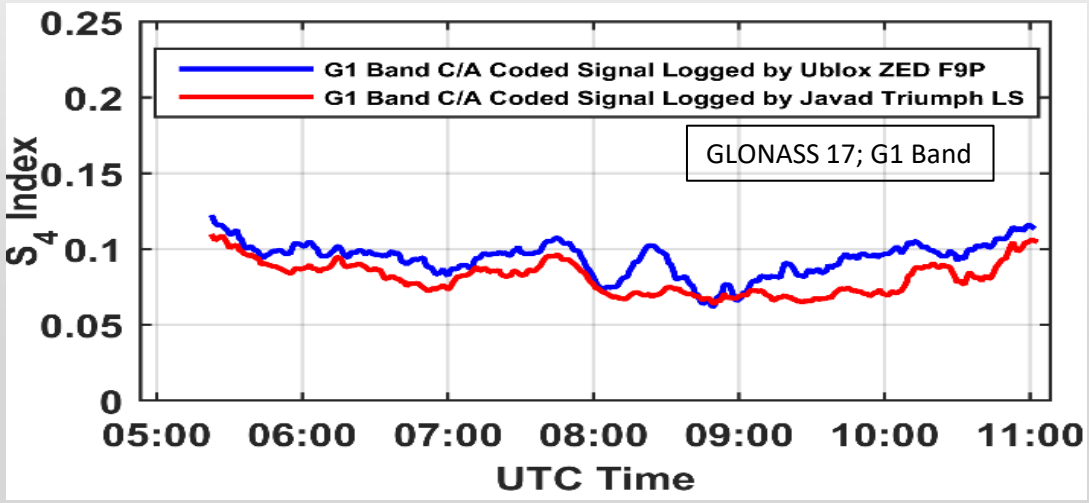


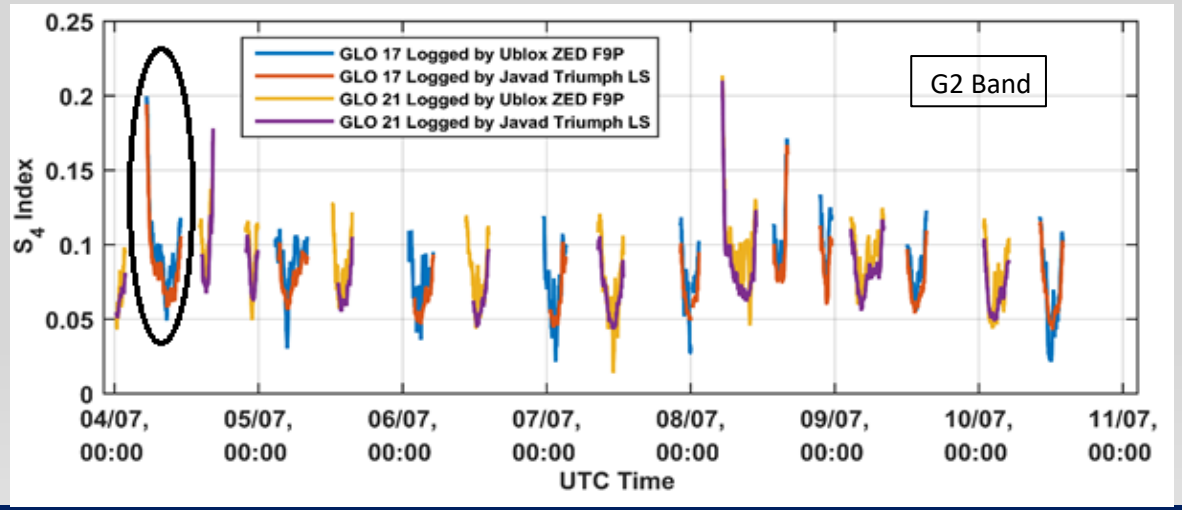


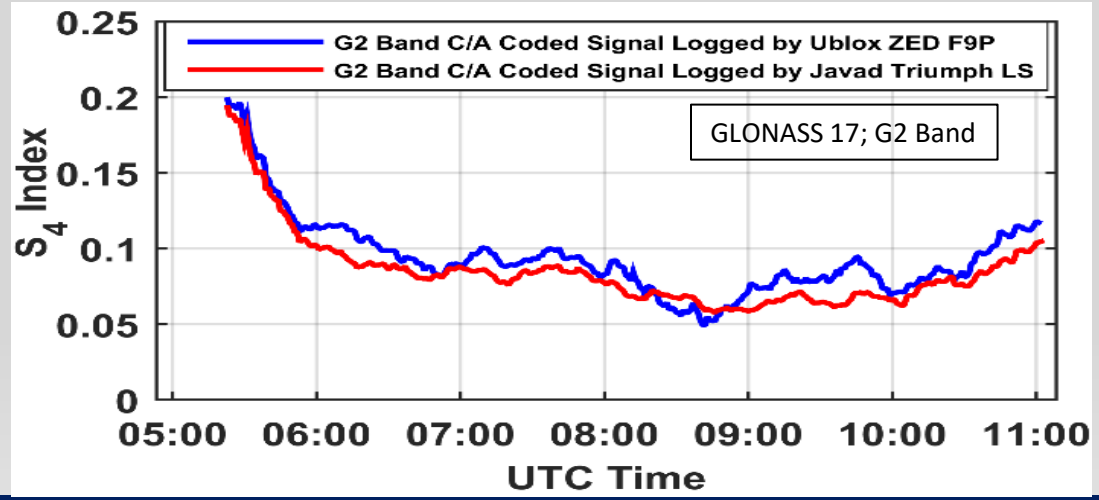
Dan, S., Santra, A., Mahato, S., Koley, C., Banerjee, P. and Bose, A., On use of low cost, compact GNSS receiver modules for ionosphere monitoring. *Radio Science*, *56*(12), 2021

S4 Comparison (GLONASS) (With low S4 values)

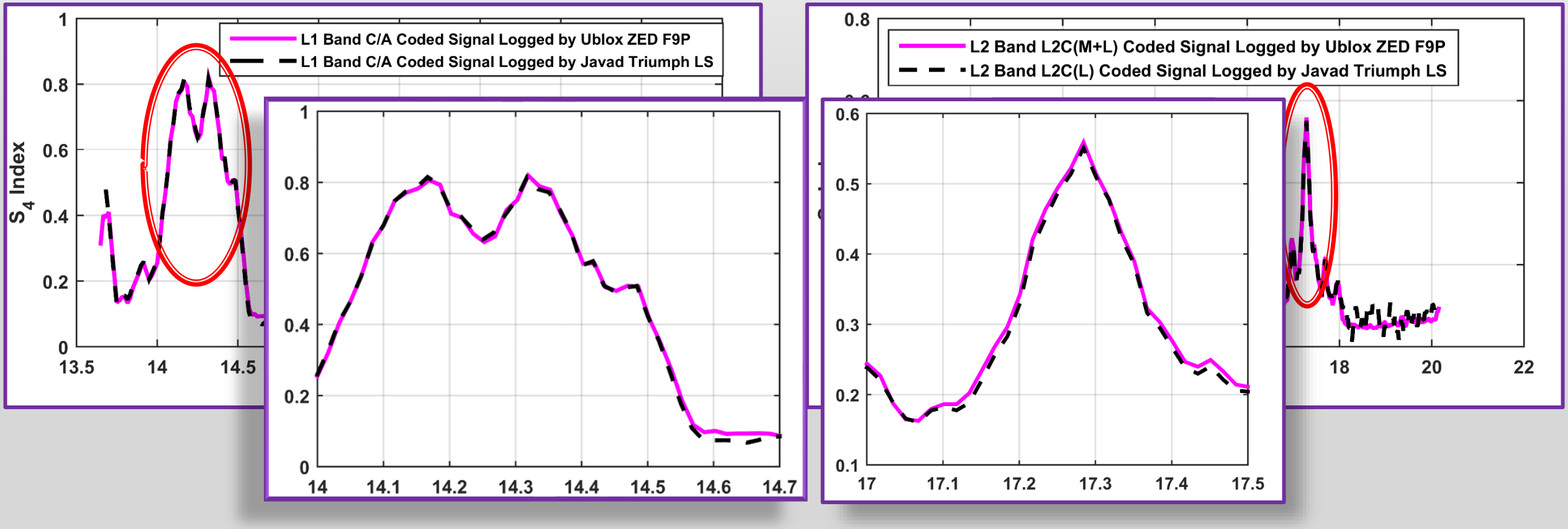




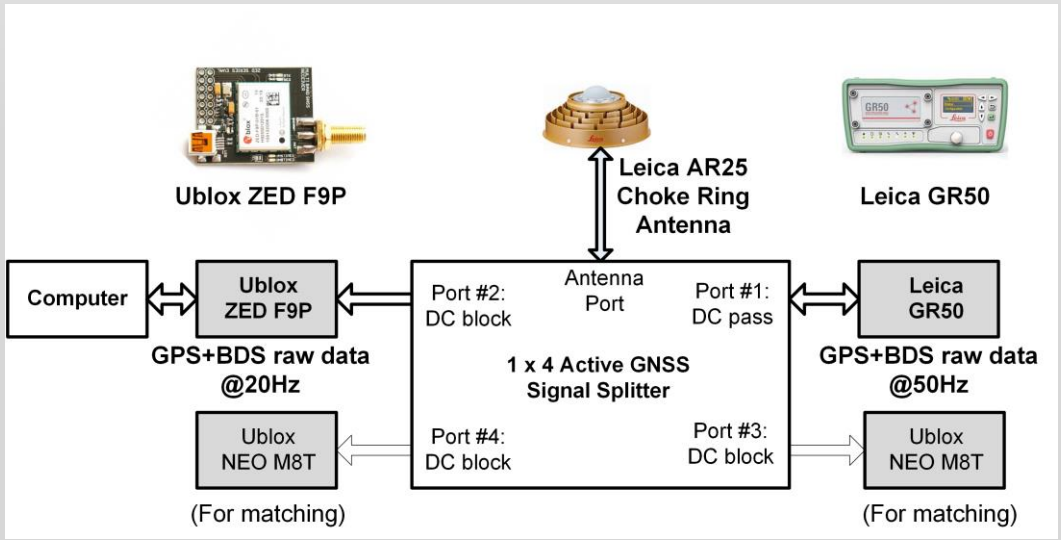




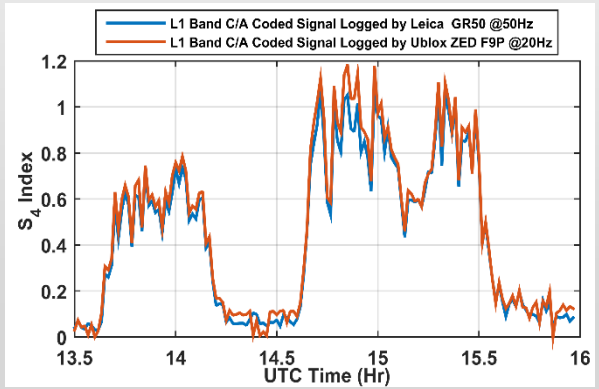
S_4 Comparison (GPS, March 2022) (With higher S4 values)

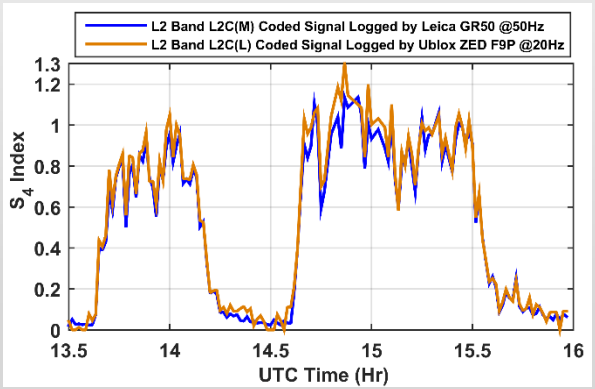


S_4 Comparison (GPS, October 2022) (With high S4 values)

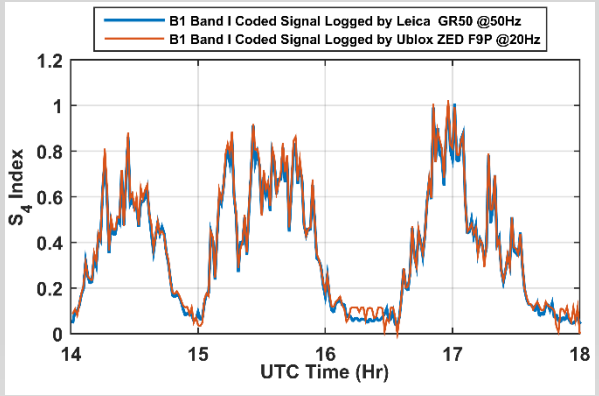


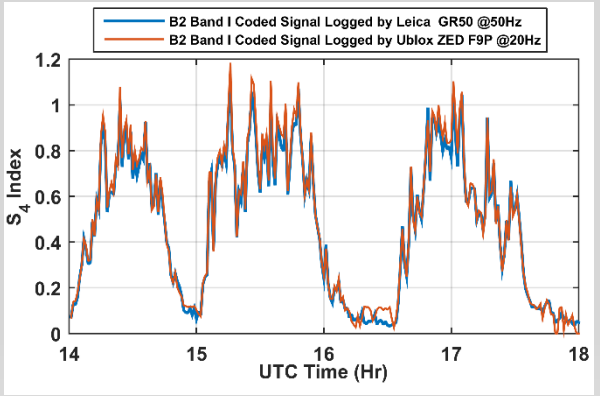
Fine structure analysis (Fade rate) also reveals similar results for both types of GNSS hardware





GPS (left) L1 band and (right) L2 band, PRN #4 [Date: 05/10/2022]





BDS (left) B1 band and (right) B2 band, PRN #16 [Date: 05/10/2022]

In Time Transfer

- All compact Module chips come with 1pps output pin on the SoC
- Some of the EVKs come with 1pps over convenient output option (SMA)
- Preliminary studies using some of the modules have been taken up with special emphasis on NavIC timing capabilities

Limitations:

- Off-the-shelf compact modules always do not offer convenient 1pps output
- In most of the cases, no provision for 1o MHz reference IN signal is not there

uBlox M8T

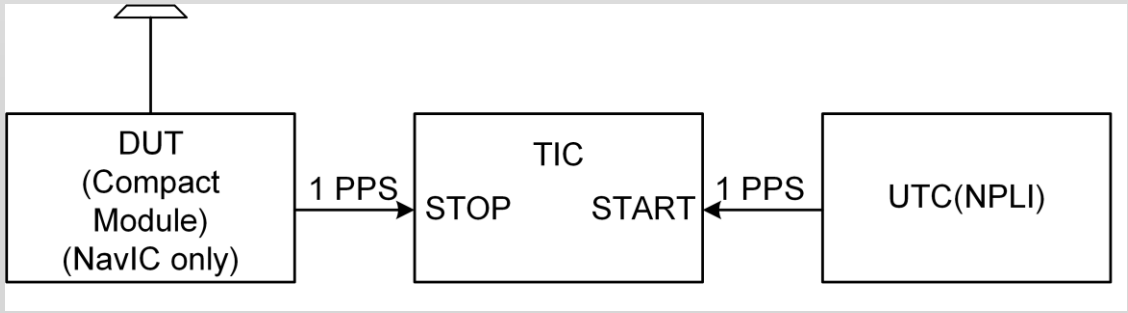
NTLab 104

uBlox F9T

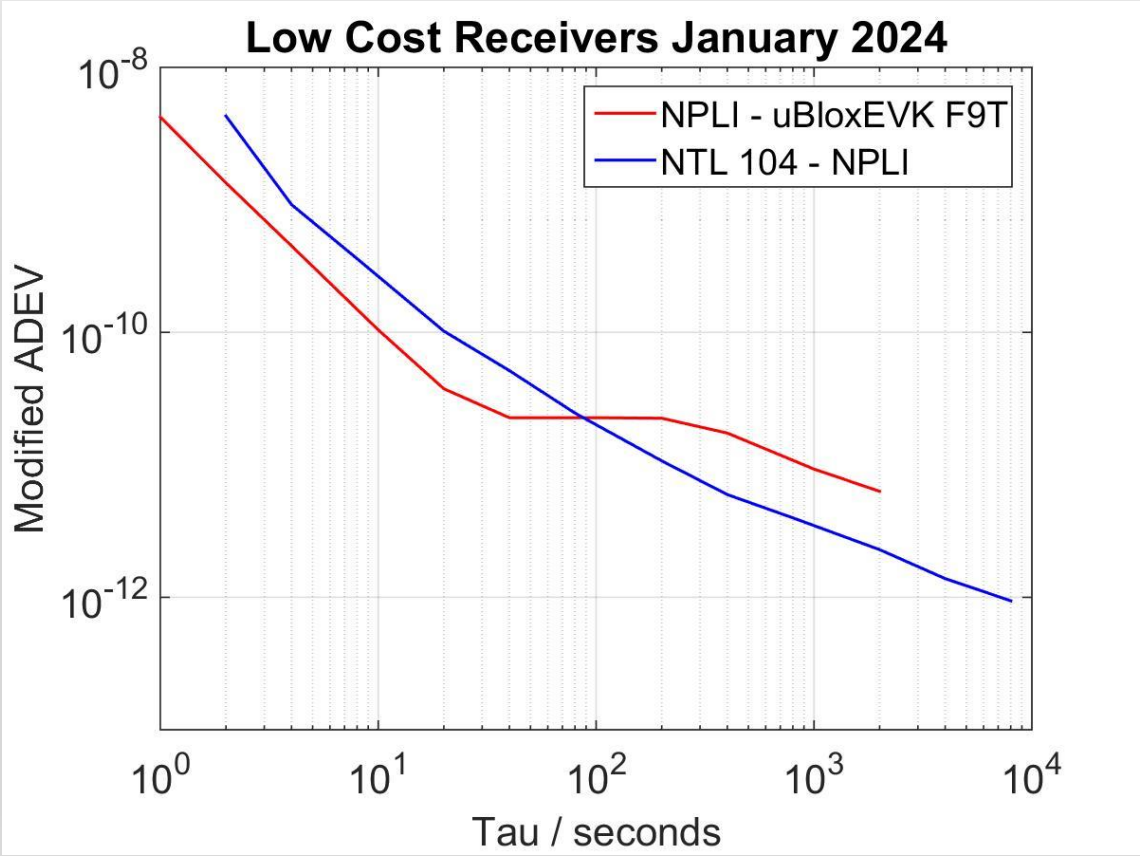
TELIT SE868K5-I

In Time Transfer
(Initial results using NavIC-enabled Compact Modules)

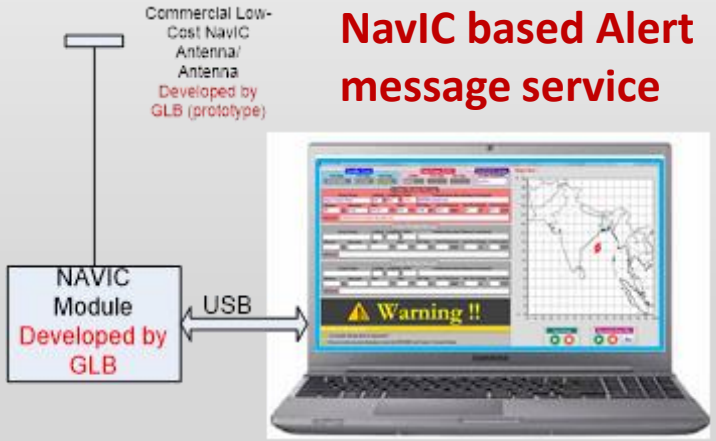
- Experiments performed at CSIR-NPL, New Delhi with the availability of standard time reference



- Both for GPS and NavIC, uBlox F9T shows <10ns jitter over 1 day w.r.t UTC(NPLI)
- For NavIC, NTLab 104 module shows ~12ns jitter over 1 day w.r.t UTC(NPLI)
- More study needs to be undertaken

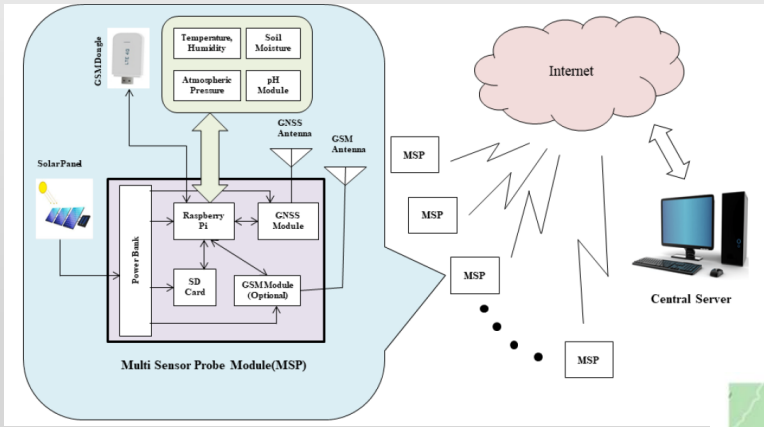


Mass Market Application Examples



NavIC based Alert message service

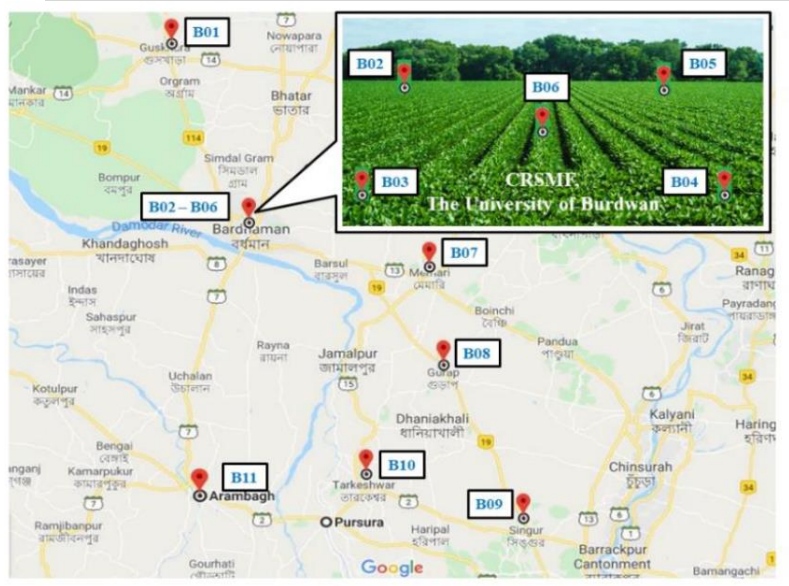
- Can provide Real Time Alert Messages for High Tide, Cyclone, Tsunami (as transmitted by INCOIS)
- Also provides Fishing Zone Alert info
- The application is developed using a USD 10 NavIC Module



Project: Smart and precision agriculture for potato cultivation in West Bengal: An Information and Communication Technology (ICT) based effort

Sponsor: DST, SERB, Govt of India

- GIS-GNSS-IoT integrated service
- GNSS module cost ~5 USD for the multi-sensor device
- RTK used for precision agri.



FINAL REMARKS

- The compact, cost-efficient modules have potential for mass market PNT and non-PNT applications with the advantages of size, weight, cost and power efficiency
- The associated positioning technology may be chosen as per the user requirements
- Need for more training and capacity building efforts – this event is a suitable platform to discuss the issue
- Need for more synergy between Industry-Academia-Research and Users

THANK YOU

Acknowledgement

- Space Application Center (SAC), ISRO, Ahmedabad
- AICTE, New Delhi
- DRDO HQ, New Delhi
- ITR-DRDO, Chandipur
- SERB-DST, GoI
- NGP-DST, GoI

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