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

Source: EUSPA EO and GNSS Market Report, Issue 2, copyright © European Union Agency for the Space Programme, 2024

Multi GNSS environment: Advantage Asia

The Asia Oceania Region is the Multi-GNSS signal hotspot (Multi-GNSS Asia-MGA)

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

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

GNSS receiver screenshot

The Asia Oceania Region is the Multi-GNSS signal hotspot

GNSS View App Screenshot
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)

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

<table>
<thead>
<tr>
<th>Coordinate</th>
<th>X (m)</th>
<th>Y (m)</th>
<th>Z (m)</th>
</tr>
</thead>
<tbody>
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<td>Date</td>
<td>GPS</td>
<td>GLO</td>
<td>GPS+GLO</td>
</tr>
<tr>
<td>24/04/2021</td>
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<td>0.003</td>
<td>0.003</td>
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<td>0.004</td>
<td>0.004</td>
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</table>

- GPS only, uBLOX F9P, 2021
- Results from AUSPOS online PPP service
- NTLab 104v3, 2021
- Results from NRCAN online PPP service
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

- 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.

<table>
<thead>
<tr>
<th>Baseline Distance (km)</th>
<th>2DRMS (m)</th>
<th>CEP (m)</th>
<th>SEP (m)</th>
<th>MRSE (m)</th>
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<tbody>
<tr>
<td>1</td>
<td>0.053</td>
<td>0.087</td>
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<td>0.121</td>
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<td>22</td>
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<td>0.254</td>
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<td>0.242</td>
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<td>0.584</td>
<td>0.523</td>
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<tr>
<td>50</td>
<td>0.444</td>
<td>0.417</td>
<td>0.321</td>
<td>0.376</td>
</tr>
<tr>
<td>100</td>
<td>0.677</td>
<td>0.628</td>
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<td>0.605</td>
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<tr>
<td>135</td>
<td>0.829</td>
<td>0.81</td>
<td>0.802</td>
<td>0.843</td>
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<tr>
<td>220</td>
<td>0.997</td>
<td>0.968</td>
<td>0.948</td>
<td>0.989</td>
</tr>
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</table>
Experimental setup for the comparative study of Ublox ZED F9P and Javad Triumph LS receiver for GNSS-based ionosphere study
S4 Comparison (GLONASS) (With low S4 values)
S₄ Comparison (GPS, March 2022) (With higher S₄ values)
S₄ 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 10 MHz reference IN signal is not there
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

- 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

NavIC based Alert message service

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
Acknowledgement

- Space Application Center (SAC), ISRO, Ahmedabad
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- NGP-DST, Gopal

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