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GEO SPATIAL

Compact GNSS Modules for GNSS Research and Training

Somnath MAHATO and Anindya BOSE

GNSS Laboratory, Department of Physics
The University of Burdwan
Burdwan - 713 104, INDIA
Web: www.bugnss.in

Email: smahato@scholar.buruniv.ac.in

Contents

- Geodetic and Special Purpose GNSS Receivers
- Low cost, compact GNSS Modules: ideal tools for solution development
- Low Cost, Compact Receivers for
  - SPP
  - PPP
  - RTK
  - Atmospheric monitoring
- Compact Receiver for different applications
- Training with Compact GNSS receivers

Exiting type of GNSS Receivers

Geodetic Receivers



Special Purpose Receiver


Timing Receivers

GNSS ionospheric scintillation and TEC monitor (GISTM)

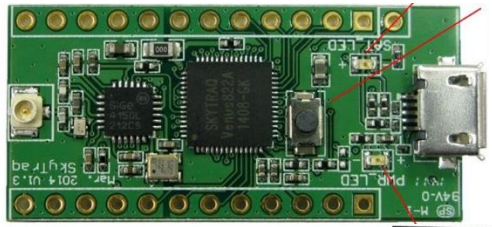
GNSS Simulators, Record and Replay Systems, SDR Receivers

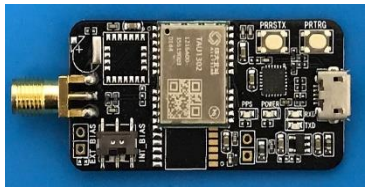

Multi-Constellation, Multi-Frequency, Data output: NMEA, RINEX, Propiteray

Compact GNSS Receivers (Non-exhaustive list)

Single Frequency

- ✓ uBlox M8T
- ✓ Skytraq NS-RAW
- ✓ Quectel L86
- ✓ Telit JF2
- ✓ Allystar TAU1302

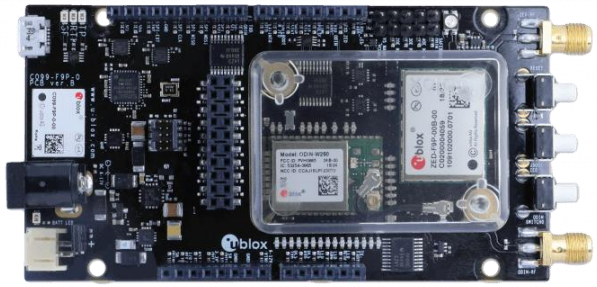


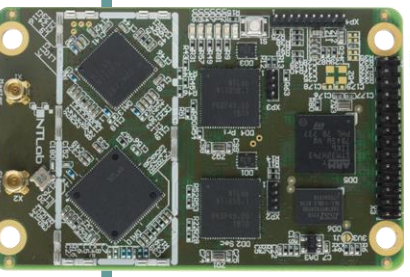


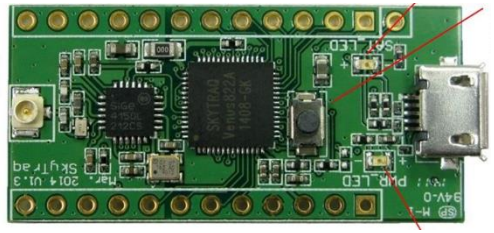
Dual Frequency

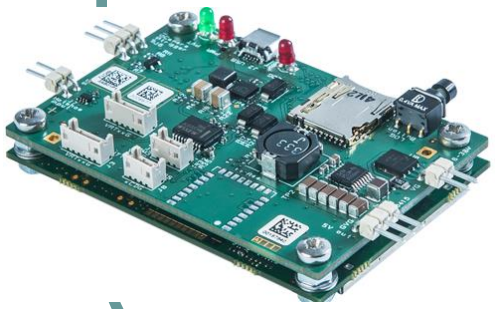
- ✓ uBlox F9P
- ✓ NTL 104, 106
- ✓ Mosaic-H

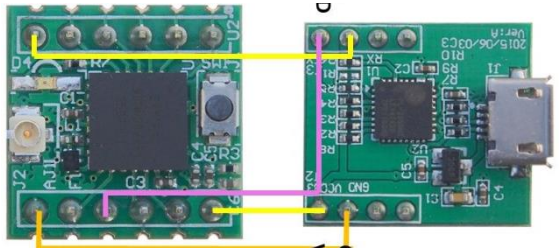
Low cost GNSS Modules: ideal tools for cost effective solution development





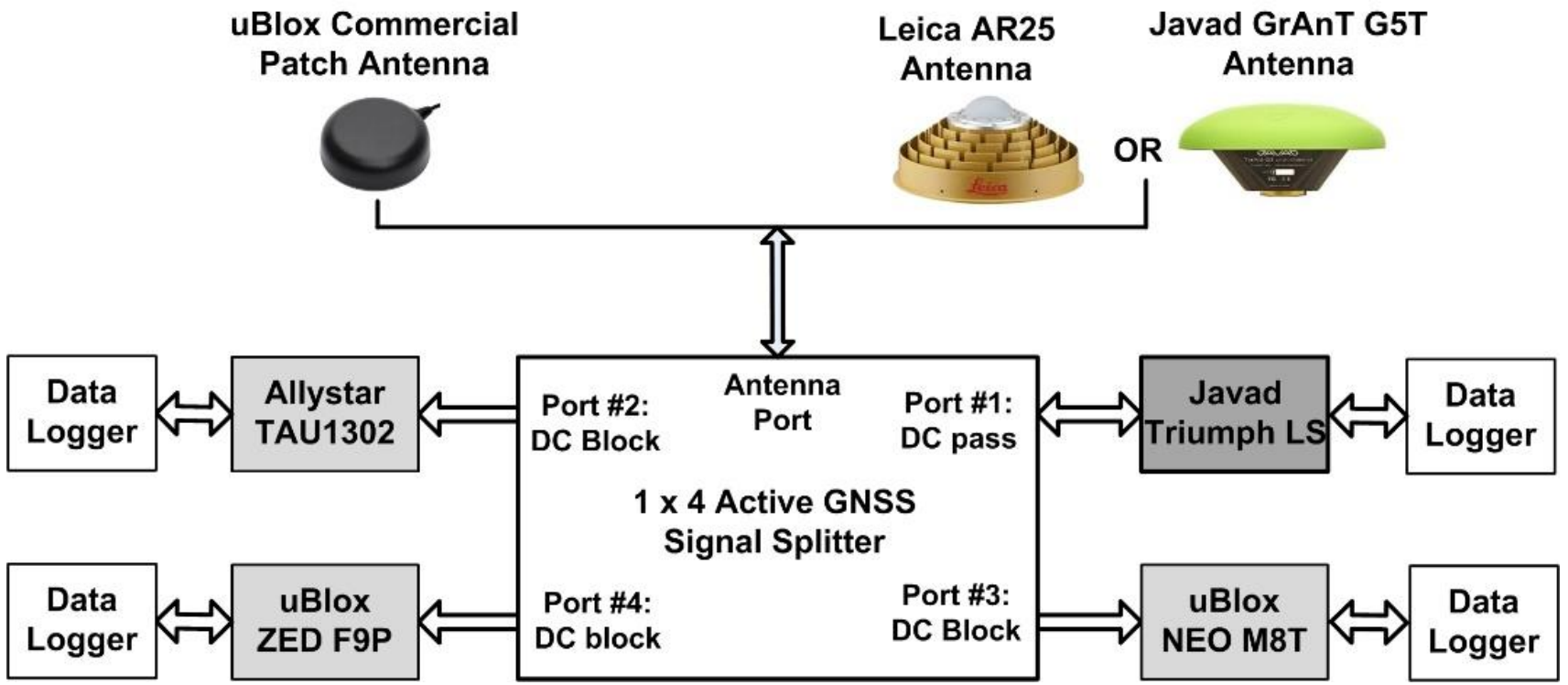






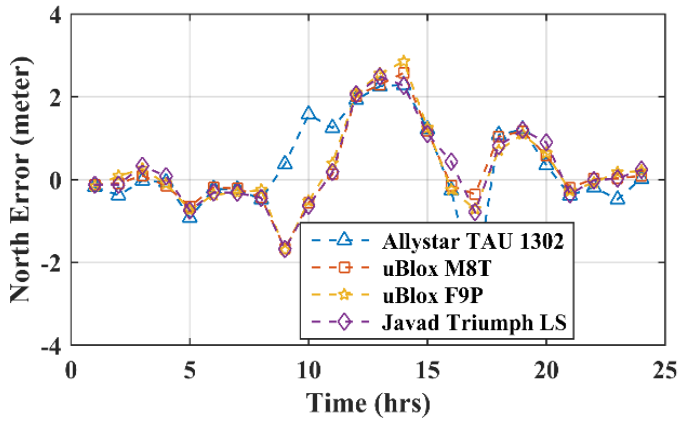
- Very low cost : below USD100-500
  Antenna cost: USD 5-50
- Small size and low-power consumption
- Can be directly attached to Computers to log data (raw/ NMEA)
- Few are Arduino Compatible
- RTK-enabled boards, Carrier phase measurements are available

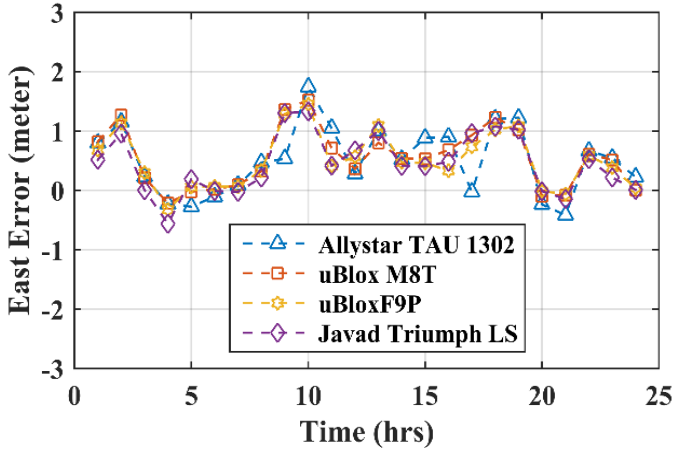
SPP: Use of Small Compact Receiver vis-à-vis Geodetic Receiver

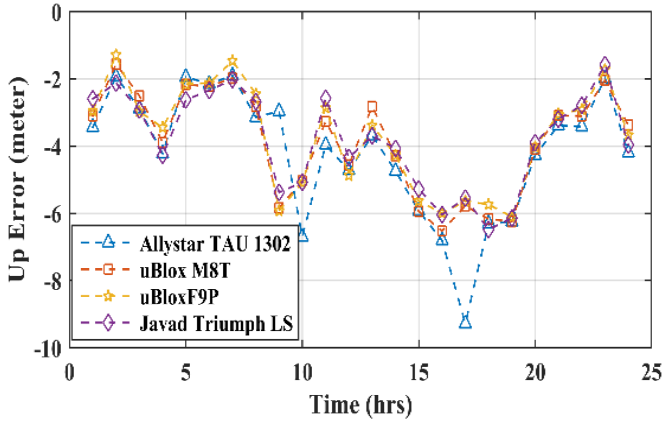


S. Mahato, A. Santra, S. Dan, P Banerjee, S. Kundu and A. Bose, "Point Positioning Capability of Compact, Low-Cost GNSS Modules," *IETE Journal of Research*, June 2021. DOI: 10.1080/03772063.2021.1939801

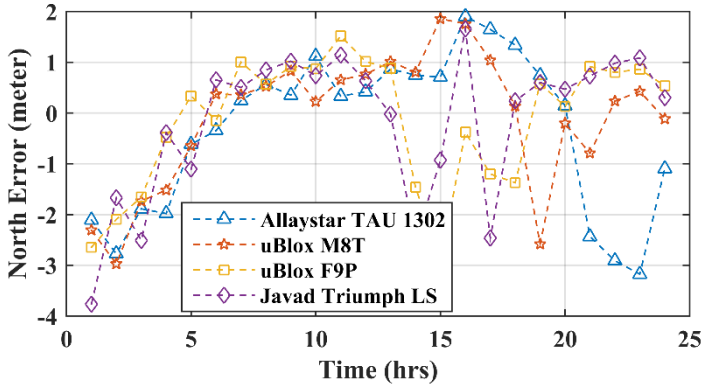
SPP: Results

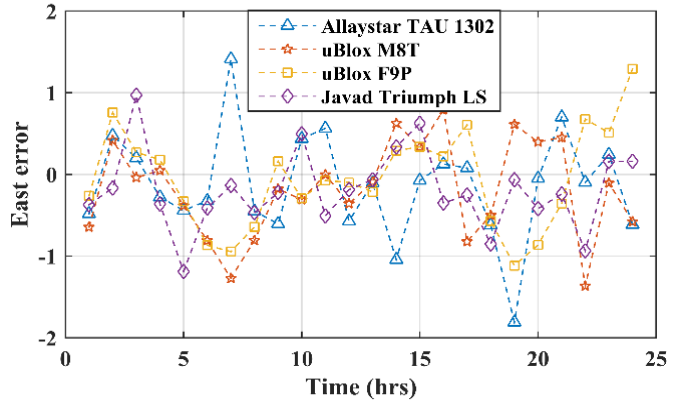


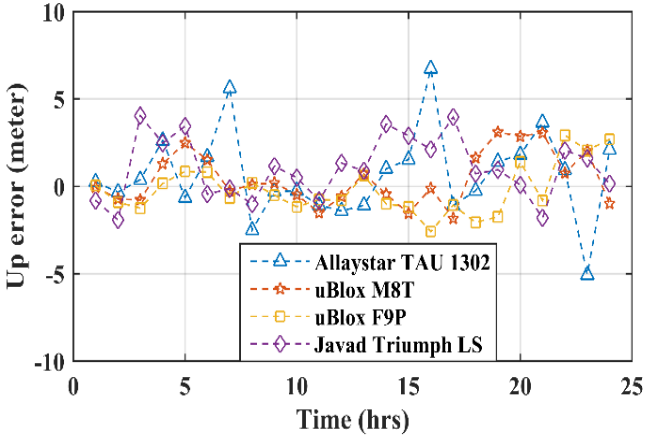




Using Survey Grade Antenna







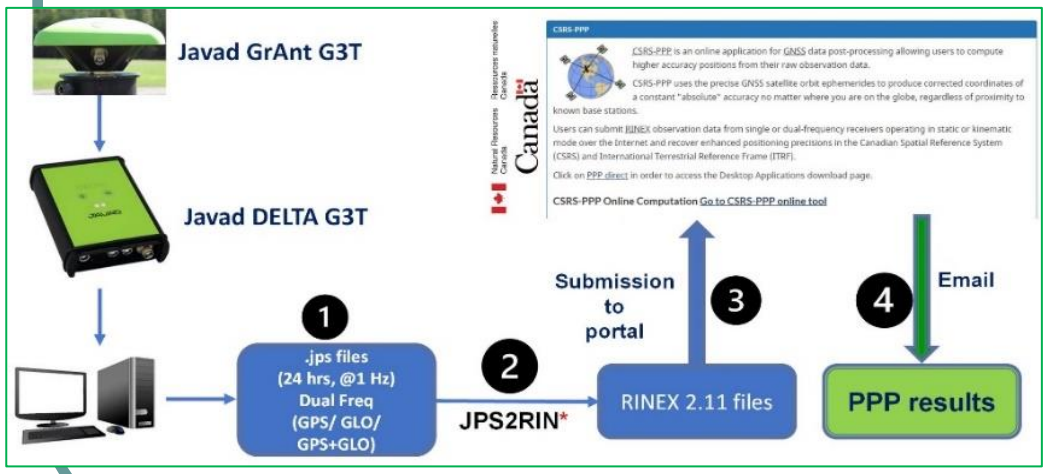
Using uBlox Commercial Patch Antenna

SPP: Comments

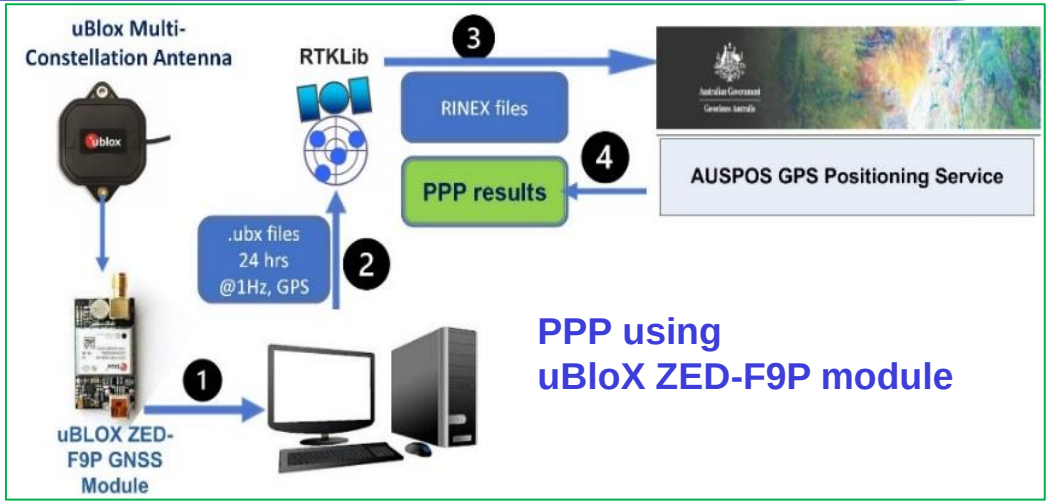
- ✓ Comparison of the performances of the commercial, low-cost, compact GNSS modules w.r.t geodetic GNSS receivers have been made
- ✓ Using different antenna hardware, cost-performance advantage of the compact modules is witnessed
- ✓ The modules can be used for mass-market GNSS applications requiring less than 5 m position solution accuracy and precision in stand-alone operation.

PPP using Compact GNSS Receivers

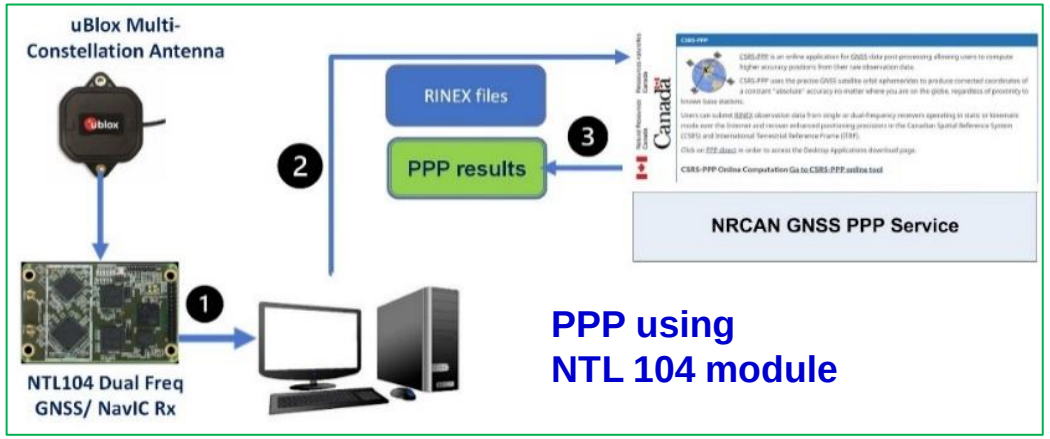
Reference station antenna, The University of Burdwan



PPP using Javad Geodetic receiver



PPP using
uBloX ZED-F9P module



PPP using
NTL 104 module

Courtesy: NTLab for Hardware Support

PPP using Compact GNSS Receivers: Results

Results for GPS, GLONASS, and GPS+GLONASS PPP for GLB, India using Javad DELTA G3T receiver

Date	Position Uncertainty (95% confidence level), Geodetic ITRF 2014, m								
	Latitude (East)			Longitude (North)			Ellipsoid Height (Up)		
	GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO
17/12/2019	0.004	0.009	0.004	0.007	0.013	0.007	0.015	0.033	0.015
18/12/2019	0.003	0.004	0.003	0.009	0.008	0.006	0.013	0.019	0.010
19/12/2019	0.003	0.005	0.003	0.008	0.009	0.006	0.014	0.021	0.011
20/12/2019	0.003	0.004	0.002	0.008	0.008	0.005	0.013	0.018	0.010
21/12/2019	0.003	0.004	0.002	0.009	0.008	0.005	0.013	0.016	0.010
22/12/2019	0.003	0.004	0.002	0.008	0.008	0.005	0.013	0.017	0.010
23/12/2019	0.003	0.004	0.002	0.008	0.007	0.005	0.012	0.017	0.010

Results for GNSS PPP for GLB, India using compact GNSS modules

Module Used (Date)	Position Uncertainty (95% confidence level), Geodetic ITRF 2014, m								
	Latitude (East)			Longitude (North)			Ellipsoid Height (Up)		
	GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO	GPS	GLO	GPS+GLO
ZED-F9P (Feb. 2021)	0.005	-	-	0.003	-	-	0.010	-	-
NTL 104 (24/04/2021)	0.003	0.080	0.003	0.003	0.015	0.003	0.013	0.036	0.012
NTL 104 (25/04/2021)	0.003	0.013	0.003	0.003	0.025	0.003	0.013	0.059	0.013
NTL 104 (26/04/2021)	0.004	0.122	0.004	0.004	0.279	0.004	0.018	0.267	0.018

A.Bose, S. Mahato, A. Santra and S. Dan, "Compact, Low-cost GNSS modules for PPP," *Spatial Data: Science, Research and Technology 2021*, Moscow, 2021. DOI: 10.1051/e3sconf/202131003001

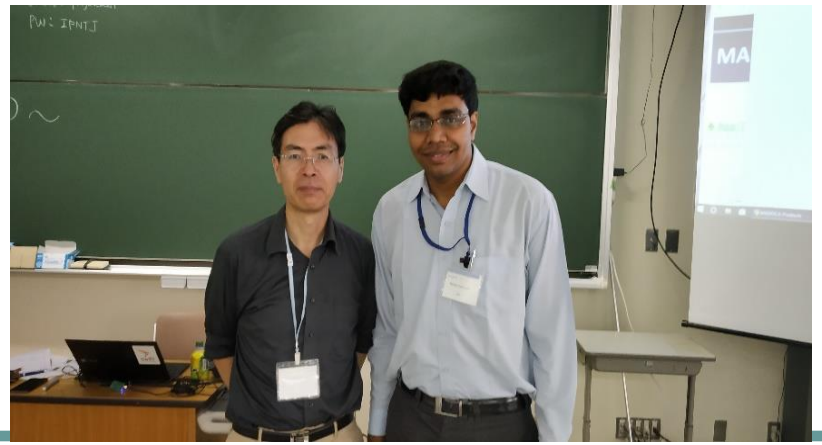
PPP using Compact GNSS Receivers: Results

- ✓ Usability of commercial, compact, dual-frequency GNSS modules is studied for the GNSS PPP solution
- ✓ Comparable PPP Result
- ✓ GPS/GPS+GLONASS below 20 cm accuracy in the vertical coordinate
- ✓ Advantages of cost, size, and power requirements, the compact modules can be efficiently used for GNSS PPP.

A. Bose, S. Mahato, A. Santra and S. Dan, “Compact, Low-cost GNSS modules for PPP,” *Spatial Data: Science, Research and Technology 2021*, Moscow, 24-26 May 2021. DOI: 10.1051/e3sconf/202131003001

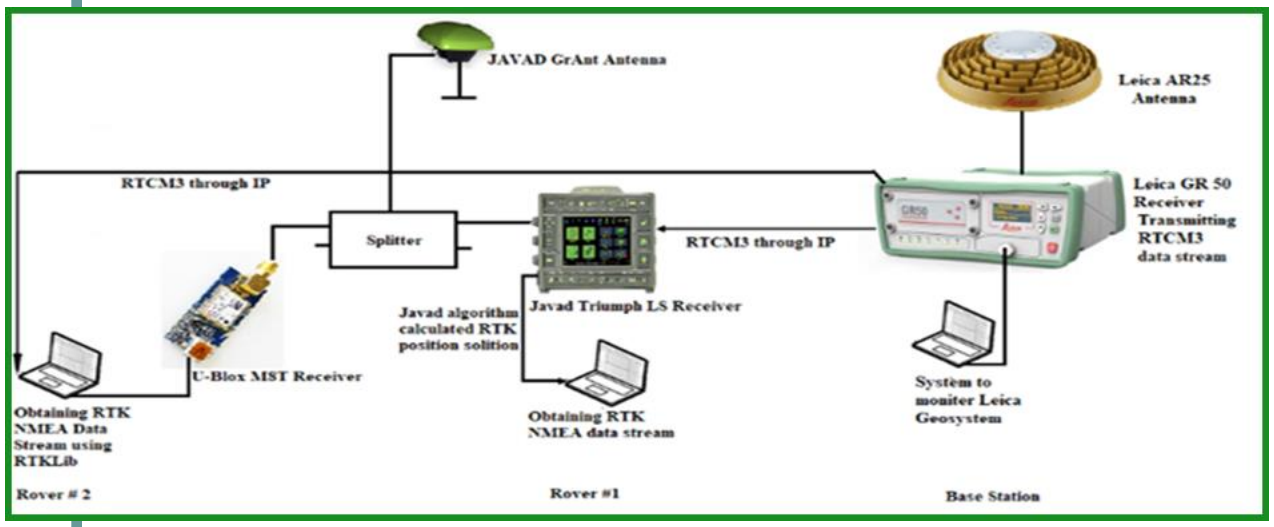
RTK: using RTKLib

- **RTKLib is a Open Source GNSS data processing software developed by Tomoji Takasu that can be used for data logging from stand alone GNSS modules, RTK and PPP**
- **Can directly log data from uBLOX, Skytraq compact GNSS Modules (Major manufacturers supported)**
- **Has LINUX variant, so can be used with Raspberry Pi**
- **Android version available, can be downloaded from RTKLib Website : http://www.rtklib.com/ or from GITHUB: https://github.com/tomojitakasu/RTKLIB**

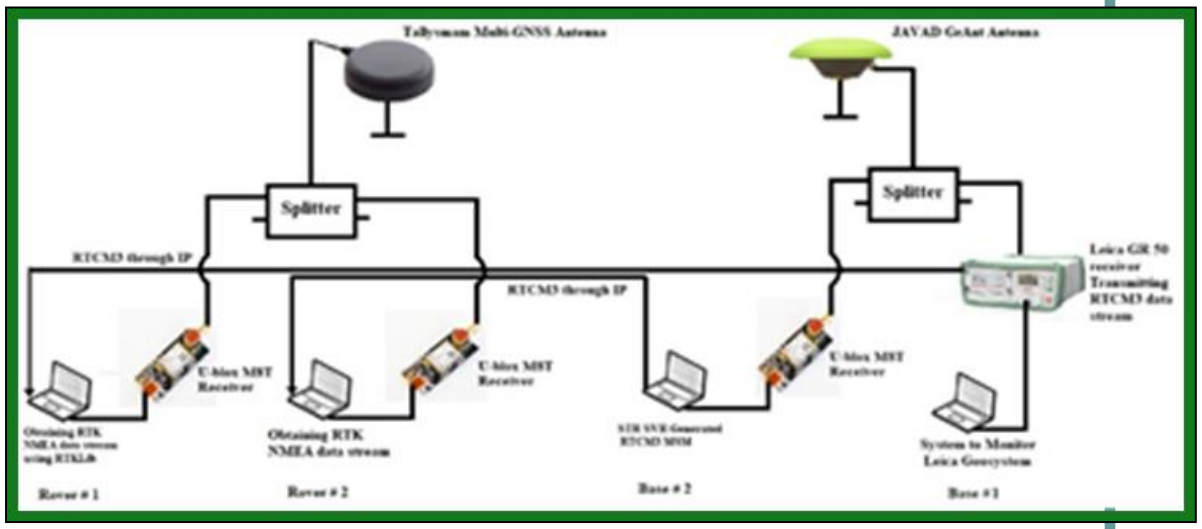


With Respected Tomoji Takasu Sir, at TUMSAT,Tokyo during GNSS Workshop

RTK using compact GNSS modules: Case studies



Compact module as Rover



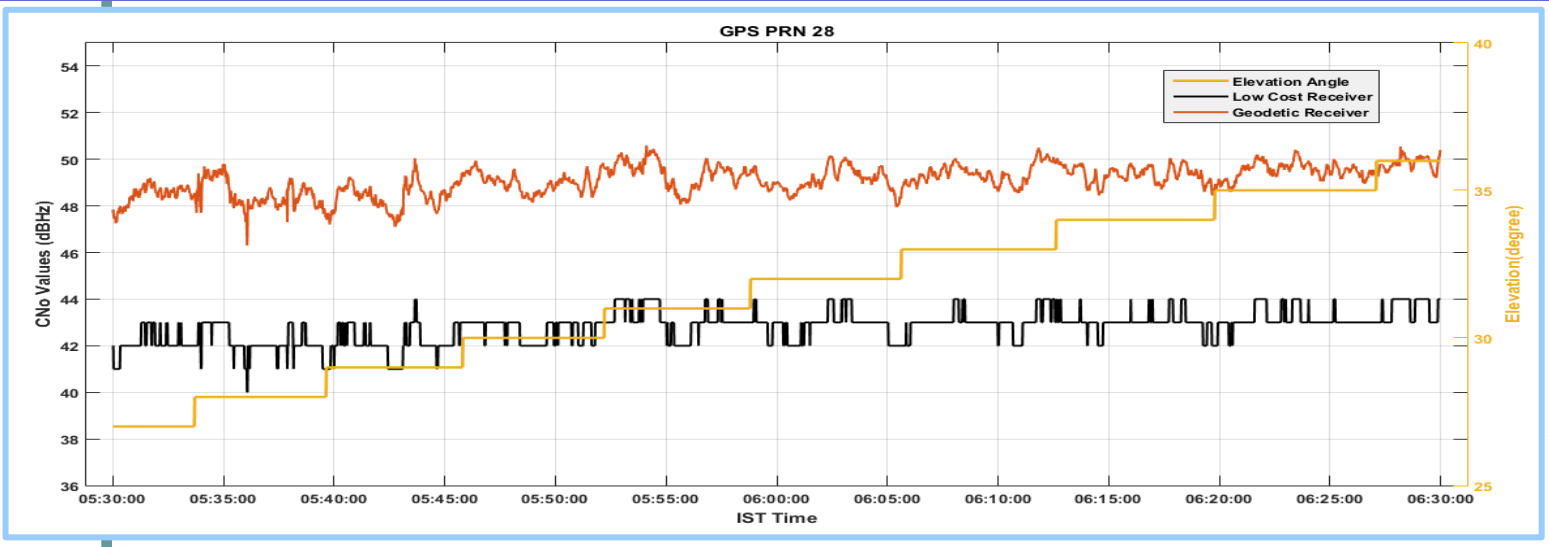
Compact modules as Base and Rover

- Baseline length of ~20 meter and 2DRMS values 26.78 cm (survey grade) and 27.76 cm (compact base)
- Compact module provide cm level of precision of both the cases

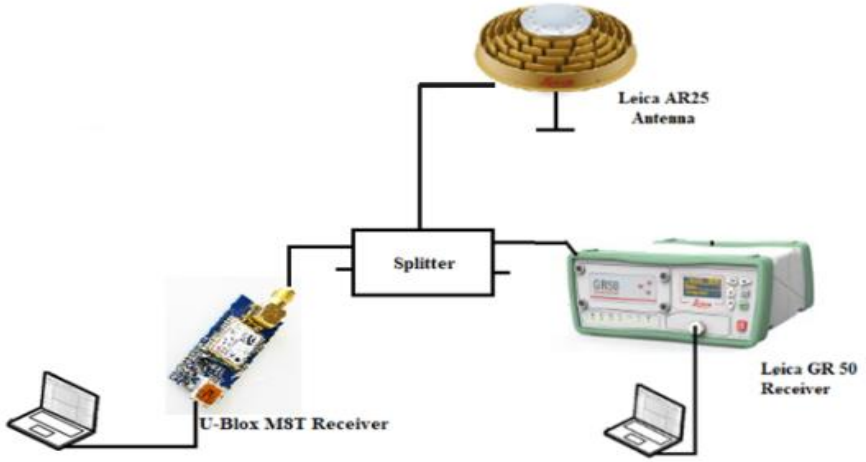
S. Mahato, A. Santra, S. Dan, P. Rakshit, P. Banerjee and A. Bose, "Preliminary Results on the Performance of Cost-effective GNSS Receivers for RTK," *URSI Asia-Pacific Radio Science Conference*, New Delhi, 2019. DOI: 10.23919/URSIAP-RASC.2019.8738736

S. Mahato, A. Santra, S. Dan, A. Bose, "Low-cost GNSS modules for Precise Positioning," *IEEE International Conference on Range Technology*, Chadipur, India, 2019. DOI: 10.1109.ICORT46471.2019.9069613

Compact Receiver for Atmospheric monitoring

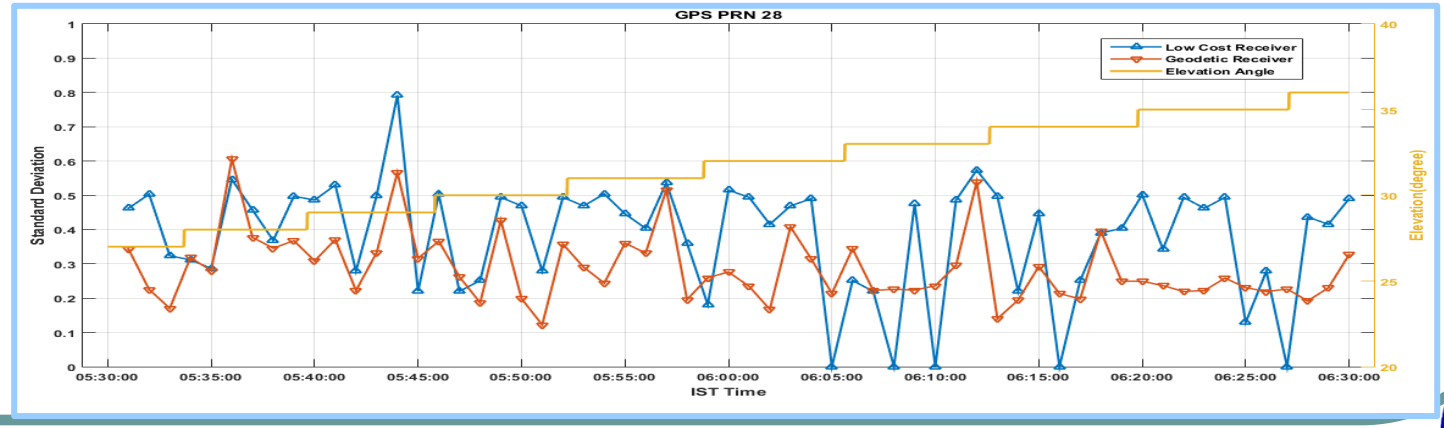


C/N0 variation of L1 band and elevation angle (GPS PRN 28)



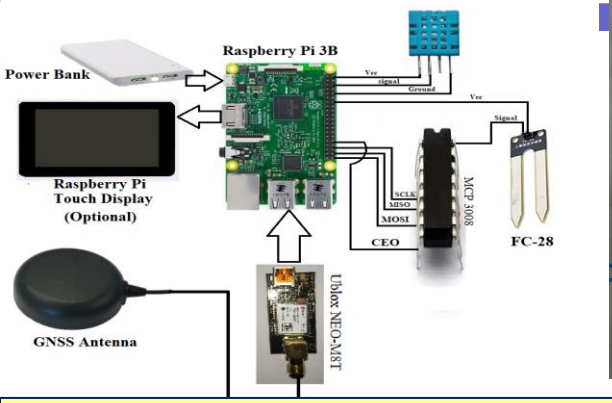
Signal strength comparison between u-Blox M8T and Leica GR50 receivers.

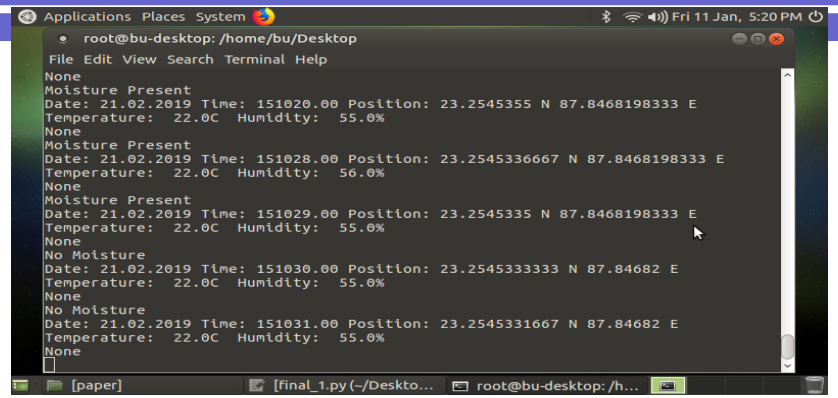
A. Santra, S. Dan, S. Mahato, P. Banerjee, S. Kundu and A. Bose, "A Low-cost Approach towards Ionospheric Probing Using Compact GNSS Receivers," *2020 URSI RCRS*, Varanasi, 2020. DOI: 10.23919/URSIRCRS49211.2020.9113577



Standard Deviation of C/N0 in L1 band and elevation angle (GPS PRN 28)

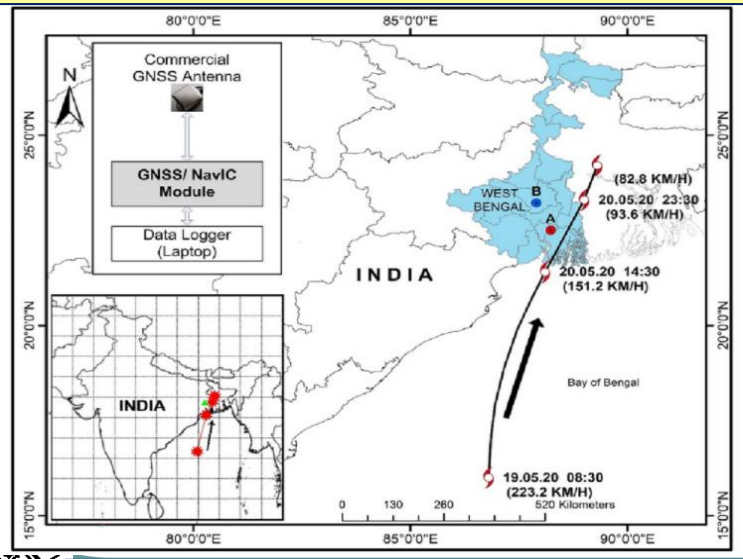
Compact Receiver for Application Development

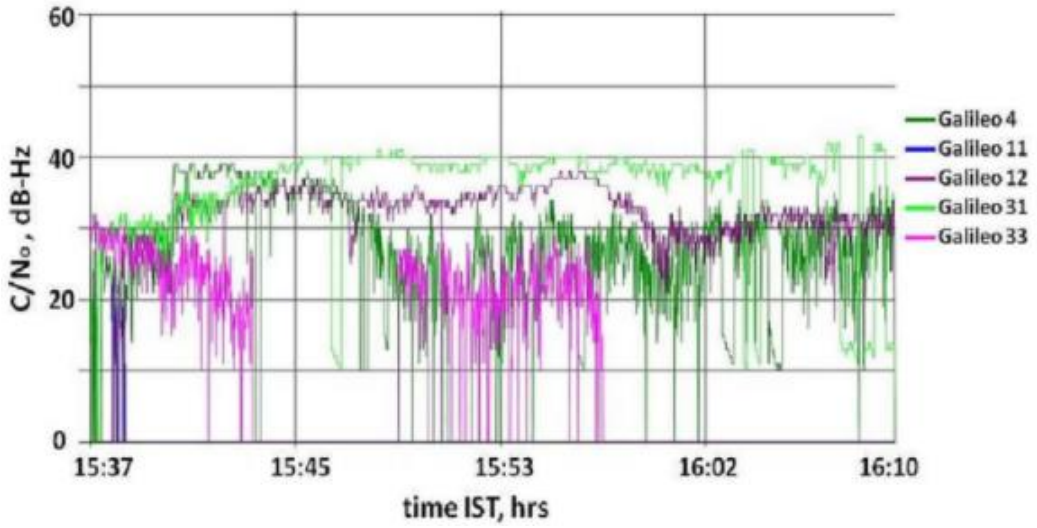




For Agriculture

S. Mahato, P. Rakshit, A. Santra, S. Dan, Noriel C Tiglao and A. Bose , "A GNSS-enabled Multi-Sensor for Agricultural Applications," *Journal of Information & Optimization Sciences*, 2020. DOI: 10.1080/02522667.2020.1714893





Disaster monitoring: Amphan 2020

S. Dey, I. Chakraborty, P. Banerjee, and A. Bose, "Anomalous GNSS Signal Strength Fluctuations during the Amphan Super Cyclone in Eastern India on May 20, 2020," *National Academy Science Letters*, pp.1-5, 2021. DOI:10.1007/s40009-021-01076-5

GNSS Training (World)

- AIT (Asian Institute of Technology) GNSS Training Course
- GNSS Summer School organized by Tokyo University of Marine Science & Technology
- Training REsearch and Applications network to Support the Ultimate Real time high accuracy EGNSS solution (TREASURE); a MARIE SKŁODOWSKA-CURIE ACTIONS Innovative Training Network (ITN)
- ICG Programme on GNSS Applications
- Multi GNSS Asia (MGA) Rapid Prototype Development (RPD) Challenge
- MGA Series of Webinar conducted by Prof. Dinesh Manandhar, The University of Tokyo

GNSS Training (India)

- Research and Training Unit For Navigational Electronics (NERTU), Hydrabad
- Global Navigation Satellite System (GNSS) Workshop at SV National Institute of Technology Surat
- 5 day Faculty Development Program in The University of Burdwan
- GNSS Remote Sensing – Indian Institute of Technology (IIT) Indore
- 5 day Faculty Development Program in National Institute of Technology Mizoram

THANK YOU

Acknowledgement

- Integrated Test Range, D.R.D.O., Govt. of India
- Science and Engineering Research Board, D.S.T., Govt. of India

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