How to Improve GNSS Accuracy? Brief Introduction of QZSS/MADOCA

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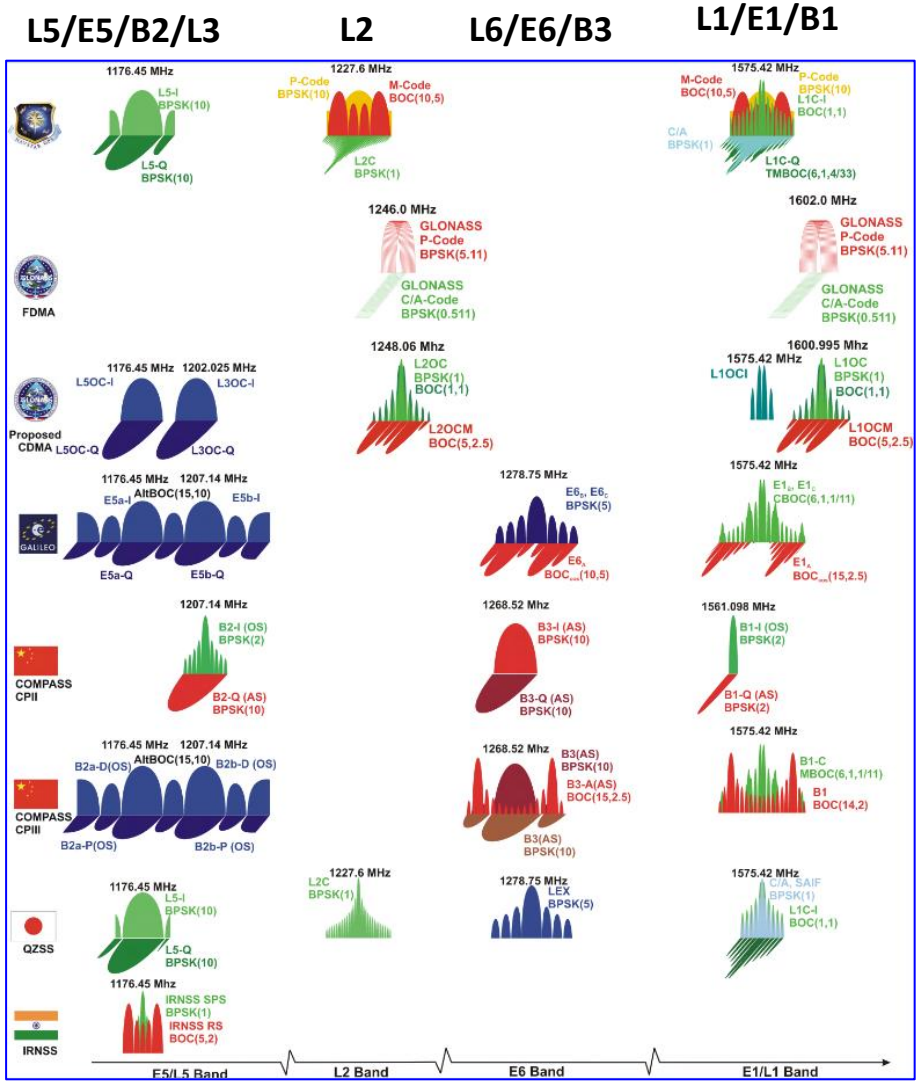
What is GNSS?

- GNSS or Global Navigation Satellite System is an acronym used to represent all navigation satellite systems such as

Satellite	Country	Coverage
GPS	USA	Global
GLONASS	Russia	Global
Galileo	Europe	Global
BeiDou (BDS)	China	Global
QZSS (Michibiki)	Japan	Regional
NavIC	India	Regional

- ✓ GPS and GLONASS have signals for civilian and military usage
  - ❖ Military signals are encrypted and not available for civilian use
- ✓ Galileo and BeiDou also have Open and Restricted Signals
- ✓ All civilian signals are freely available
- ✓ Technical information for civilian signals are made public
  - ❖ Its called ICD (Interface Control Document) or IS (Interface Specification)
  - ❖ Provides necessary information to develop a GNSS receiver



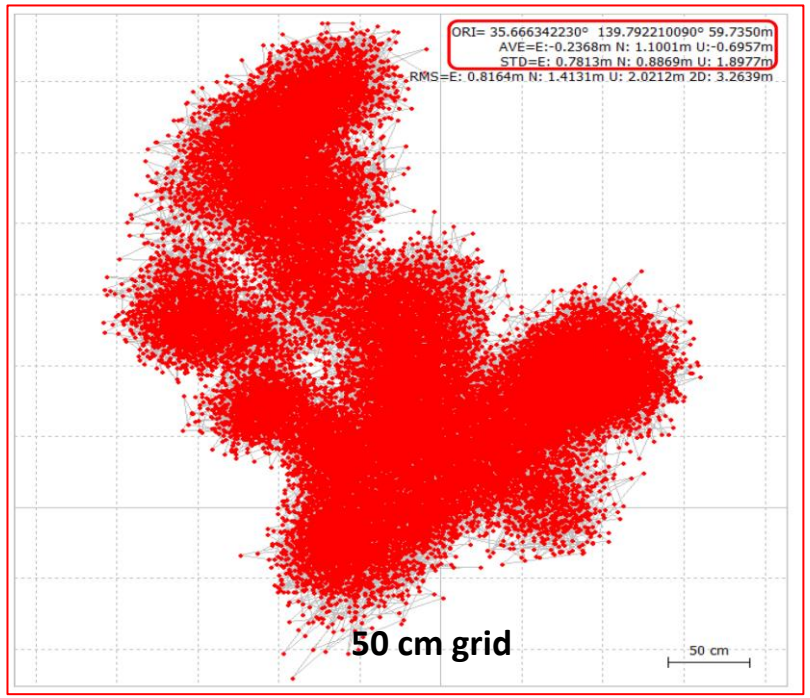
https://gssc.esa.int/navipedia/images/c/cf/GNSS_All_Signals.png

How to Improve GPS Accuracy?

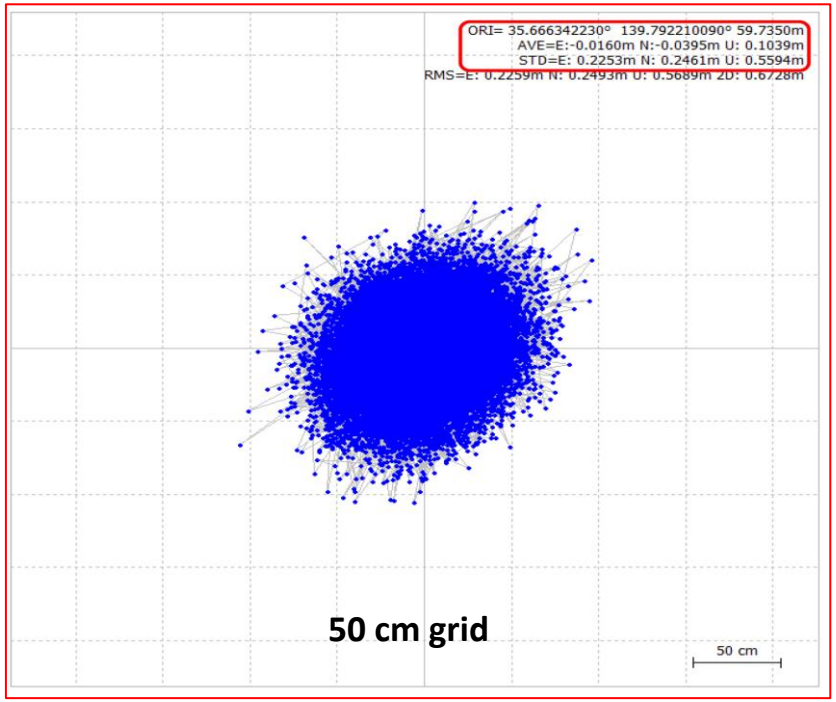
GPS Position Accuracy

How to achieve accuracy from few meters to few centimeters?

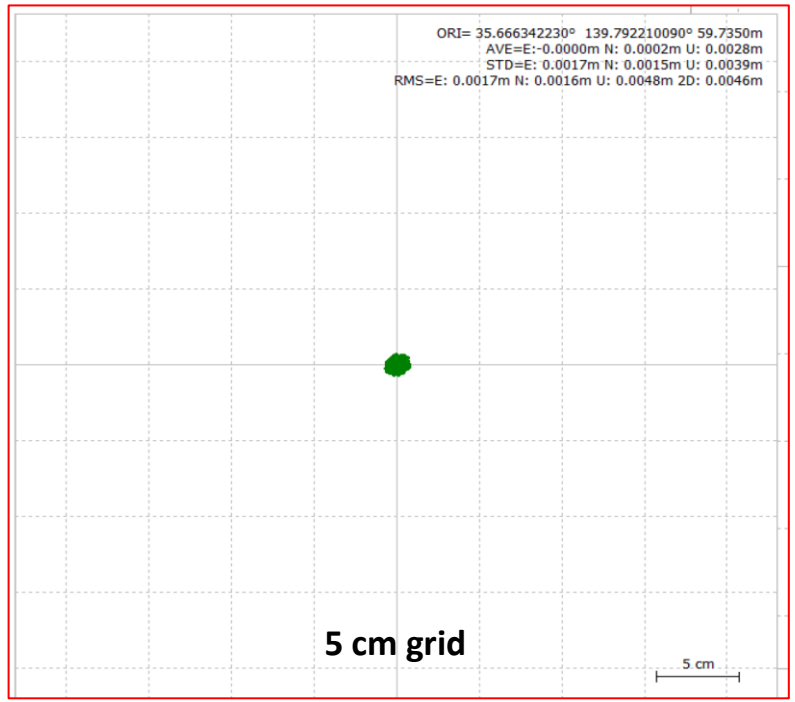
meter → centimeter



SPP (Single Point Position)

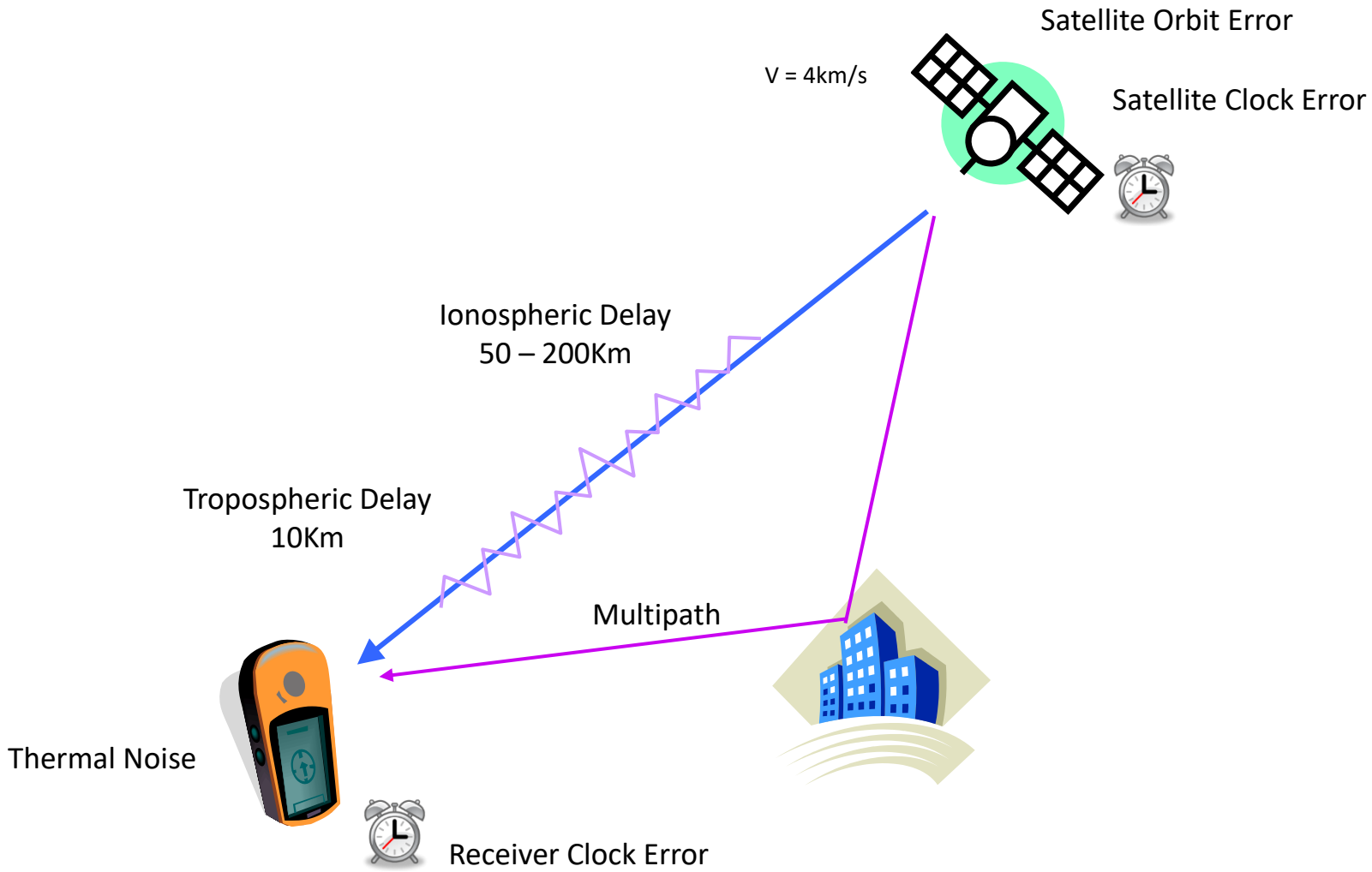


DGPS (Differential GPS)
Code-phase observation



RTK (Real Time Kinematic)
Carrier-phase observation

Error sources



Errors in GPS Observation (L1C/A Signal)

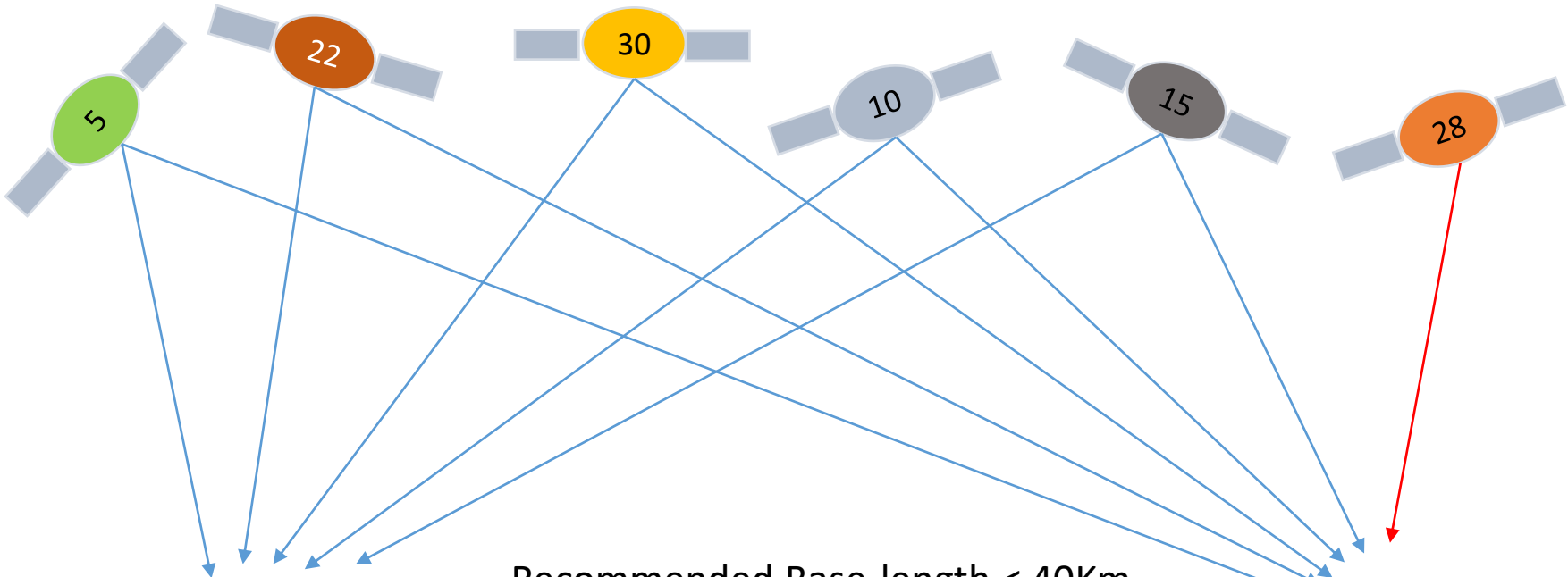
Error Sources	One-Sigma Error , m		Comments
	Total	DGPS	
Satellite Orbit	2.0	0.0	Common errors are removed
Satellite Clock	2.0	0.0	
Ionosphere Error	4.0	0.4	Common errors are reduced
Troposphere Error	0.7	0.2	
Multipath	1.4	1.4	
Receiver Circuits	0.5	0.5	

If we can remove common errors, position accuracy can be increased.

Common errors are: Satellite Orbit Errors, Satellite Clock Errors and Atmospheric Errors (within few km)

Values in the Table are just for illustrative purpose, not the exact measured values.
Table Source : http://www.edu-observatory.org/gps/gps_accuracy.html#Multipath

How to Remove or Minimize Common Errors?
Use Differential Correction (DGPS / RTK)



Recommended Base-length < 40Km

Send Observation Data to Rover for Real-Time Position

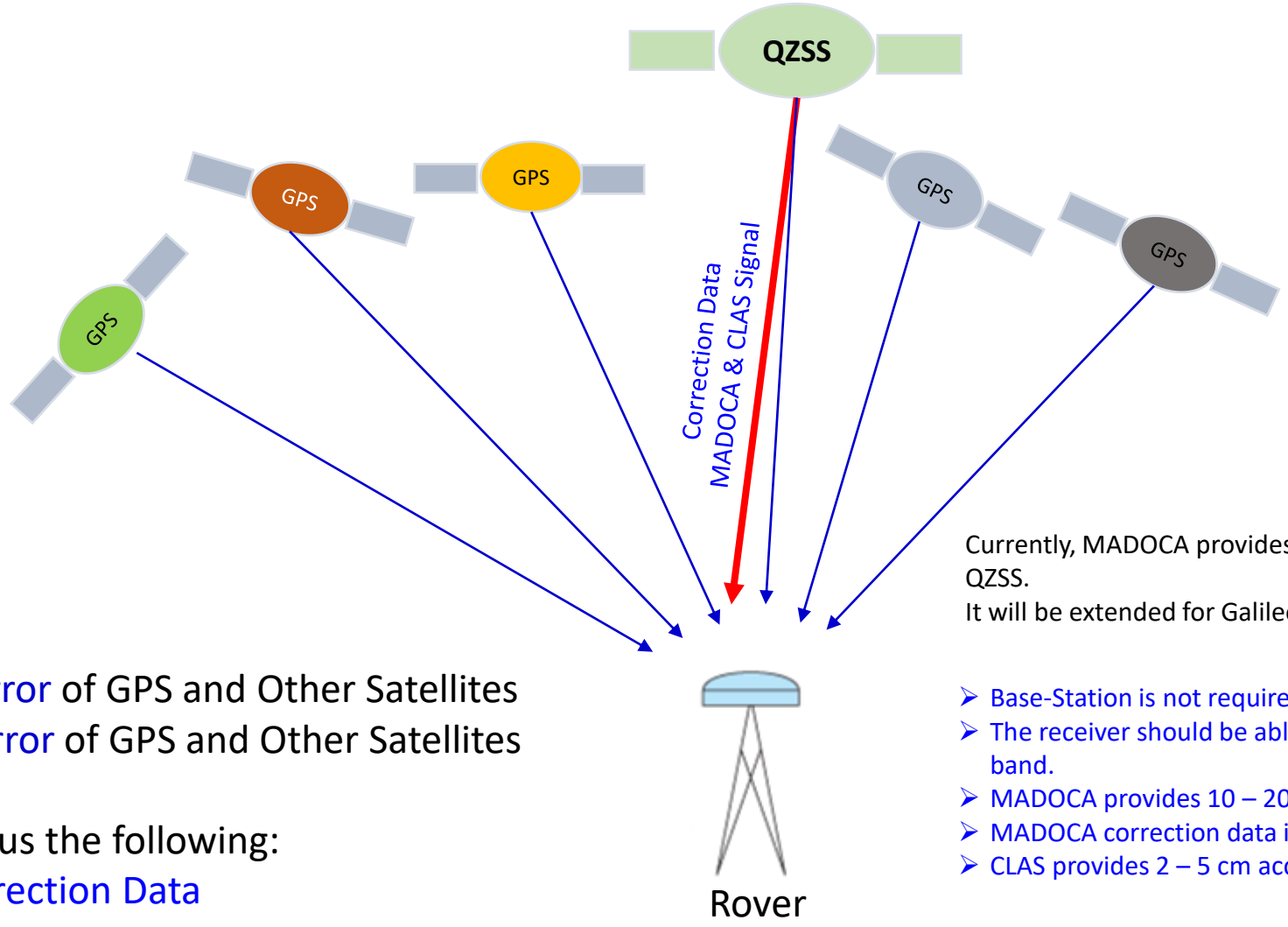
Base-Station
Antenna is installed at a known-position

For RTK, both base and rover receivers need to use data from the same satellites

Rover
User in the Field
(Either fixed or moving)
Use RINEX data for post-processing

Base-station Antenna position shall be known in advance

How to Remove or Minimize Common Errors?
Use QZSS Service MADOCA or CLAS



Correction Data:

MADOCA:

Satellite Orbit Error of GPS and Other Satellites

Satellite Clock Error of GPS and Other Satellites

CLAS:

All of MDOCA plus the following:

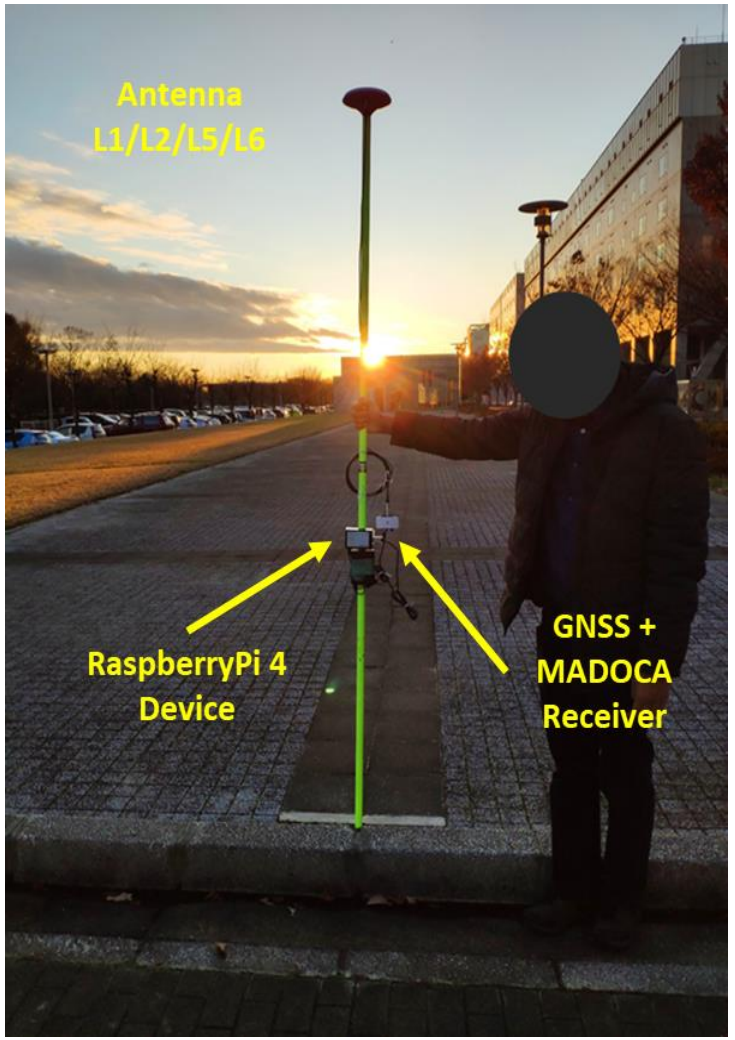
Ionospheric Correction Data

Currently, MADOCA provides correction data for GPS, GLONASS and QZSS.
It will be extended for Galileo in future.

- Base-Station is not required.
- The receiver should be able to receive MADOCA / CLAS signal in L6 band.
- MADOCA provides 10 – 20cm accuracy (Global)
- MADOCA correction data is also available online
- CLAS provides 2 – 5 cm accuracy (Japan Only)

Low-Cost High-Accuracy Receiver Systems

RTKDROID, MADROID, MAD-WIN, MAD-π



How to Make a Low-Cost GNSS Receiver System?

GNSS Module or Receiver

Low-Cost SDR Device
$30

- Memory
- Micro-Controller or Micro-Processor
- External Interface

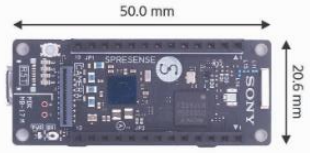
- External Memory Device

Hard Disk

- Single Board Computer

RaspberryPi

Arduino



Sony, Spresense

- WiFi, BT, Ethernet, MQTT, IoT links

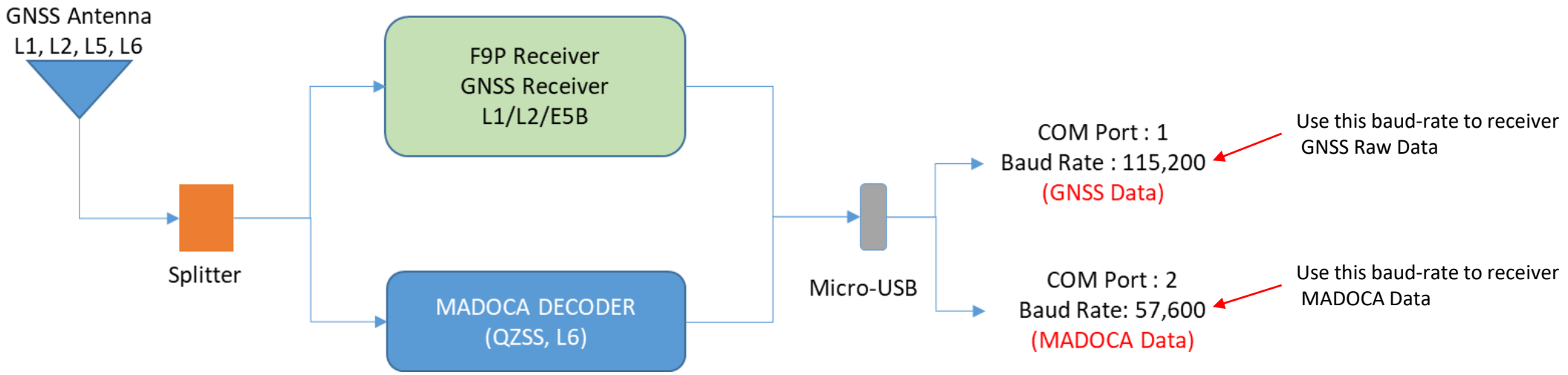
ESP32 is a powerful Micro-controller with WiFi/BT

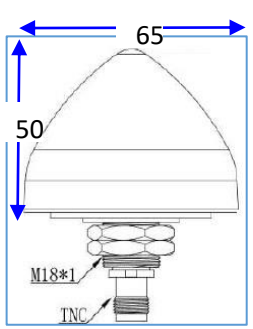
A smart-phone has everything that we need

- CPU
- Memory
- External Interface
- GNSS Receiver
- Sensors

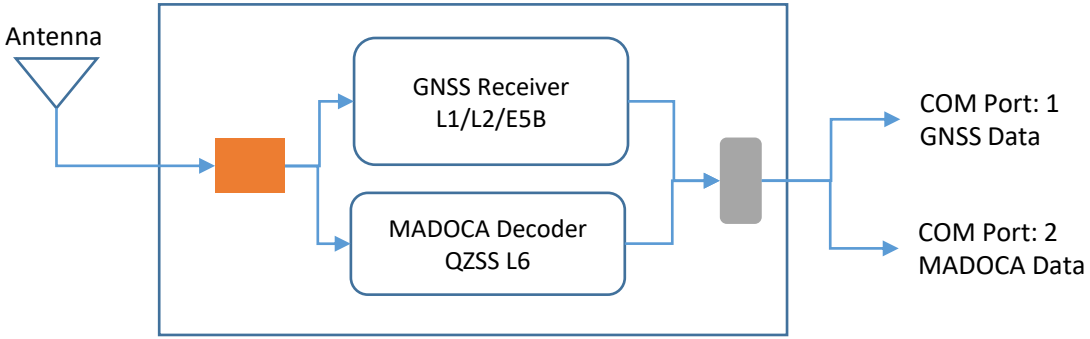
- Note: We use these modules for high accuracy positioning system based on RTK and MADOCA PPP or other GNSS/QZSS special applications.
- There are many other GNSS modules as well. We have no intention of any purpose to name some of the makers here.

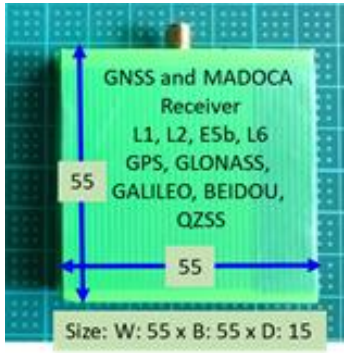
QZSS MADOCA Solution: MADOCA PPP Receiver System



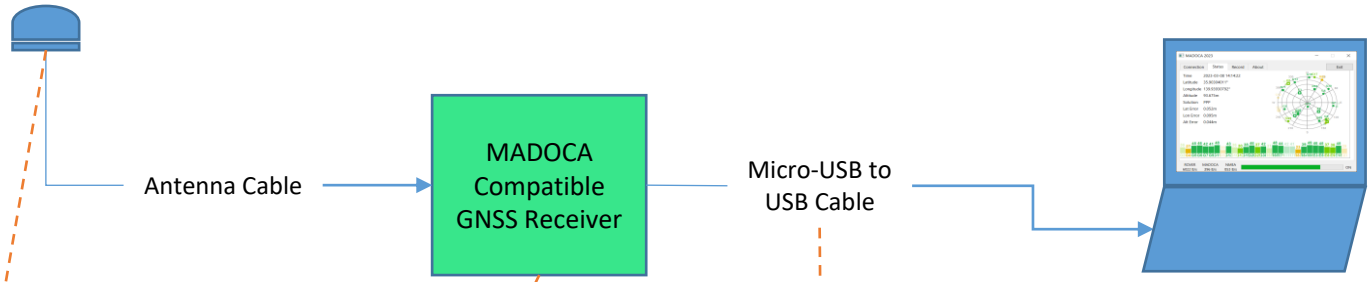


GNSS Antenna

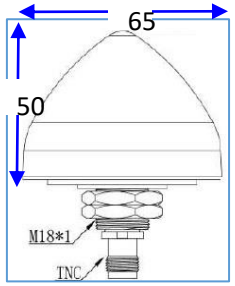




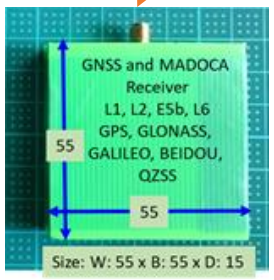
Low-Cost High-Accuracy GNSS Receiver System
GNSS MADOCA Receiver with Windows PC (MAD-WIN)



- Connect Antenna to the GNSS/MADOCA receiver using the provided antenna cable.
- Connect the receiver to an Android device using a “micro-USB to USB” cable and an OTG cable.
- OTG (On-The-Go) cable may be either Type-C or Micro-USB Type depending upon android device’s connection port.



GNSS Antenna



UT RECEIVER


Micro-USB to USB Cable

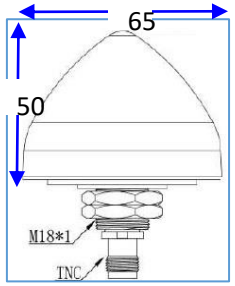
Low-Cost High-Accuracy GNSS Receiver System
GNSS MADOCA Receiver with RaspberryPi Device (MAD-PI)

- Connect Antenna to the GNSS/MADOCA receiver using the provided antenna cable.
- Connect the receiver to a RaspberryPi 4 device using a "micro-USB to USB" cable.
- Connect a USB Memory Drive to RasPi device.
- Either use a Power Bank or an AC Adapter for power supply.

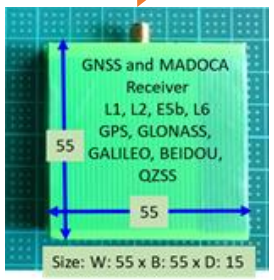
Antenna Cable

MADOCA Compatible GNSS Receiver

Micro-USB to USB Cable



GNSS Antenna



UT RECEIVER

Micro-USB to USB Cable

Micro-USB to USB Cable

OR

Power Adapter for Raspl4

USB Memory

Low-Cost High-Accuracy GNSS Receiver System
GNSS MADOCA Receiver with Android Device (MADROID)

Antenna Cable

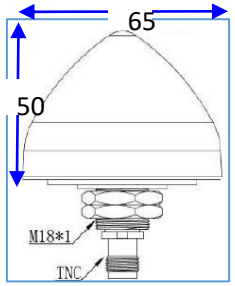
MADOCA Compatible GNSS Receiver

Micro-USB to USB Cable

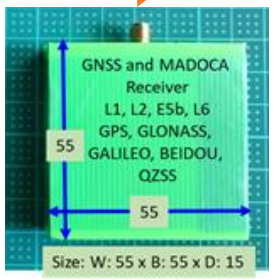
OTG Cable

- Connect Antenna to the GNSS/MADOCA receiver using the provided antenna cable.
- Connect the receiver to an Android device using a “micro-USB to USB” cable and an OTG cable.
- OTG (On-The-Go) cable may be either Type-C or Micro-USB Type depending upon android device’s connection port.

Select OTG Cable based on Android Device Connector Type



GNSS Antenna



UT RECEIVER

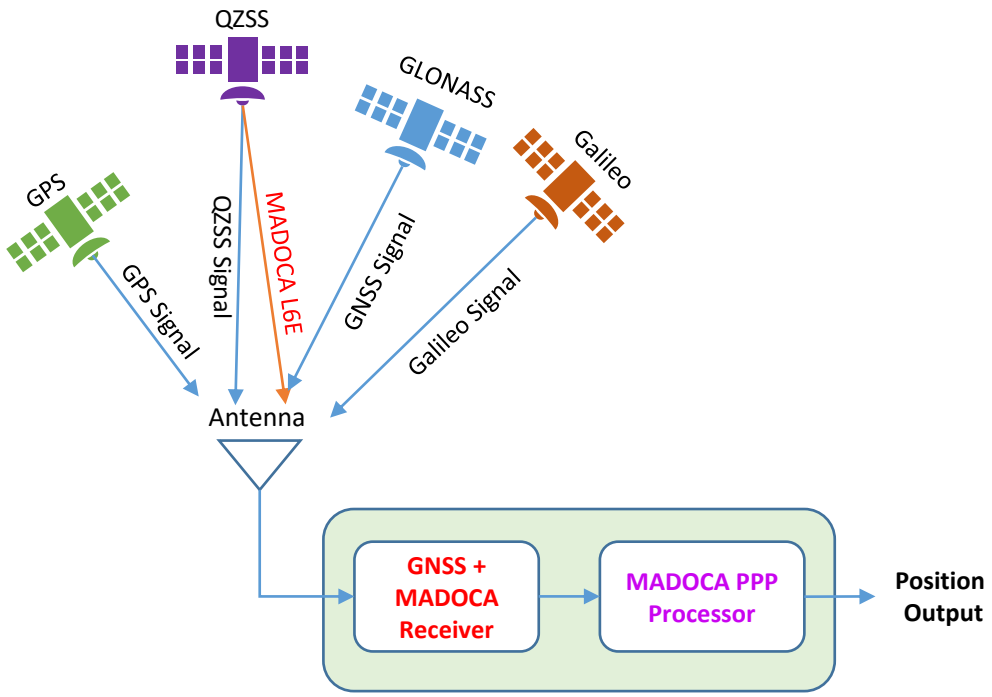
Micro-USB to USB Cable

OTG Cable Type: C

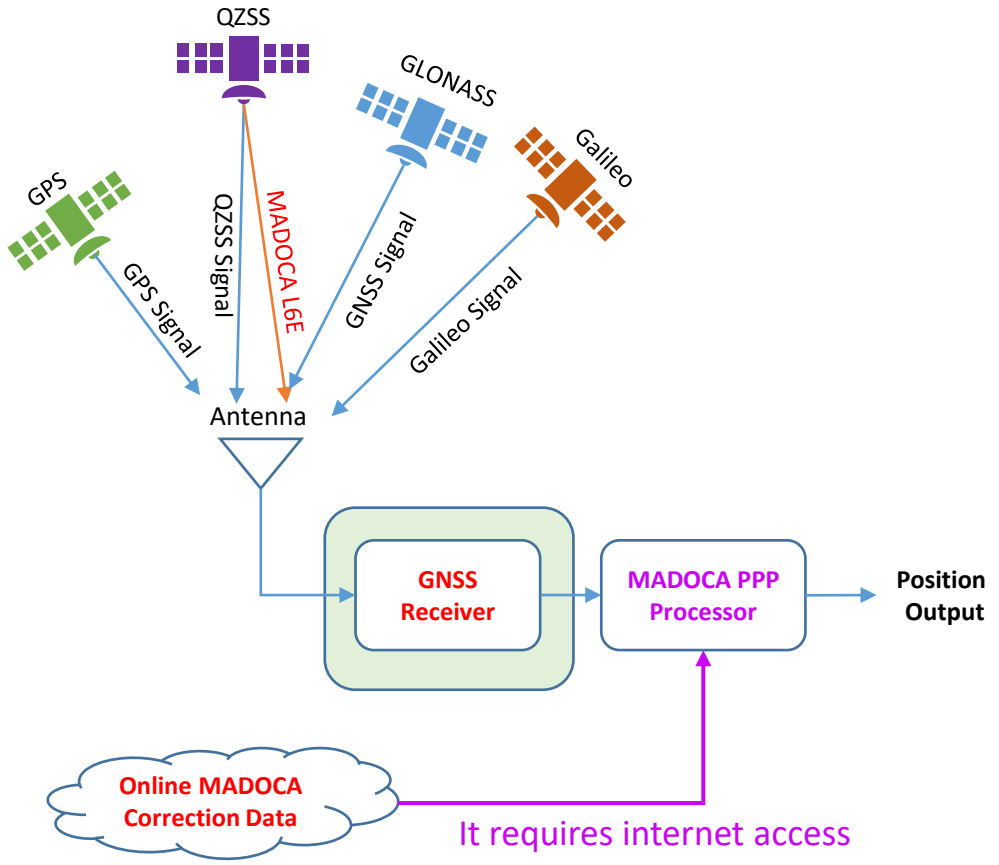
OTG Cable Type: Micro USB

MADOCA System: Direct from QZSS or Online Correction Data

If you have
GNSS + MADOCA Receiver

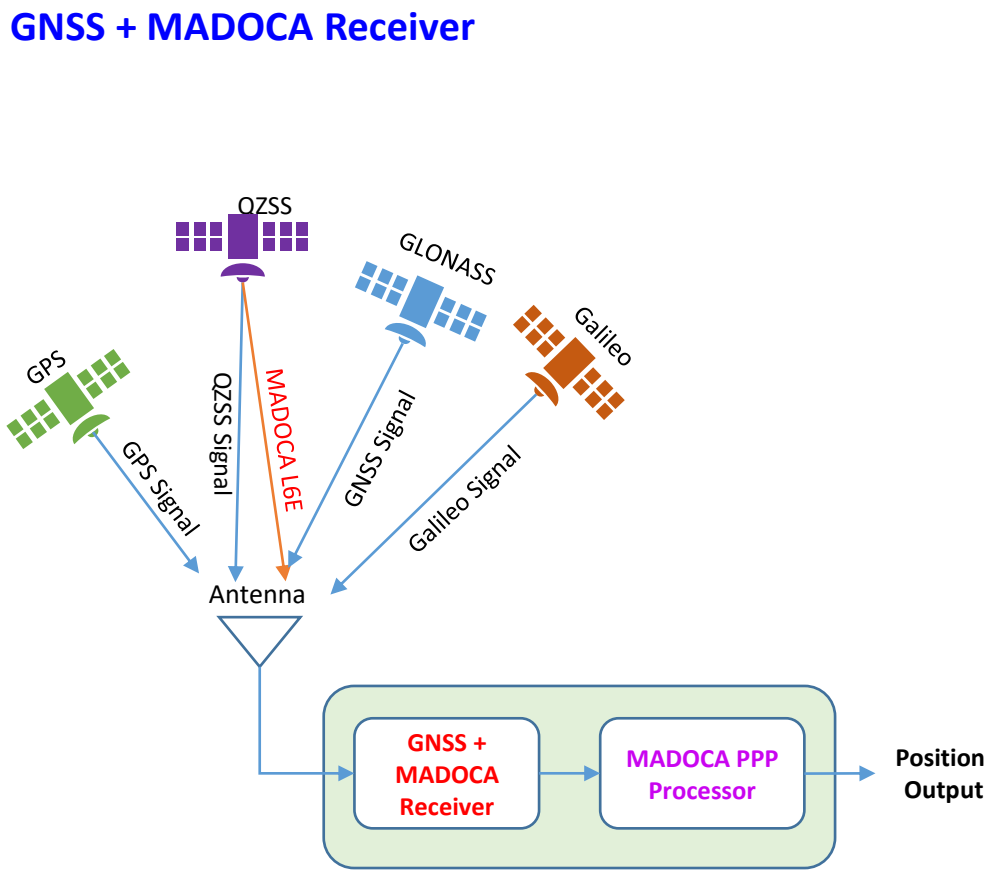


If you have
GNSS Receiver Only



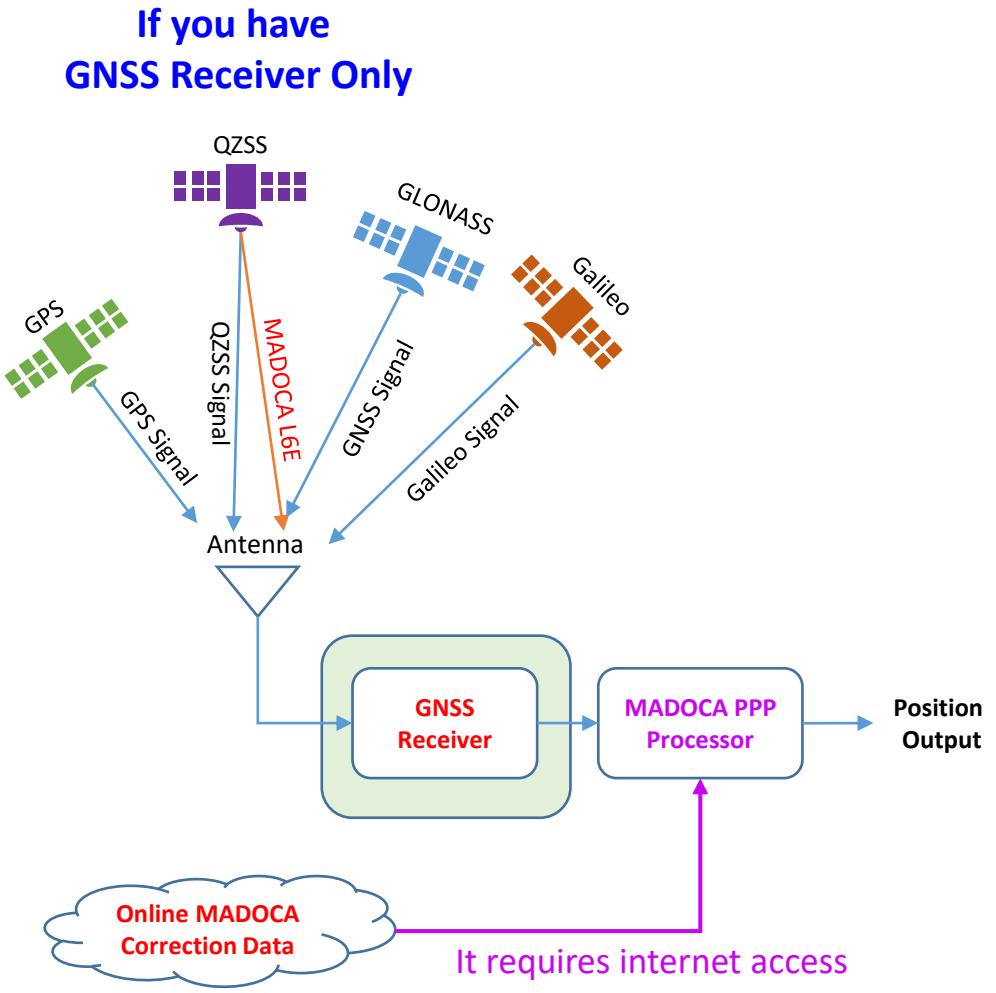
QZSS MADOCA Solution: Using GNSS/MADOCA Receiver

- GNSS Receiver:
  - Multi-Frequency GNSS Receiver
- MADOCA Correction Data:
  - QZSS L6E Signal Decoder
- U-Blox Module:
  - GNSS: F9P Module
  - QZSS L6 Signal Decoder: D9C
- Septentrio
  - MOSAIC Module
    - GNSS + L6 Signal combined



QZSS MADOCA Solution: Using GNSS only Receiver

- GNSS Receiver:
  - Multi-Frequency GNSS Receiver
- MADOCA Correction Data:
  - Online Correction Service
- U-Blox Module:
  - GNSS: F9P Module
- Septentrio
  - MOSAIC Module
    - GNSS + L6 Signal combined

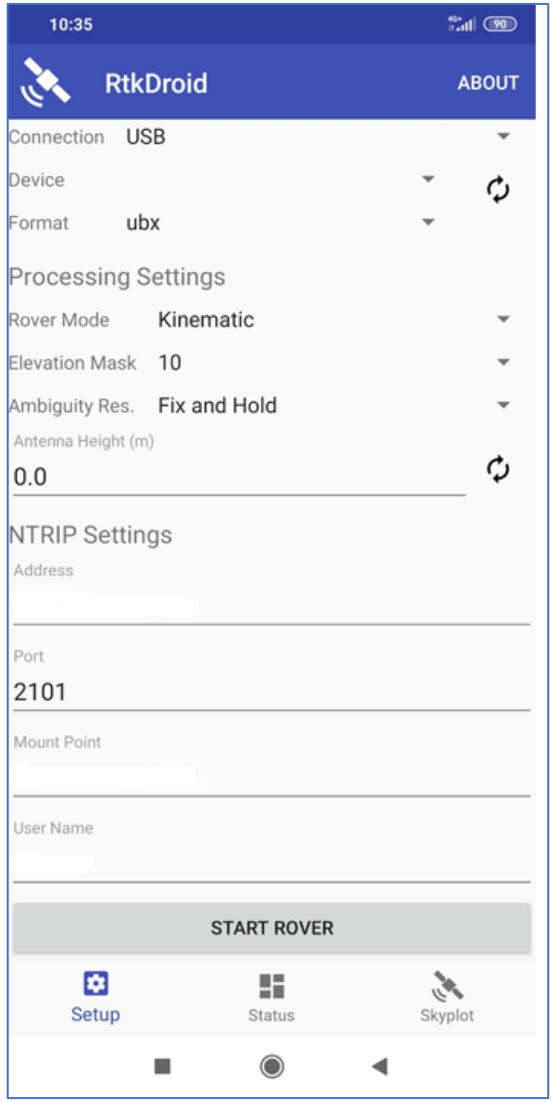


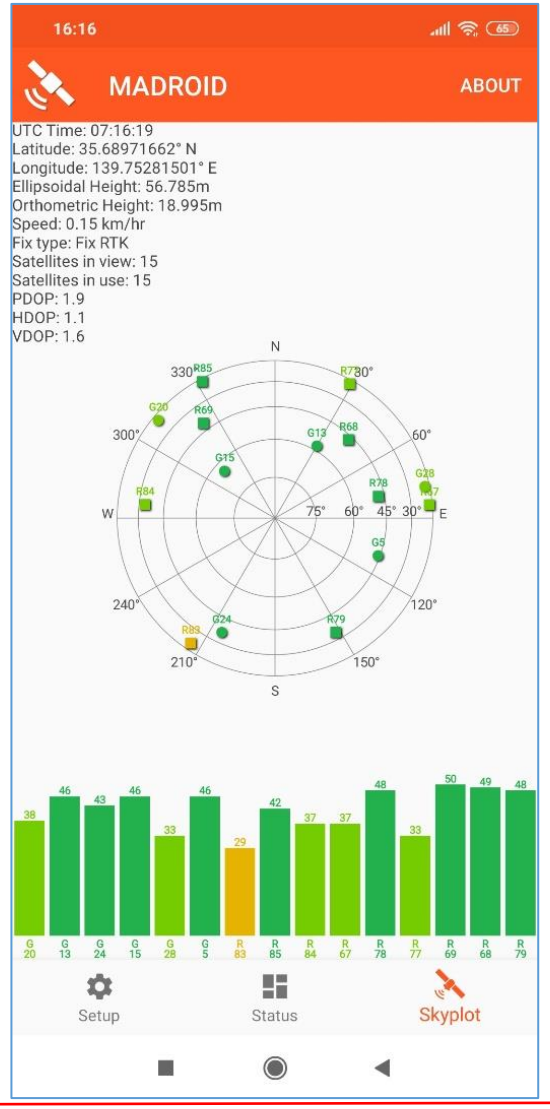
Screen Shots of RTKDROID and MADROID

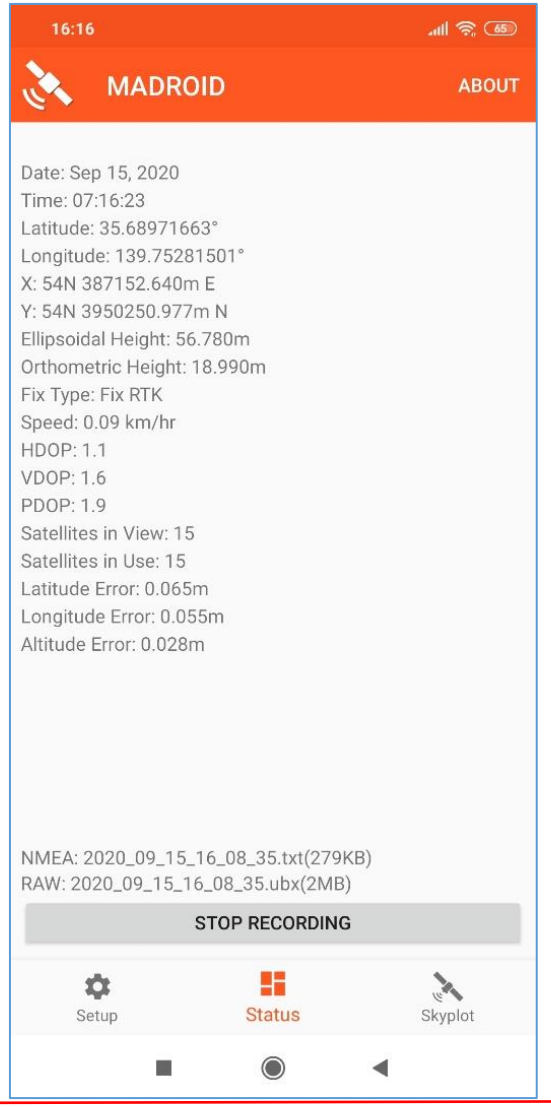
Connect GNSS receiver to Android device

(1) RTKDROID :
For RTK or PPK

(2) MADROID:
for MADOCA-PPP,
MADOCA-PPP/AR (future)

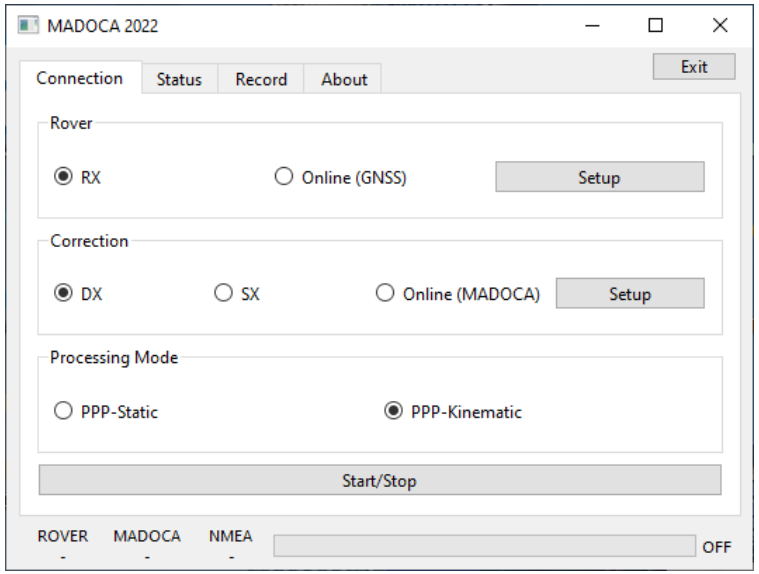




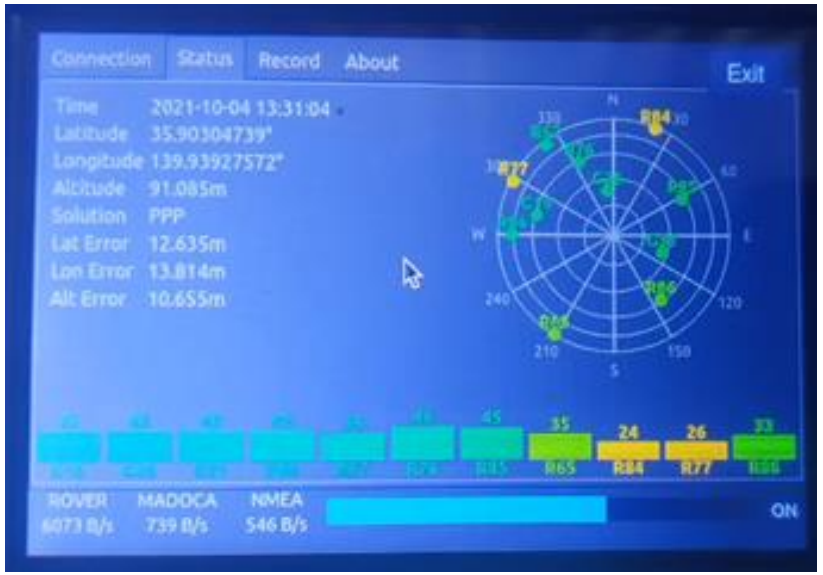


MAD-WIN / MAD-PI / MADROID

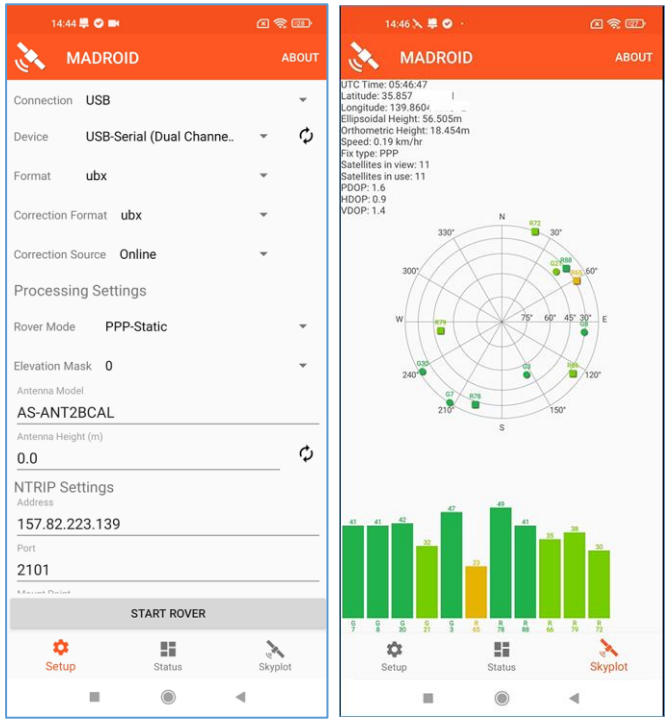
MAD-WIN



MAD-PI

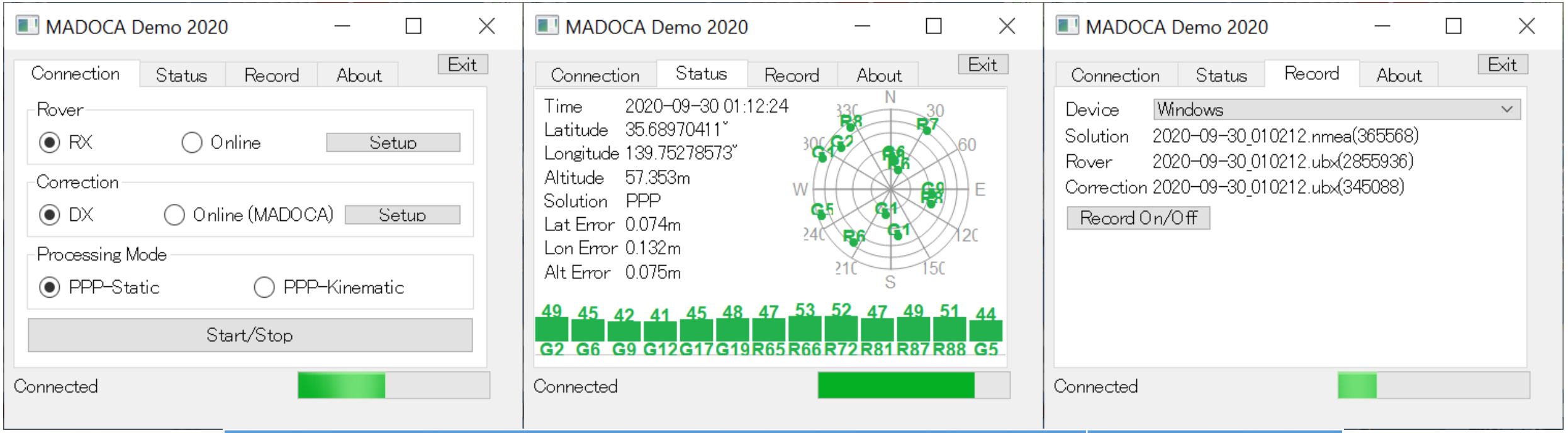


MADROID



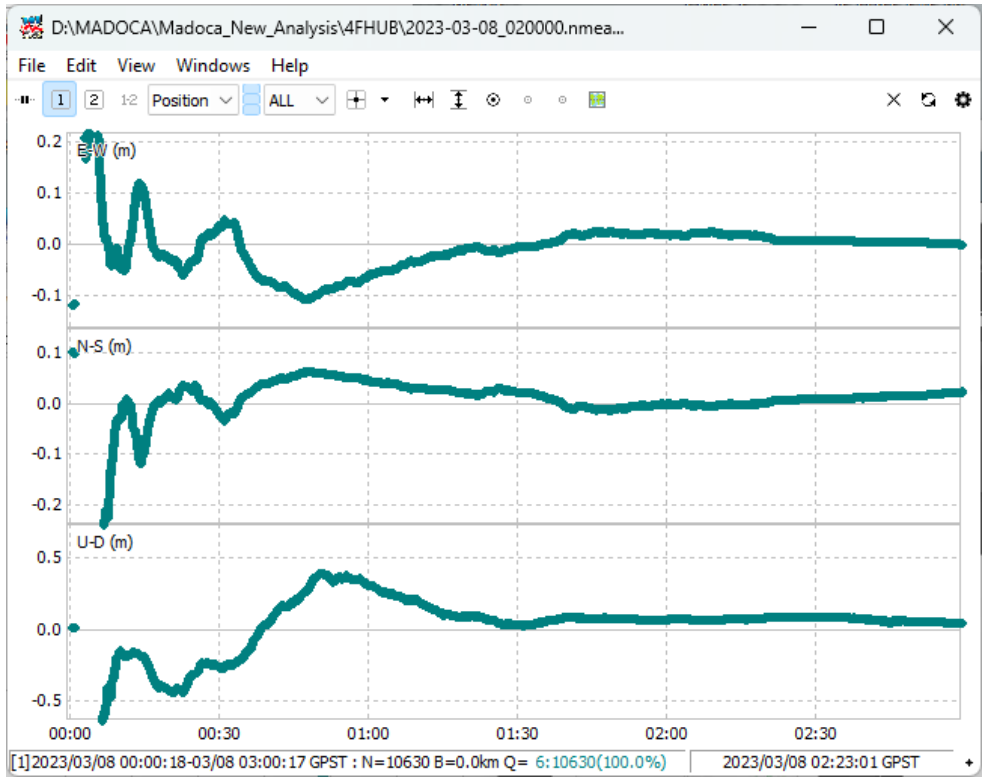
MAD-WIN and MAD-PI GUIs are the same

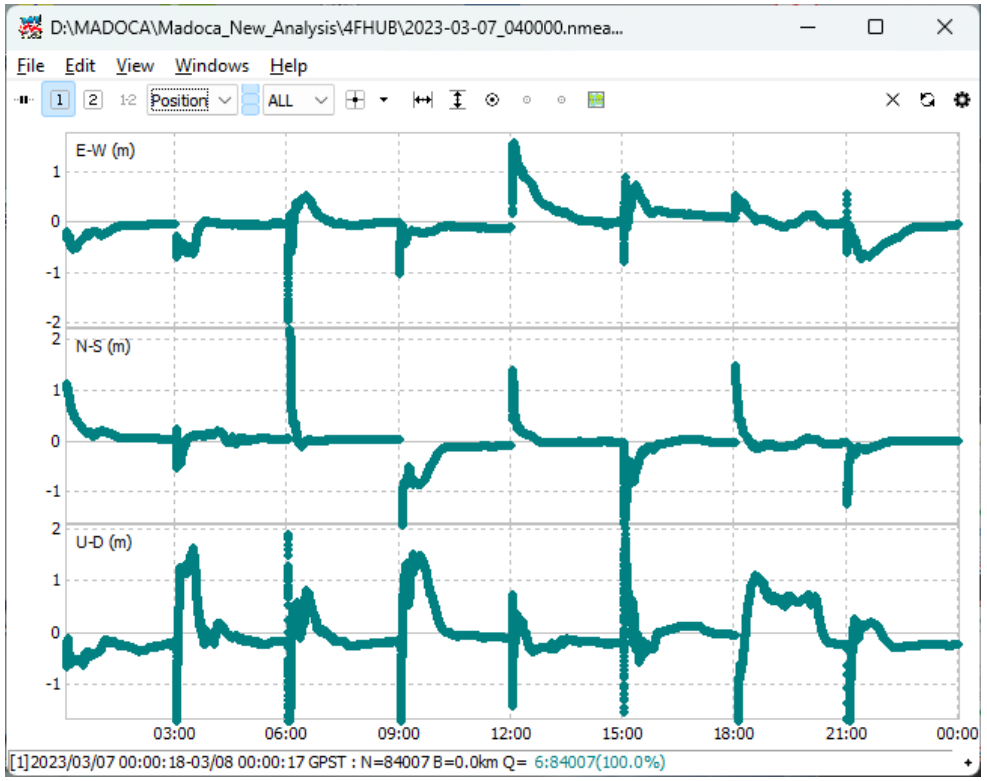
MAD-WIN / MAD-PI User Interface



Receiver Output Files		
Solution	MADOCA PPP Solution	NMEA Format
Rover	Rover RAW Data in receiver's proprietary format Can be used for PPK (Post-Processing Kinematic) Solution or Post-Processing PPP	UBX, SBF, BINEX or RTCM3
Correction	MADOCA PPP Correction Data in receiver's proprietary format Can be used for Post-Processing MADOCA	UBX or SBF

MADOCA PPP Position Accuracy





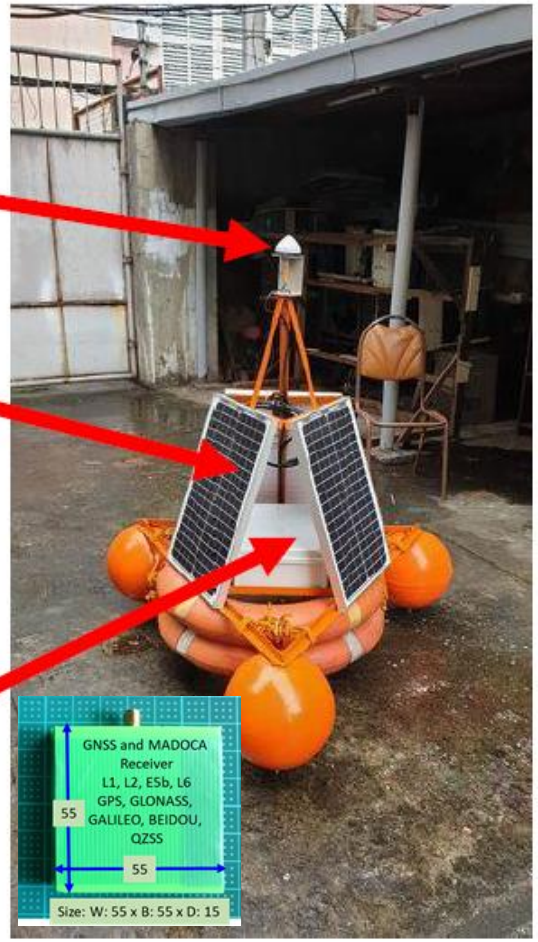
Reset every 3 hour interval to analyze convergence time

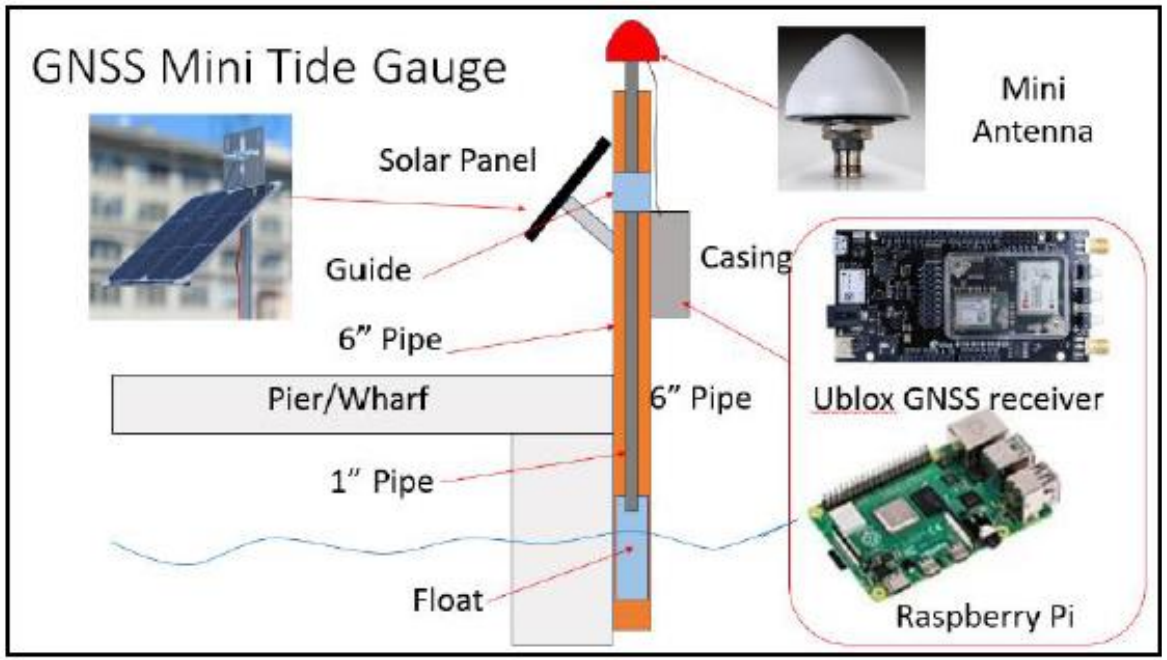
Low-Cost MADOCA Receiver for Sea-Level Rise Measurement

GNSS antenna

Solar power

TiBox enclosure containing the battery, raspberry pi and Ublox and MADOCA decoder





Source: Technical Report, GNSS/QZSS MADOCA PPP Data Acquisition for Sea Level Rise Measurement, DR. ROSALIE B. REYES, UP DGE and Project Leader, CLSR-Phil Project

MADOCA DEMO