Low-Cost High-Accuracy GNSS Receiver

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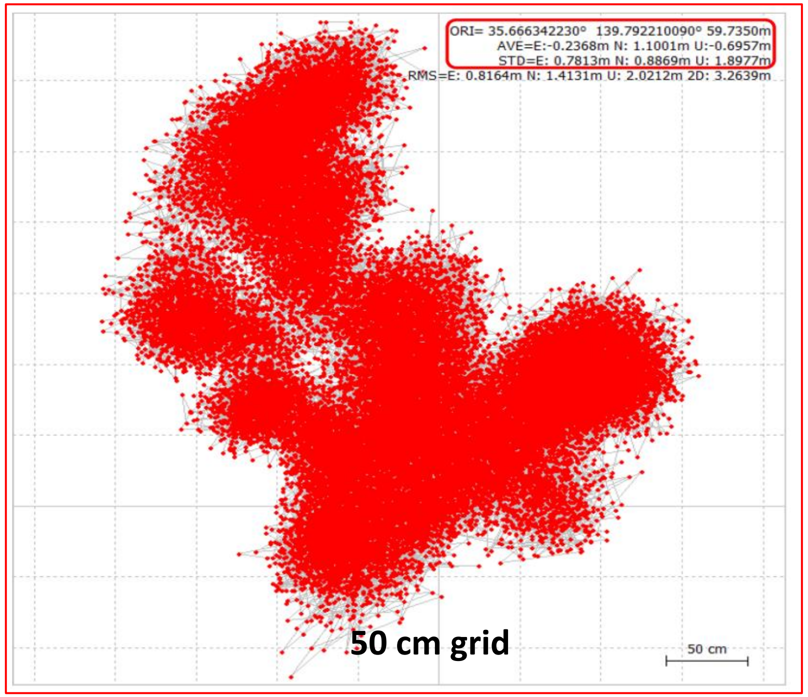
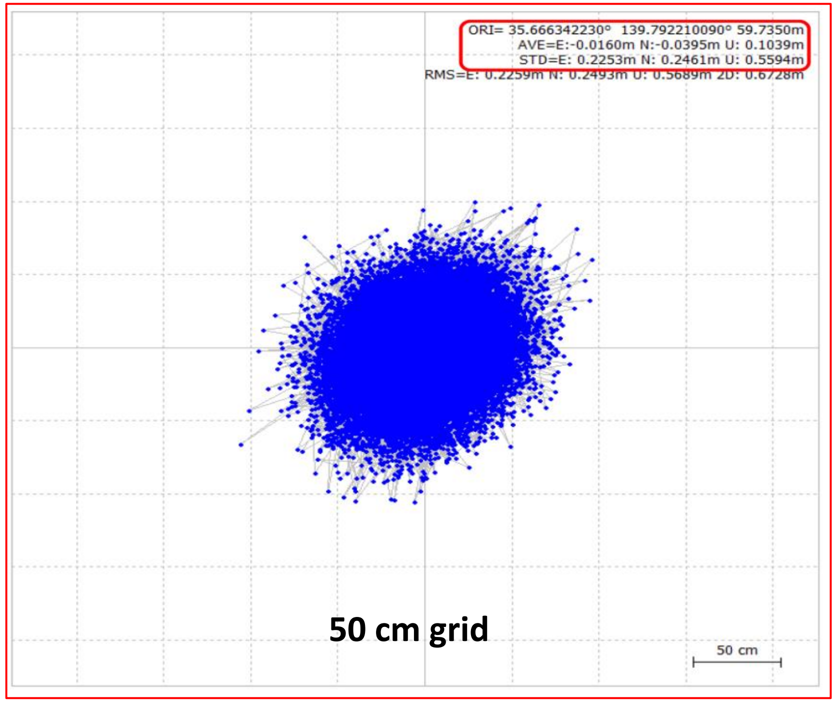
High Accuracy Receivers are Expensive

- High-Accuracy Survey Grade Receivers are multi-frequency and multi-system receivers
  - L1/L2/L5, G1/G2, B1/B2/B3 etc
  - GPS, GLONASS, BGALILEO, BeiDou, QZSS etc
  - Price varies from $5,000 to $30,000 or more.
- However, Low Cost Receivers are also capable of
  - Multi-System: GPS, GLONASS, GALILEO, BeiDou, QZSS, SBAS etc
  - Currently only in L1-Band Frequency
  - Low Cost: $300
  - Very soon: Multi Frequency, L1/L5
    - Broadcom already announced production of L1/L5 GNSS chip

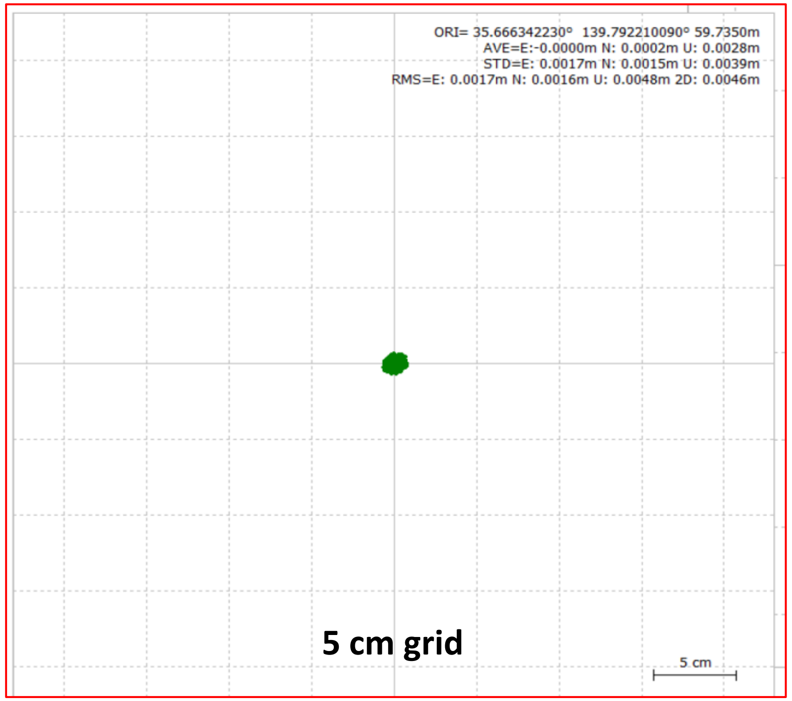
How accurate is GPS Position?



SPP (Single Point Position)



DGPS (Differential GPS)



RTK (Real Time Kinematic)

Errors in GPS Observation (L1C/A Signal)

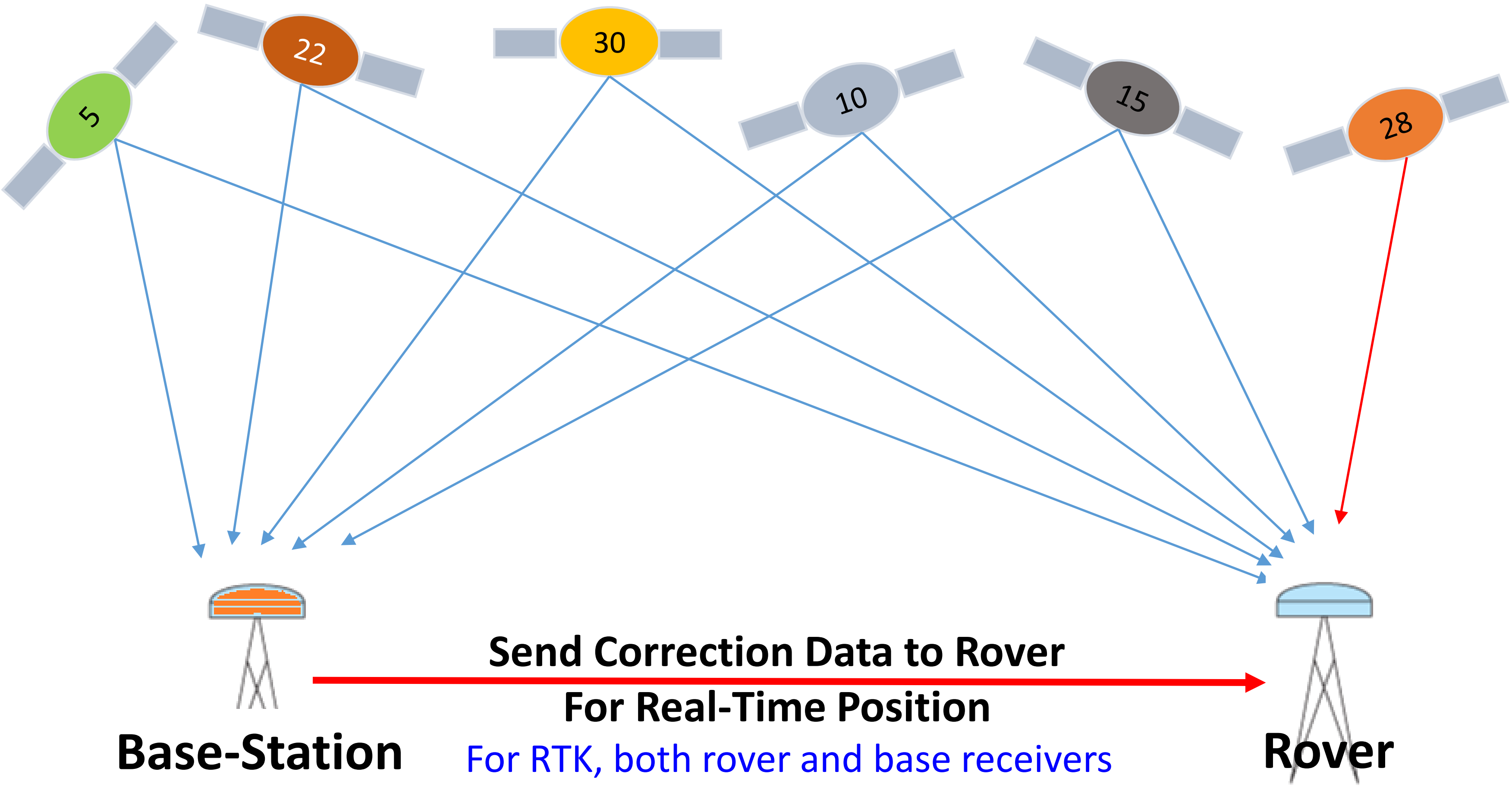
Error Sources	One-Sigma Error , m		Comments
	Total	DGPS	
Satellite Orbit	2.1	0.0	Common errors are removed
Satellite Clock	2.1	0.0	
Ionosphere Error	4.0	0.4	Common errors are reduced
Troposphere Error	0.7	0.2	
Multipath	1.4	1.4	
Receiver Circuits	0.5	0.5	

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

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

Table Source : http://www.edu-observatory.org/gps/gps_accuracy.html#Multipath

Principle of Differential Correction



Send Correction Data to Rover

For Real-Time Position

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

Base-Station

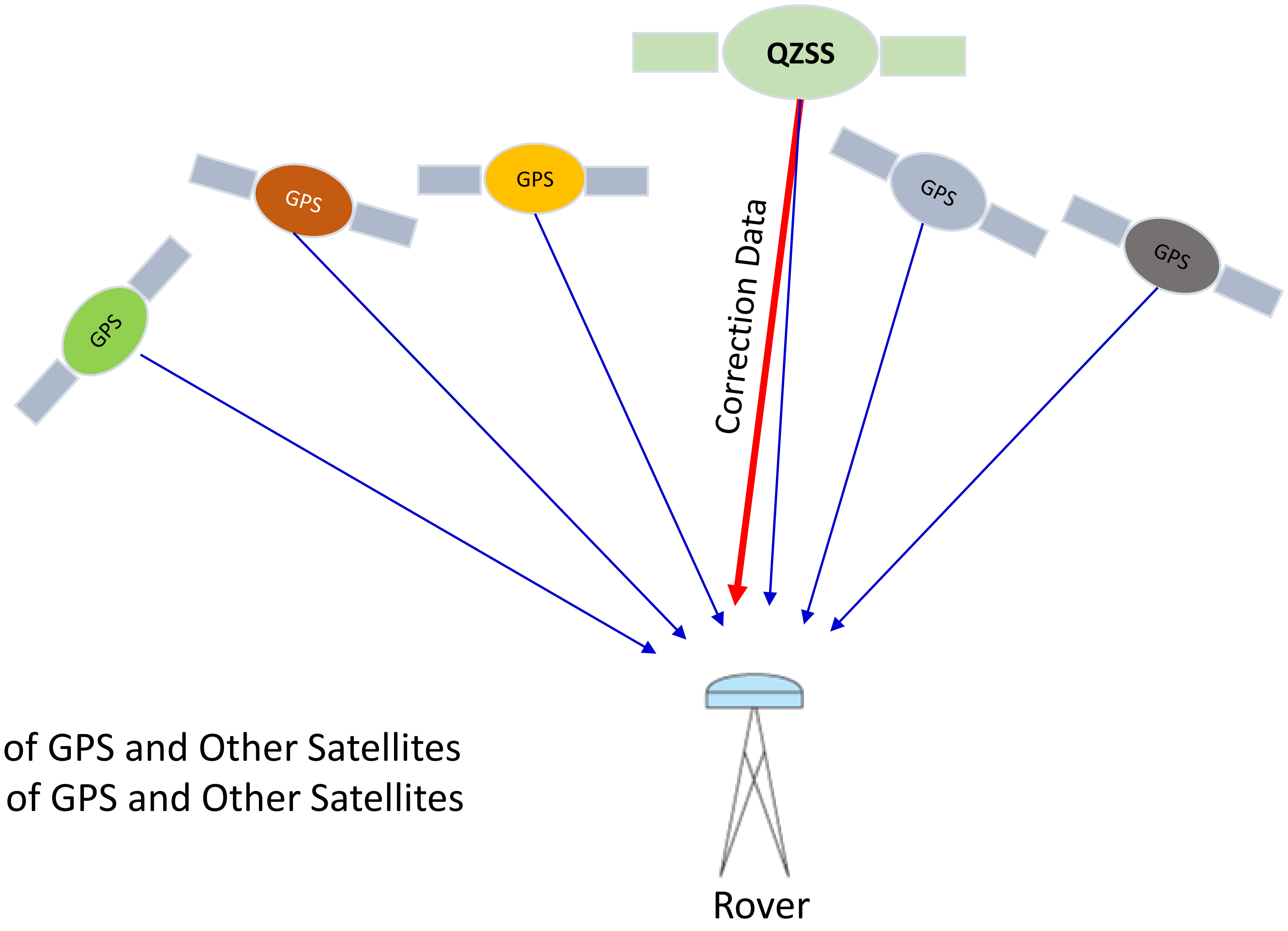
Antenna is installed at a known-position

Rover

User in the Field

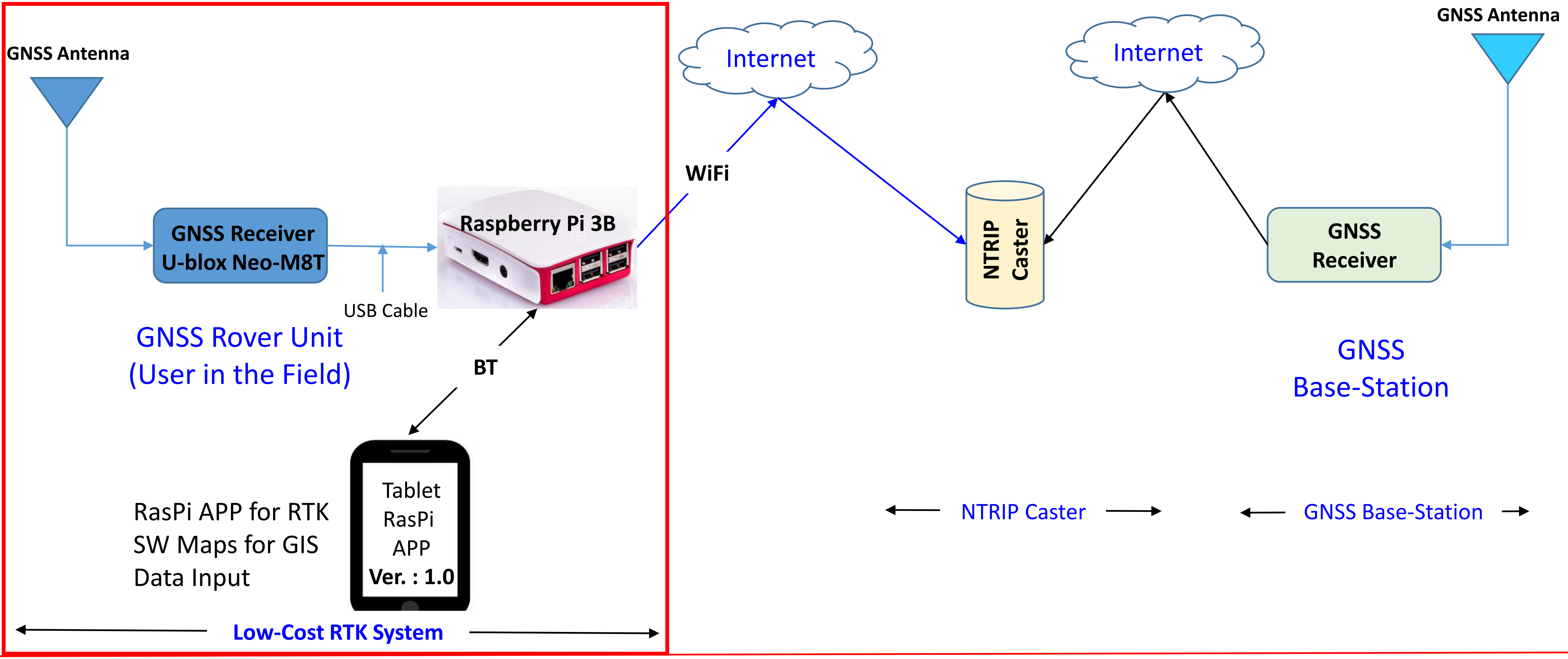
(Either fixed or moving)

Principle of QZSS MADOCA / CLAS Service

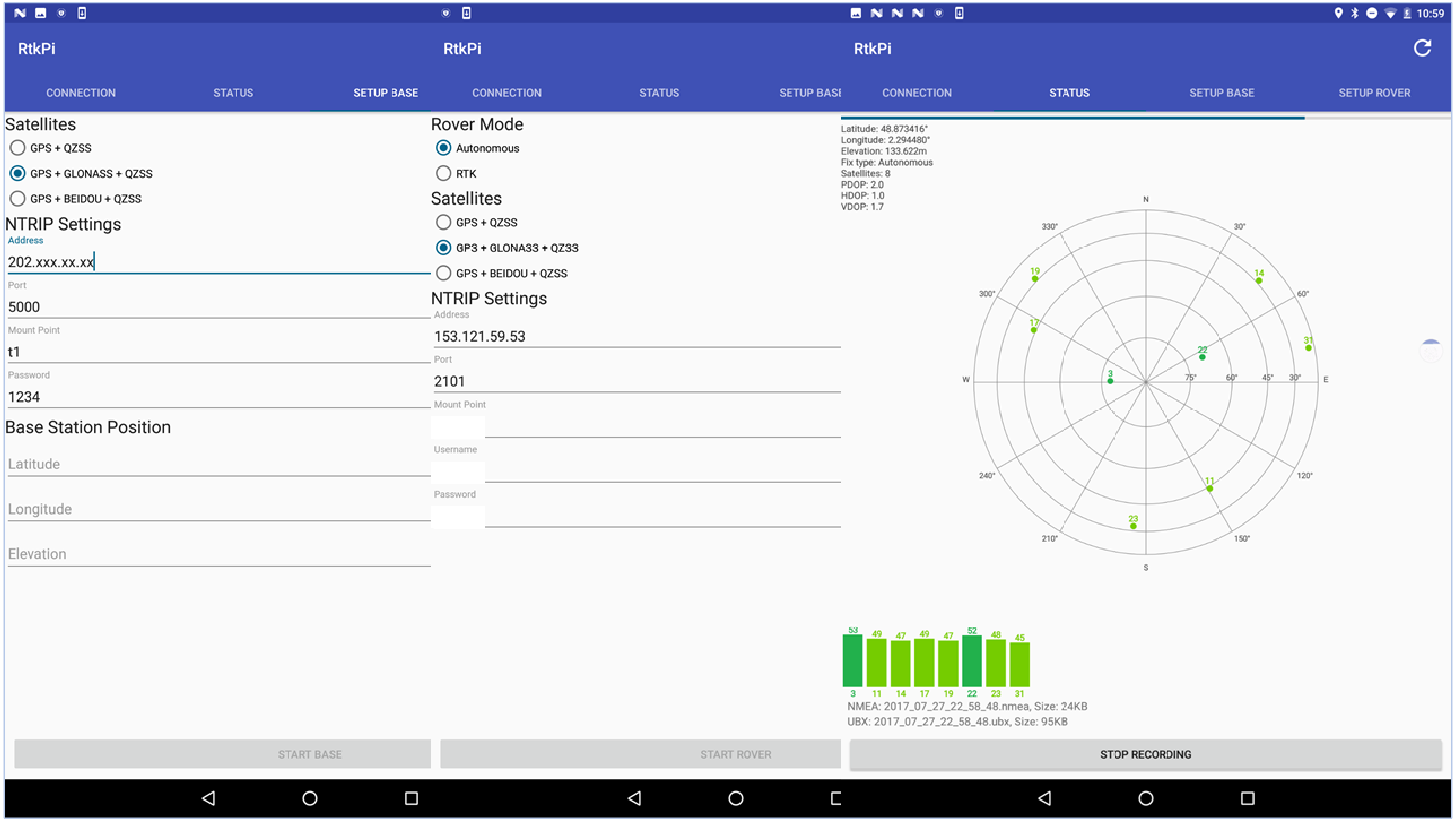


Correction Data:
Satellite Orbit Error of GPS and Other Satellites
Satellite Clock Error of GPS and Other Satellites

Low-Cost High Accuracy System



RtkPi APP for Low-Cost RTK System

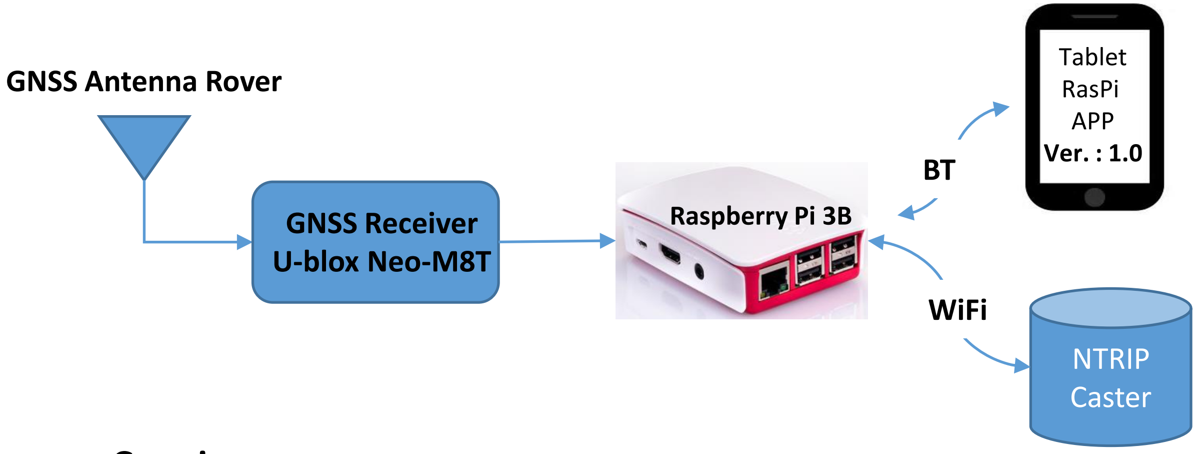


Board Computer for Low-Cost RTK System

Raspberry Pi 3B for Realtime and Postprocessing RTK

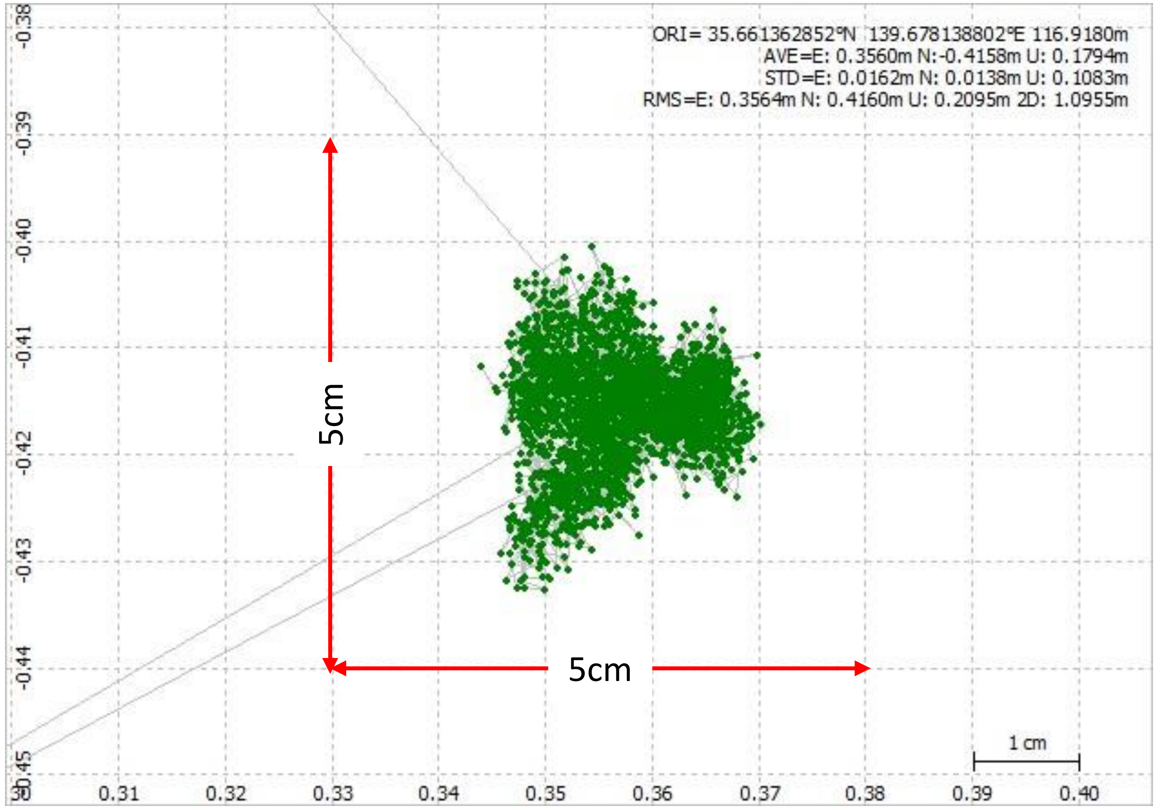
Raspberry Pi Zero w/WiFi & BT for Post-processing RTK

Accuracy from Low-Cost RTK System

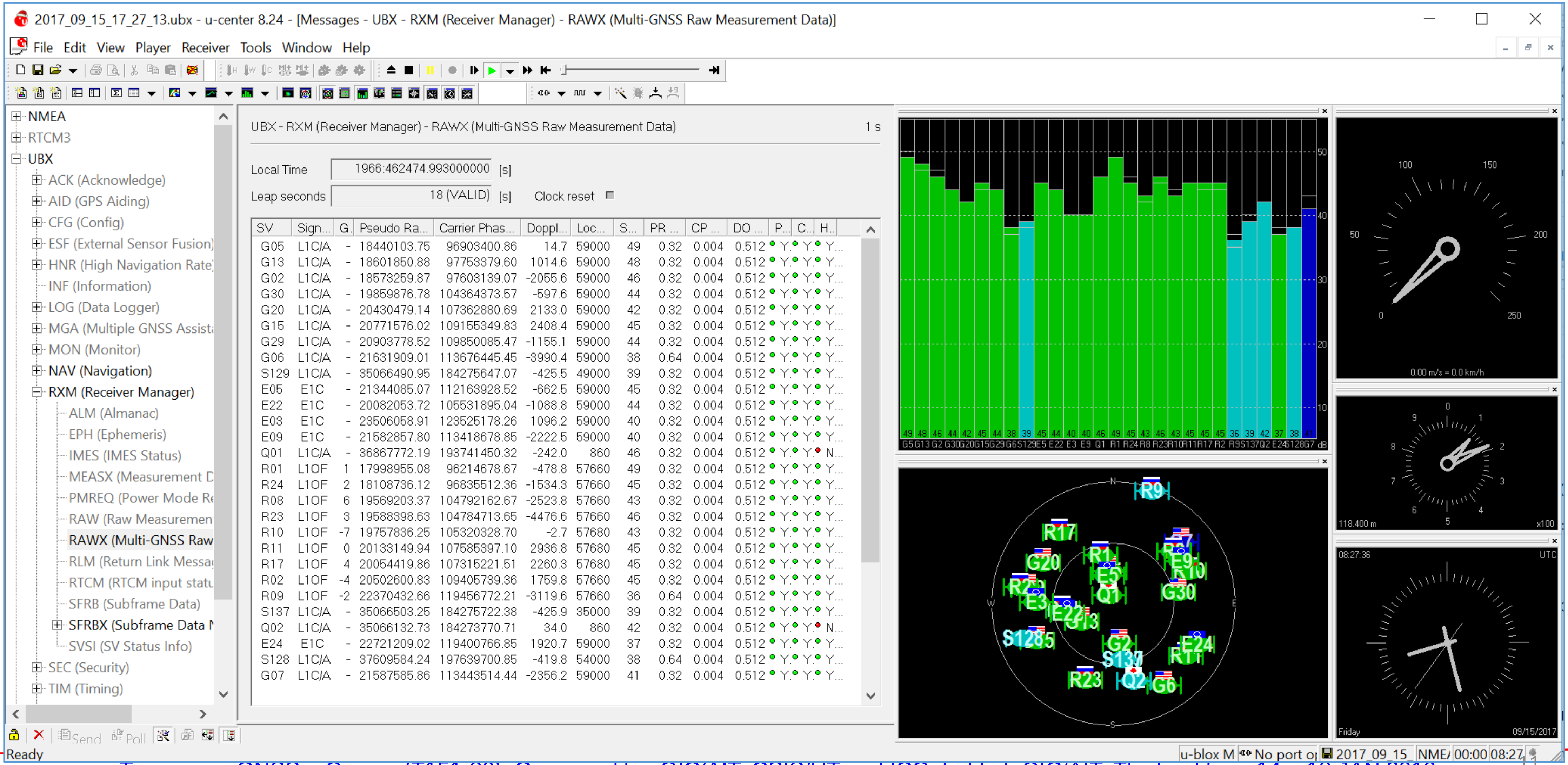


Rover-Station:
Receiver: u-blox M8T
Antenna: Zephyr 2
Computer: RaspberryPi 3B+
Distance between Base and Rover : about 12Km

Base-Station:
Receiver: Trimble NetR9
Antenna: Zephyr 2

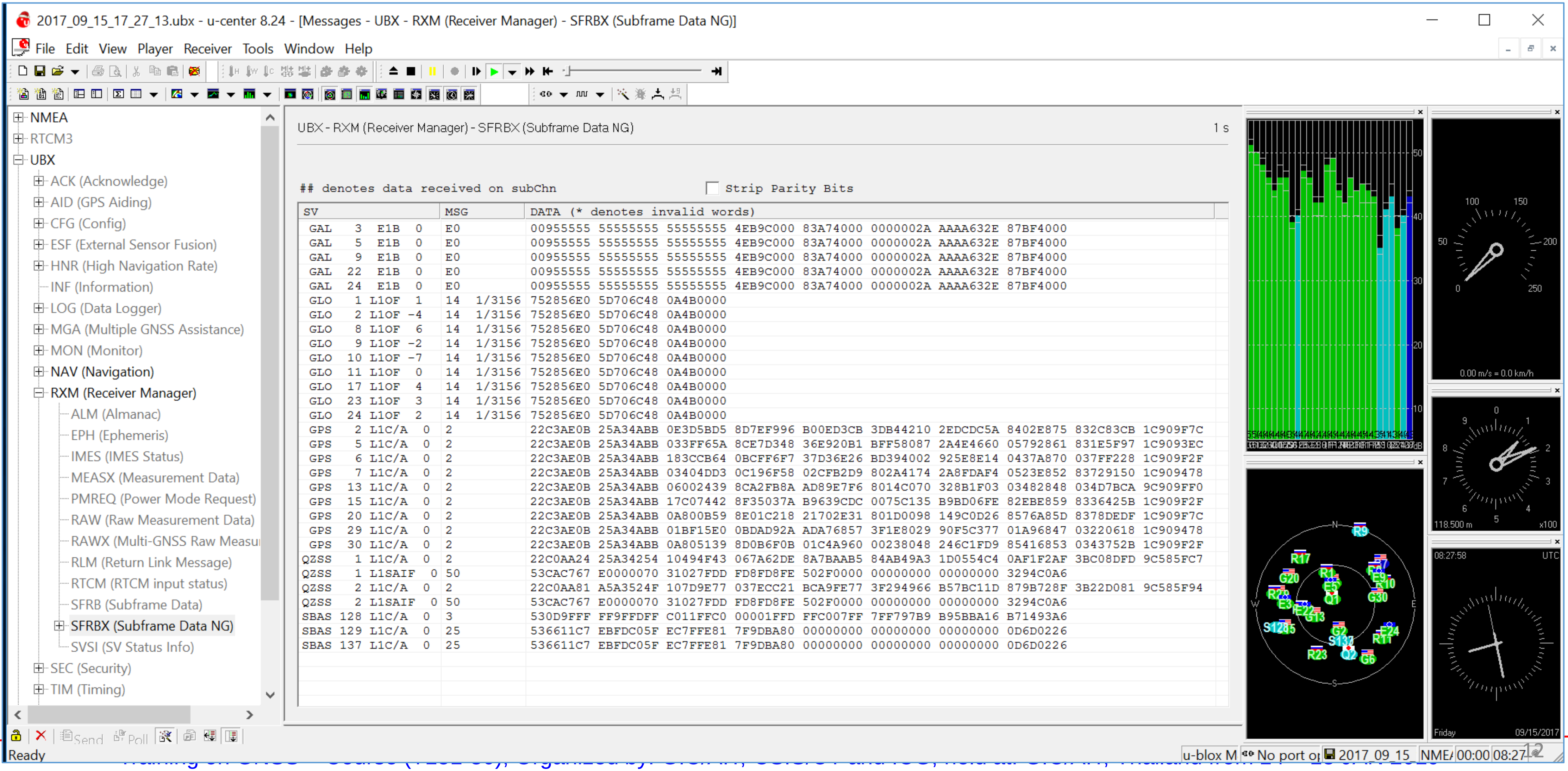


Data from Low-Cost RTK System

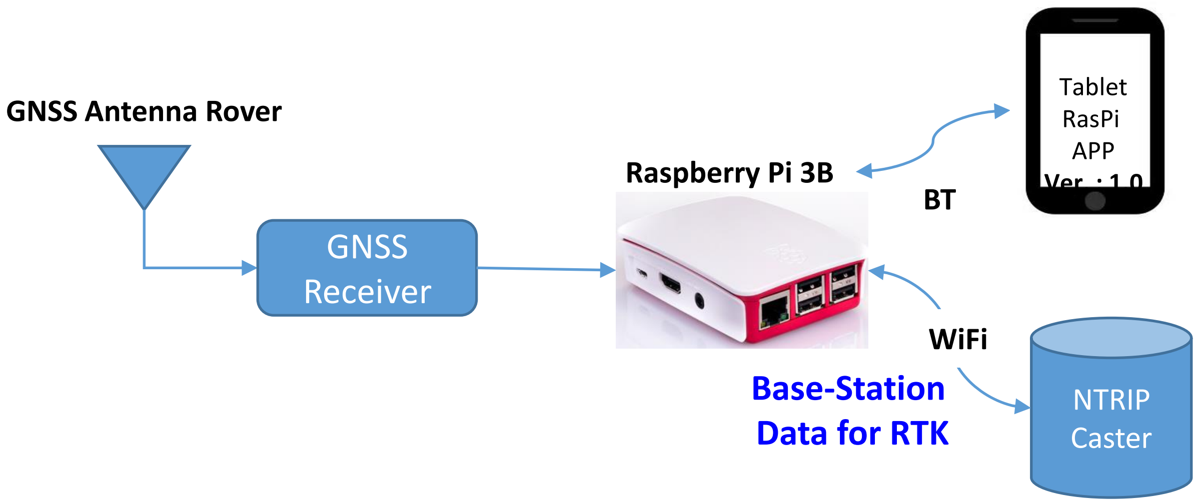


SV	Sign...	G.	Pseudo Ra...	Carrier Phas...	Doppl...	Loc...	S...	PR ...	CP ...	DO ...	P...	C...	H...
G05	L1C/A	-	18440103.75	96903400.86	14.7	59000	49	0.32	0.004	0.512	Y.	Y.	Y...
G13	L1C/A	-	18601850.88	97753379.60	1014.6	59000	48	0.32	0.004	0.512	Y.	Y.	Y...
G02	L1C/A	-	18573259.87	97603139.07	-2055.6	59000	46	0.32	0.004	0.512	Y.	Y.	Y...
G30	L1C/A	-	19859876.78	104364373.57	-597.6	59000	44	0.32	0.004	0.512	Y.	Y.	Y...
G20	L1C/A	-	20430479.14	107362880.69	2133.0	59000	42	0.32	0.004	0.512	Y.	Y.	Y...
G15	L1C/A	-	20771576.02	109155349.83	2408.4	59000	45	0.32	0.004	0.512	Y.	Y.	Y...
G29	L1C/A	-	20903778.52	109850085.47	-1155.1	59000	44	0.32	0.004	0.512	Y.	Y.	Y...
G06	L1C/A	-	21631909.01	113676445.45	-3990.4	59000	38	0.64	0.004	0.512	Y.	Y.	Y...
S129	L1C/A	-	35066490.95	184275647.07	-425.5	49000	39	0.32	0.004	0.512	Y.	Y.	Y...
E05	E1C	-	21344085.07	112163928.52	-662.5	59000	45	0.32	0.004	0.512	Y.	Y.	Y...
E22	E1C	-	20082053.72	105531895.04	-1088.8	59000	44	0.32	0.004	0.512	Y.	Y.	Y...
E03	E1C	-	23506058.91	123525178.26	1096.2	59000	40	0.32	0.004	0.512	Y.	Y.	Y...
E09	E1C	-	21582857.80	113418678.85	-2222.5	59000	40	0.32	0.004	0.512	Y.	Y.	Y...
Q01	L1C/A	-	36867772.19	193741450.32	-242.0	860	46	0.32	0.004	0.512	Y.	Y.	N...
R01	L1OF	1	17998955.08	96214678.67	-478.8	57660	49	0.32	0.004	0.512	Y.	Y.	Y...
R24	L1OF	2	18108736.12	96835512.36	-1534.3	57660	45	0.32	0.004	0.512	Y.	Y.	Y...
R08	L1OF	6	19569203.37	104792162.67	-2523.8	57660	43	0.32	0.004	0.512	Y.	Y.	Y...
R23	L1OF	3	19588398.63	104784713.65	-4476.6	57660	46	0.32	0.004	0.512	Y.	Y.	Y...
R10	L1OF	-7	19757836.25	105320328.70	-2.7	57680	43	0.32	0.004	0.512	Y.	Y.	Y...
R11	L1OF	0	20133149.94	107585397.10	2936.8	57680	45	0.32	0.004	0.512	Y.	Y.	Y...
R17	L1OF	4	20054419.86	107315221.51	2260.3	57680	45	0.32	0.004	0.512	Y.	Y.	Y...
R02	L1OF	-4	20502600.83	109405739.36	1759.8	57660	45	0.32	0.004	0.512	Y.	Y.	Y...
R09	L1OF	-2	22370432.66	119456772.21	-3119.6	57660	36	0.64	0.004	0.512	Y.	Y.	Y...
S137	L1C/A	-	35066503.25	184275722.38	-425.9	35000	39	0.32	0.004	0.512	Y.	Y.	Y...
Q02	L1C/A	-	35066132.73	184273770.71	34.0	860	42	0.32	0.004	0.512	Y.	Y.	N...
E24	E1C	-	22721209.02	119400766.85	1920.7	59000	37	0.32	0.004	0.512	Y.	Y.	Y...
S128	L1C/A	-	37609584.24	197639700.85	-419.8	54000	38	0.64	0.004	0.512	Y.	Y.	Y...
G07	L1C/A	-	21587585.86	113443514.44	-2356.2	59000	41	0.32	0.004	0.512	Y.	Y.	Y...

Data from Low-Cost RTK System

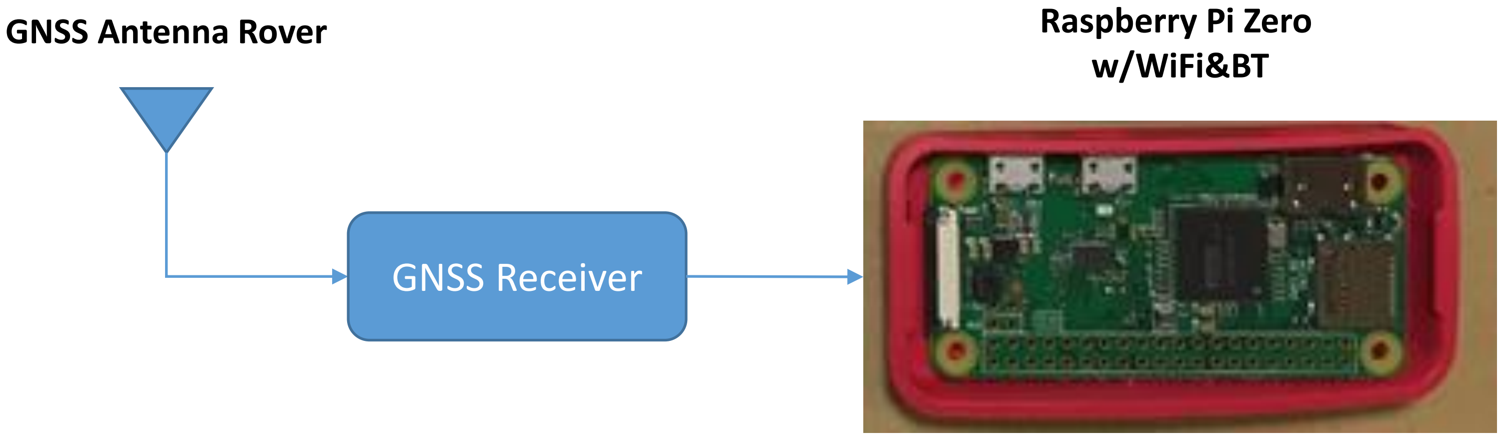


Type – R1: GNSS Receiver with RaspberryPi-3



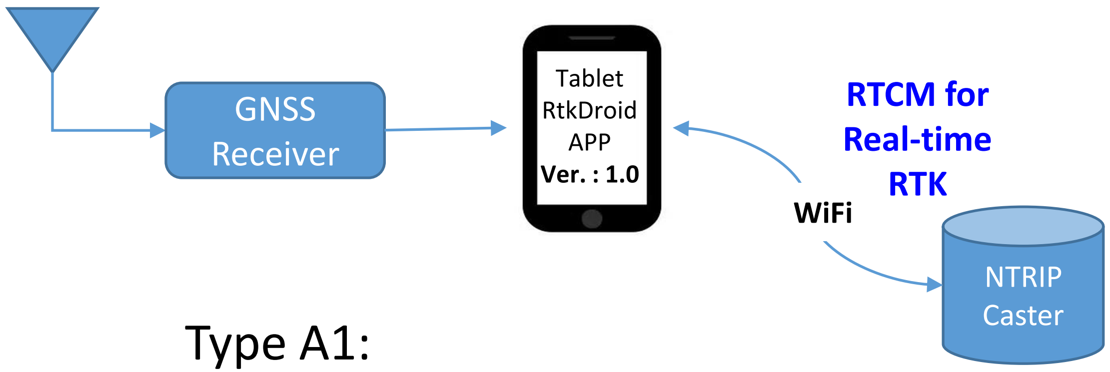
Type R1:
Base or Rover Mode
Real-Time and Post-Processing RTK
Based on RTKLIB Engine

Type – R2: GNSS Receiver with RaspberryPi-Zero/W



Type R2:
Rover Mode
SPS + Post-Processing RTK
Log Necessary Raw Data for Post-processing RTK
Based on RTKLIB Engine

Type – A1: GNSS Receiver with Android Device

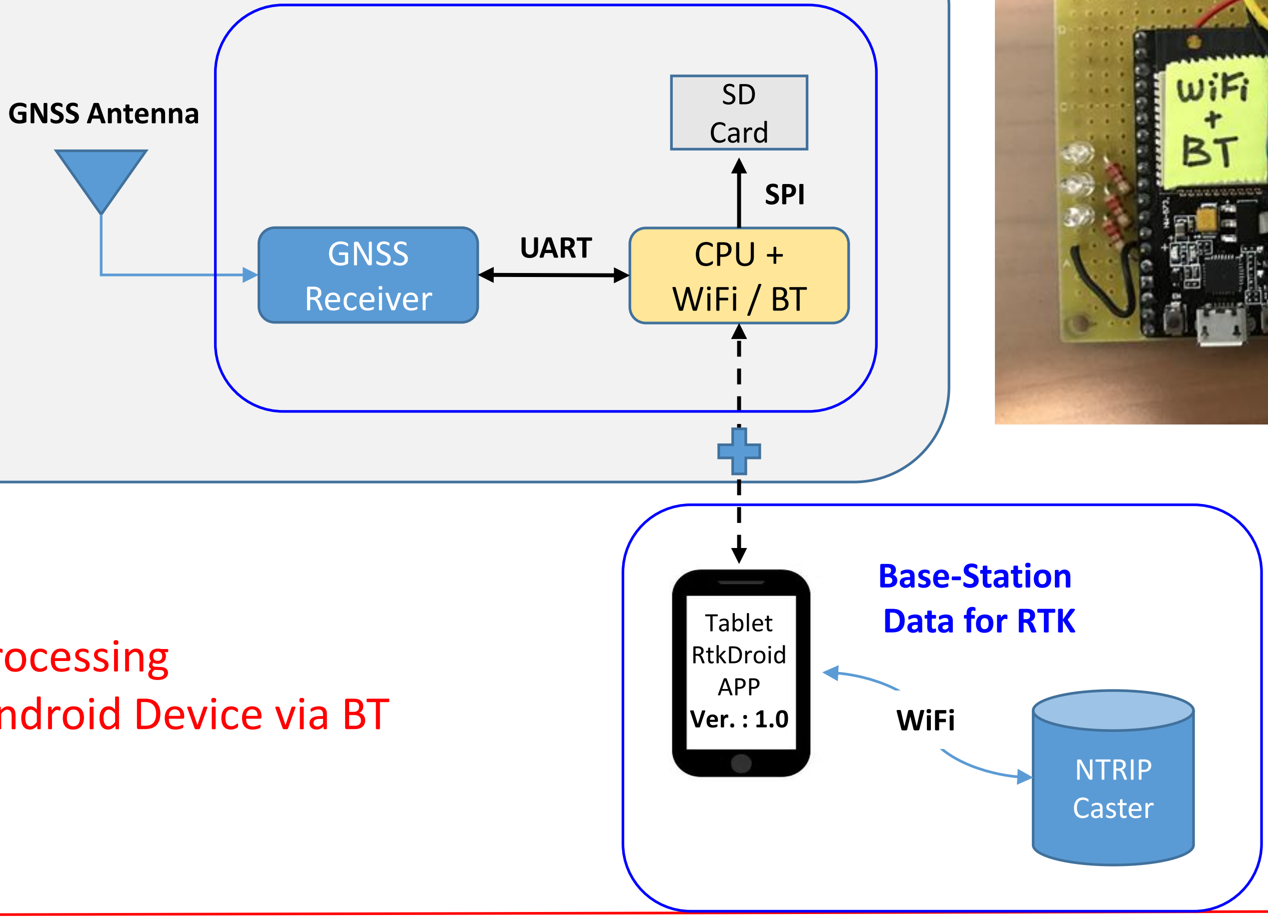


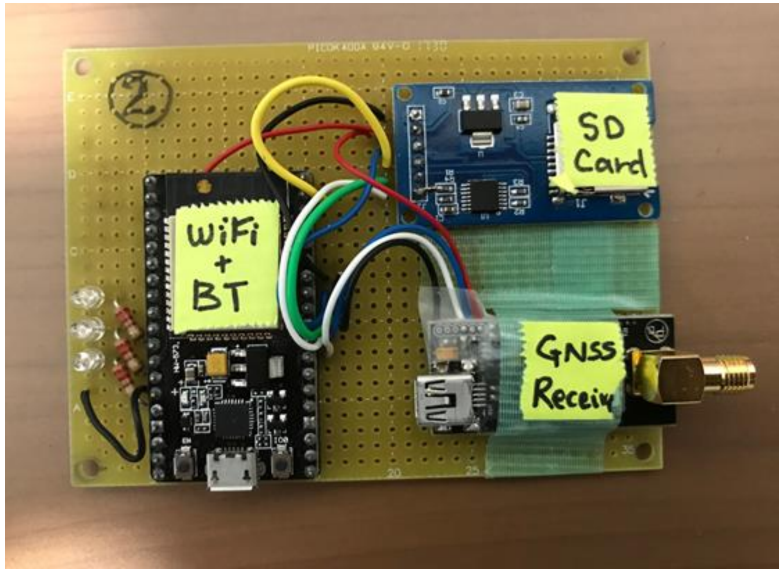
Type A1:
Rover Mode
Real-Time or/and Post-Processing RTK
Based on RTKLIB Engine
Real-time processing in Android Device
APP: RTKDroid

GNSS Receiver Module

Type – W1: GNSS Receiver + WiFi + BT

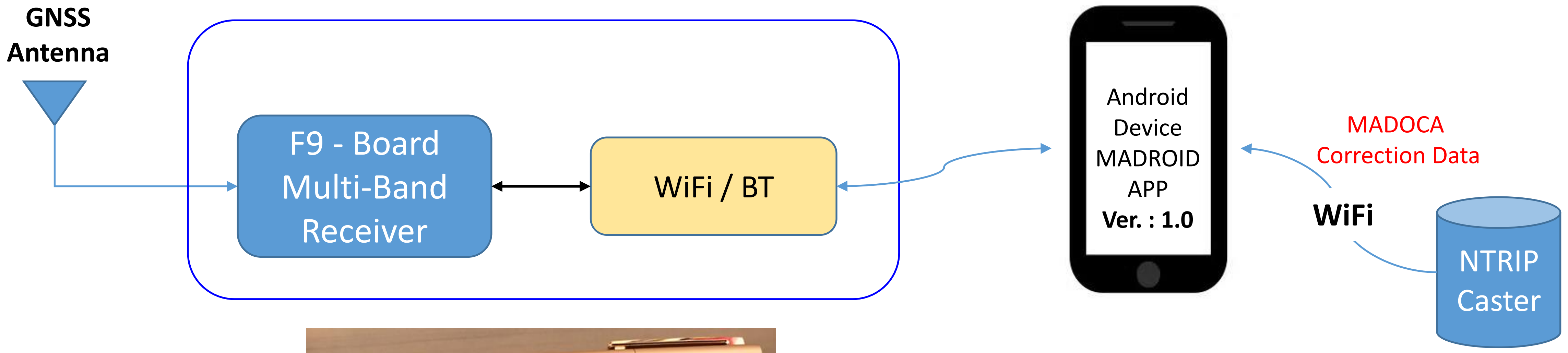
For Post-Processing
Just power-on the device
Data will be logged to SD Card



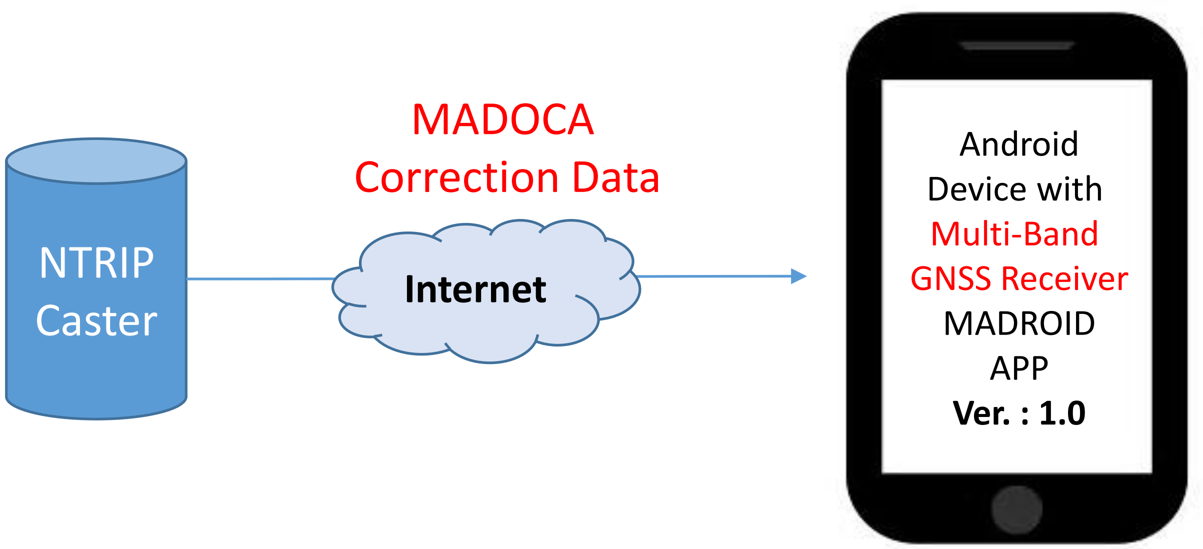


For Real-Time Processing
Connect to an Android Device via BT

Type - M1: MADOCA Network + Android Device + F9 Board (MAF)



Type - M3: MADOCA Network + Android Device (MA)



GNSS L1, L2, L5/E5
e. g. Xiomi Mi8