

Low-Cost High-Accuracy GNSS Receiver

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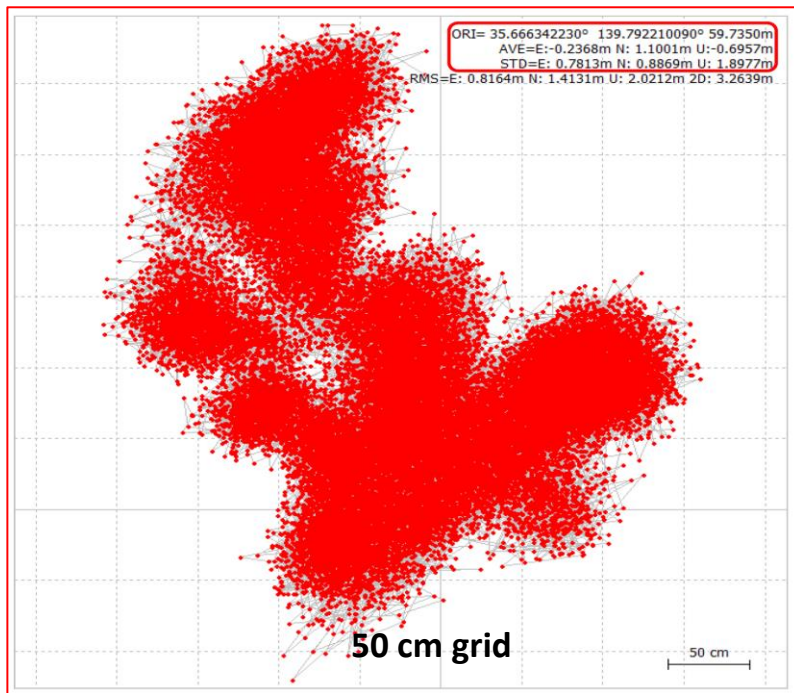
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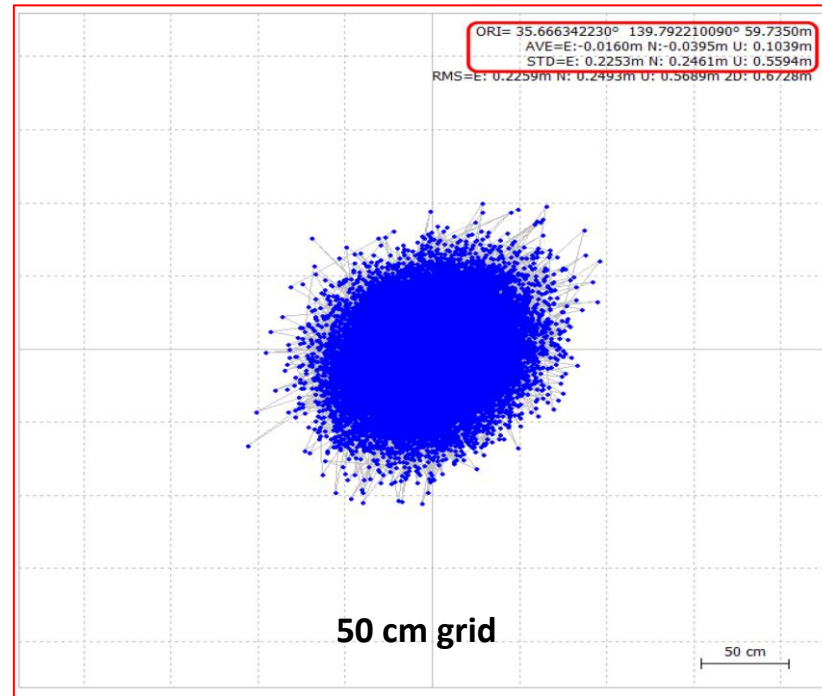
High Accuracy Receivers are Expensive

- High-Accuracy Survey Grade Receivers are multi-frequency and multi-system receivers
 - L1/L2/L5, G1/G2, B1/B2/B3 etc
 - GPS, GLONASS, GALILEO, 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

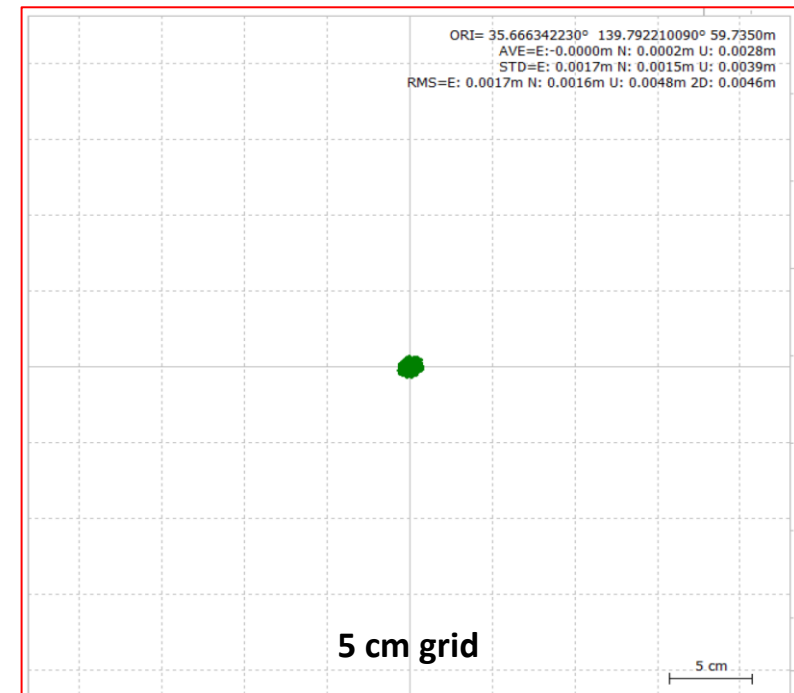
How accurate is GPS Position?



SPP (Single Point Position)



DGPS (Differential GPS)



RTK (Real Time Kinematic)

Errors in GPS Observation (L1C/A Signal)

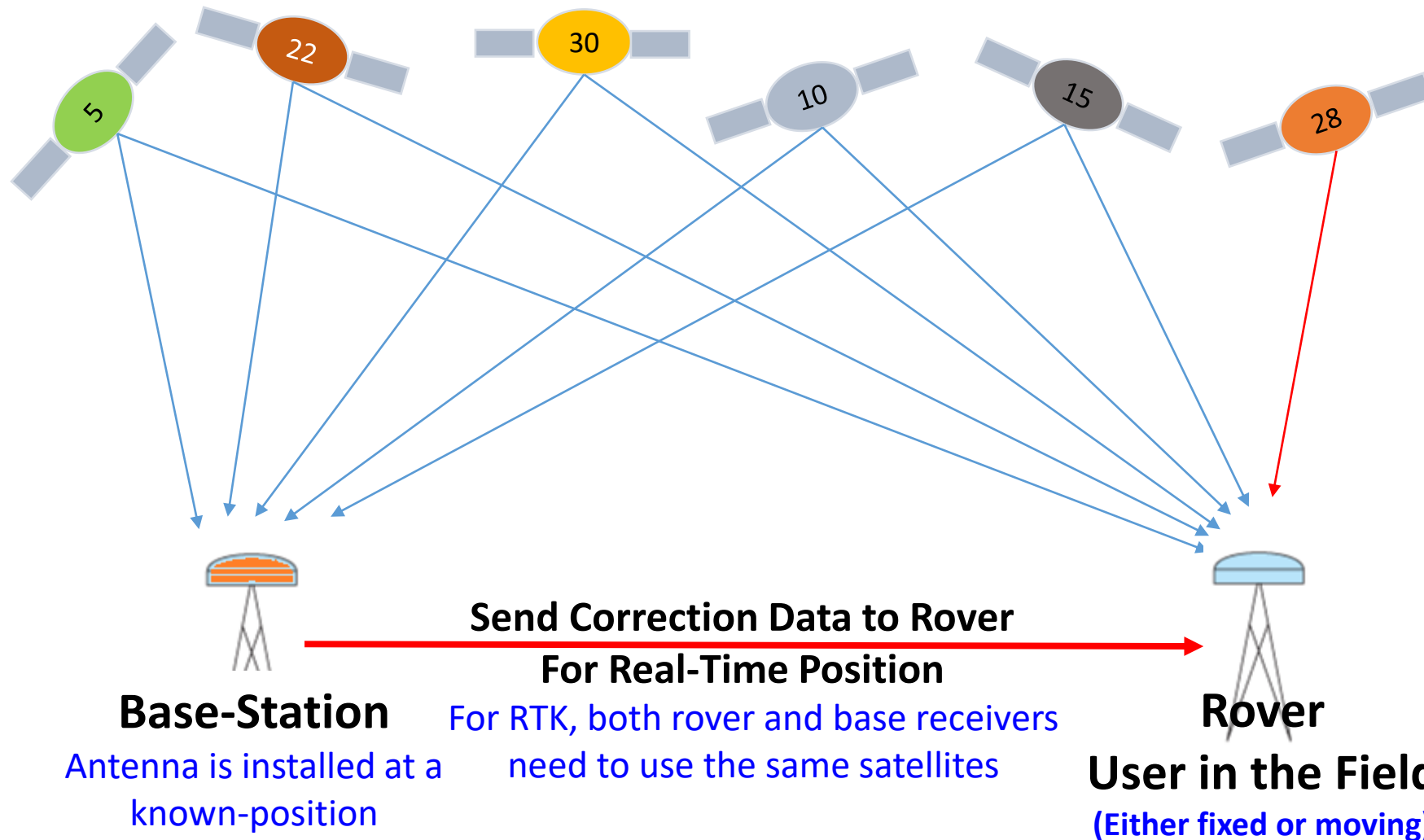
Error Sources	One-Sigma Error , m		Comments
	Total	DGPS	
Satellite Orbit	2.1	0.0	Common errors are removed
Satellite Clock	2.1	0.0	
Ionosphere Error	4.0	0.4	Common errors are reduced
Troposphere Error	0.7	0.2	
Multipath	1.4	1.4	
Receiver Circuits	0.5	0.5	

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

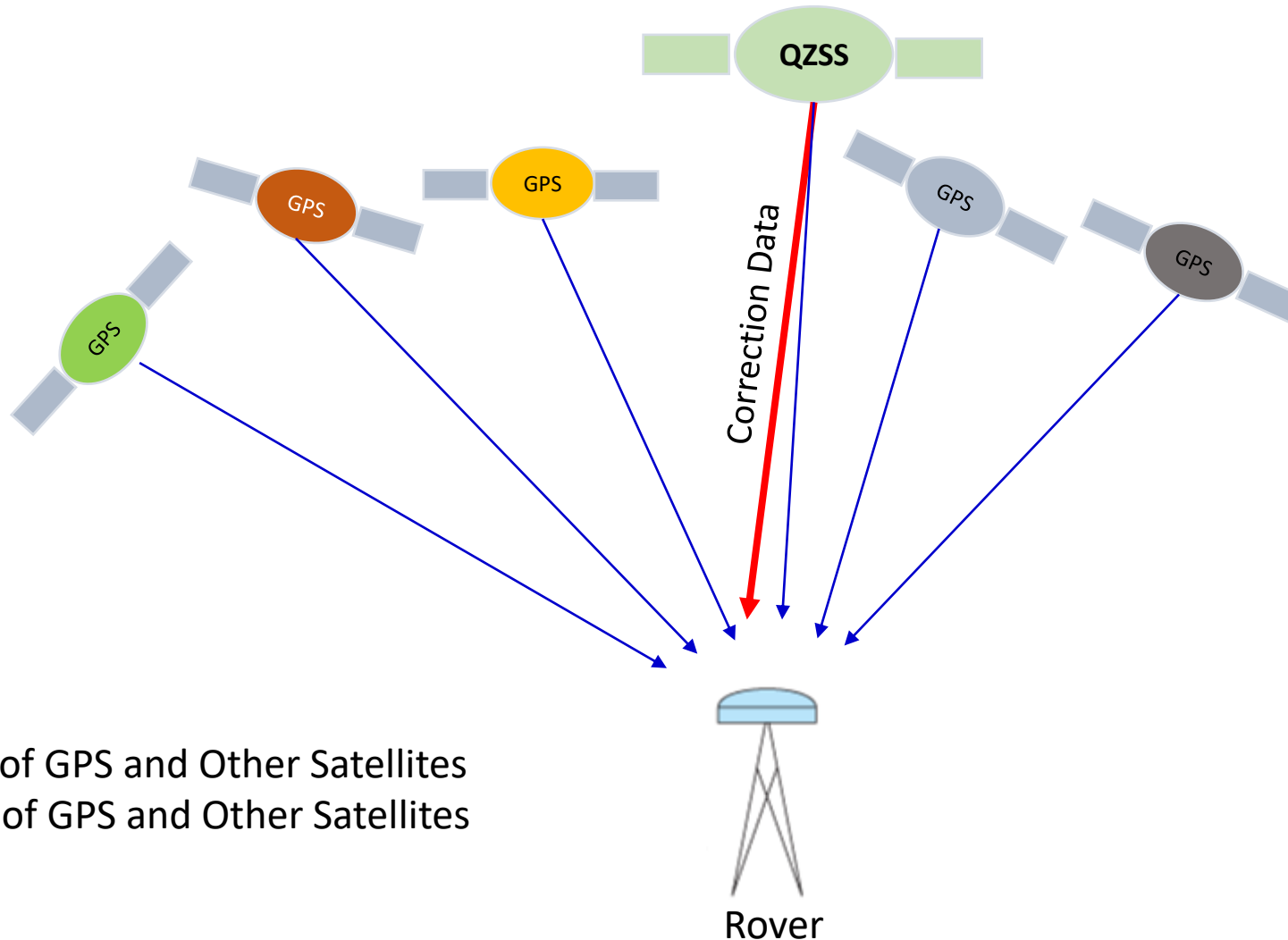
Common errors are: Satellite Orbit Errors, Clock Errors and Atmospheric Errors (within few km)

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

Principle of Differential Correction



Principle of QZSS MADOCA / CLAS Service

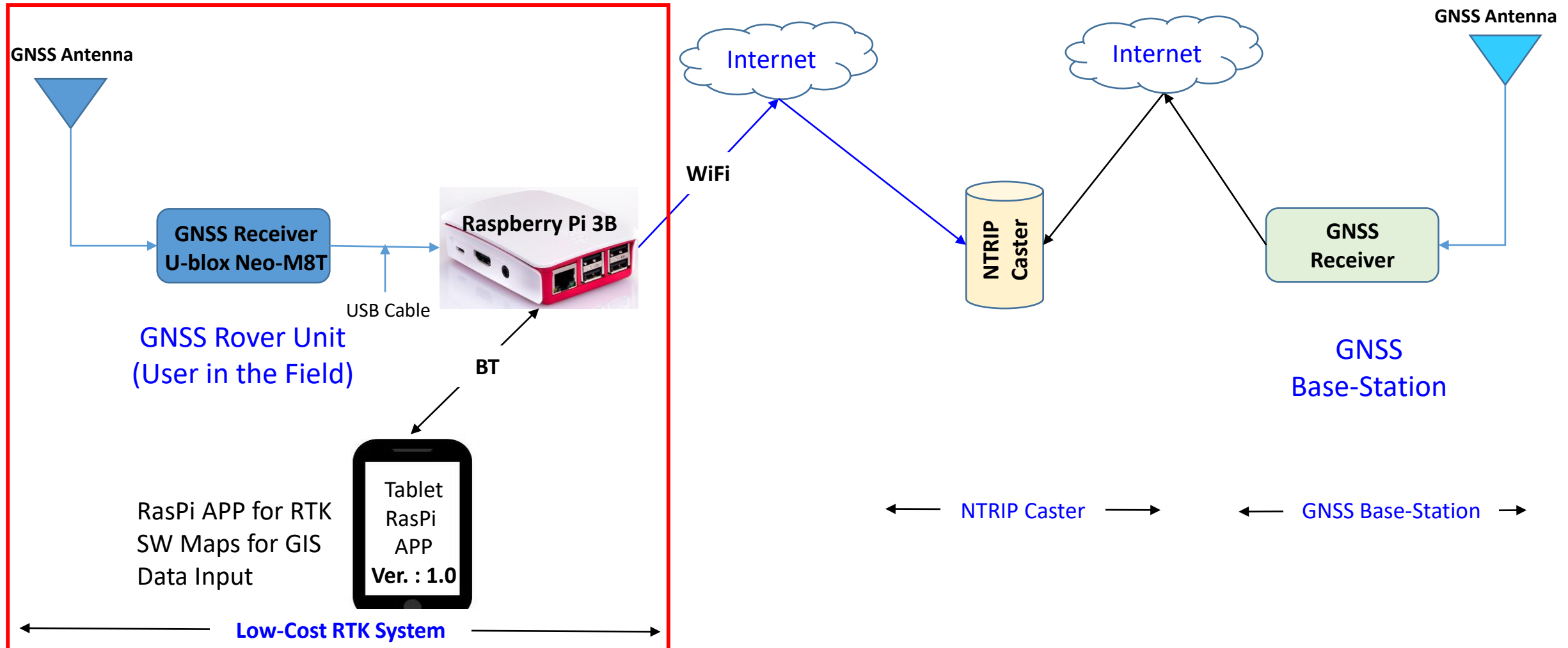


Correction Data:

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

The screenshot displays the RtkPi application interface, which is divided into several sections for configuring the RTK system. The interface is presented in a three-panel view, likely representing different stages of the setup process.

Left Panel (Base Station Configuration):

- Satellites:** Radio buttons for GPS + QZSS, **GPS + GLONASS + QZSS** (selected), and GPS + BEIDOU + QZSS.
- NTRIP Settings:**
 - Address: 202.xxx.xx.xx
 - Port: 5000
 - Mount Point: t1
 - Password: 1234
- Base Station Position:** Fields for Latitude, Longitude, and Elevation.

Middle Panel (Rover Mode Configuration):

- Rover Mode:** Radio buttons for **Autonomous** (selected) and RTK.
- Satellites:** Radio buttons for GPS + QZSS, **GPS + GLONASS + QZSS** (selected), and GPS + BEIDOU + QZSS.
- NTRIP Settings:**
 - Address: 153.121.59.53
 - Port: 2101
 - Mount Point: (empty)
 - Username: (empty)
 - Password: (empty)

Right Panel (Status and Sky Plot):

- Status:**
 - Latitude: 48.873416°
 - Longitude: 2.294480°
 - Elevation: 133.622m
 - Fix type: Autonomous
 - Satellites: 8
 - PDOP: 2.0
 - HDOP: 1.0
 - VDOP: 1.7
- Sky Plot:** A circular plot showing the positions of 8 satellites (labeled 3, 11, 14, 17, 19, 22, 23, 31) relative to the horizon. The plot includes a grid for azimuth (0° to 330°) and elevation (0° to 90°).
- Signal Strength Bar:** A bar chart showing signal strength for the 8 satellites, with values: 53, 49, 47, 49, 47, 52, 48, 45.
- Data Log:**
 - NMEA: 2017_07_27_22_58_48.nmea, Size: 24KB
 - UBX: 2017_07_27_22_58_48.ubx, Size: 95KB

Bottom Panel (Action Buttons):

- START BASE
- START ROVER
- STOP RECORDING

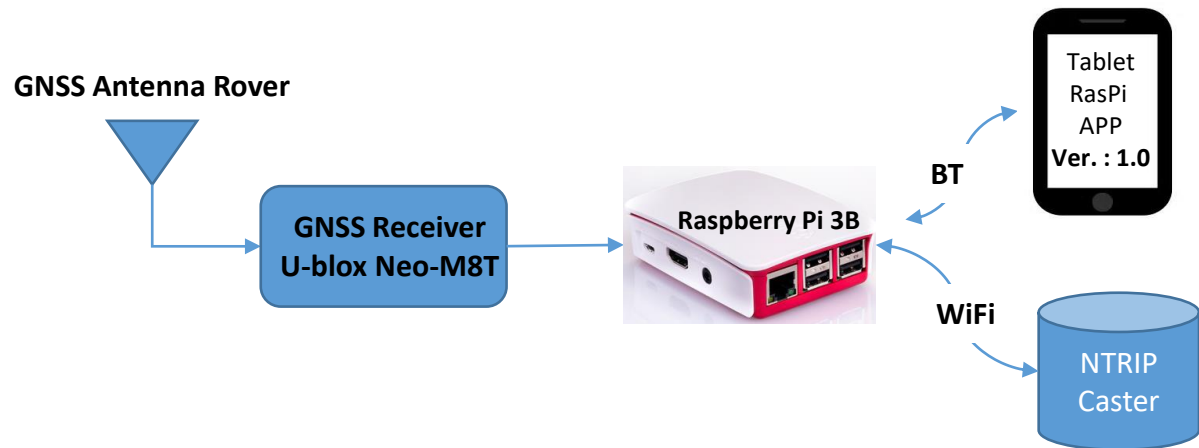
Board Computer for Low-Cost RTK System

Raspberry Pi 3B for
Realtime and Postprocessing RTK

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

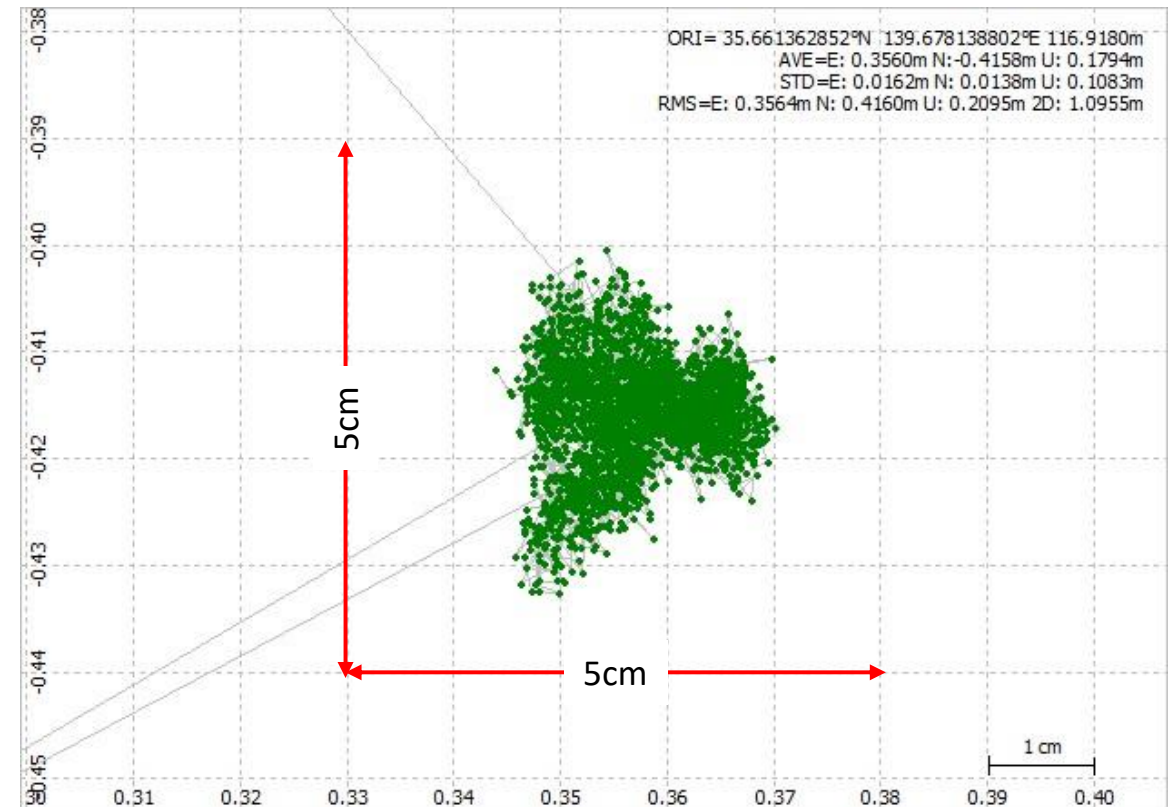


Accuracy from Low-Cost RTK System



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

2017_09_15_17_27_13.ubx - u-center 8.24 - [Messages - UBX - RXM (Receiver Manager) - RAWX (Multi-GNSS Raw Measurement Data)]

File Edit View Player Receiver Tools Window Help

UBX - RXM (Receiver Manager) - RAWX (Multi-GNSS Raw Measurement Data) 1 s

Local Time 1966:462474.993000000 [s]

Leap seconds 18 (VALID) [s] Clock reset

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

Speedometer 1: 0.00 m/s = 0.0 km/h

Speedometer 2: 118.400 m x100

Speedometer 3: 08:27:36 UTC

u-blox M No port of 2017 09 15 NME/00:00 08:27

Data from Low-Cost RTK System

2017_09_15_17_27_13.ubx - u-center 8.24 - [Messages - UBX - RXM (Receiver Manager) - SFRBX (Subframe Data NG)]

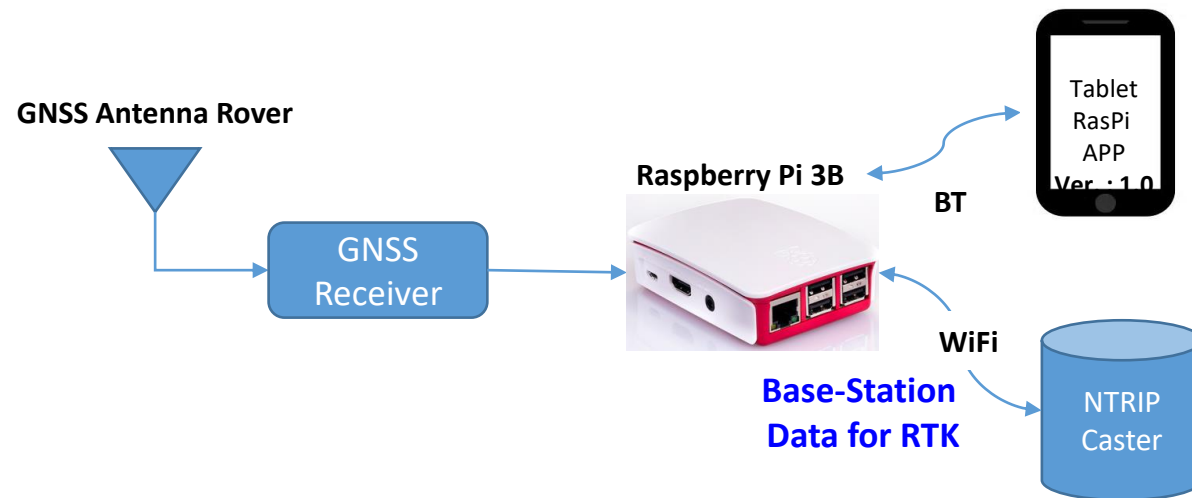
File Edit View Player Receiver Tools Window Help

UBX - RXM (Receiver Manager) - SFRBX (Subframe Data NG) 1 s

denotes data received on subChn Strip Parity Bits

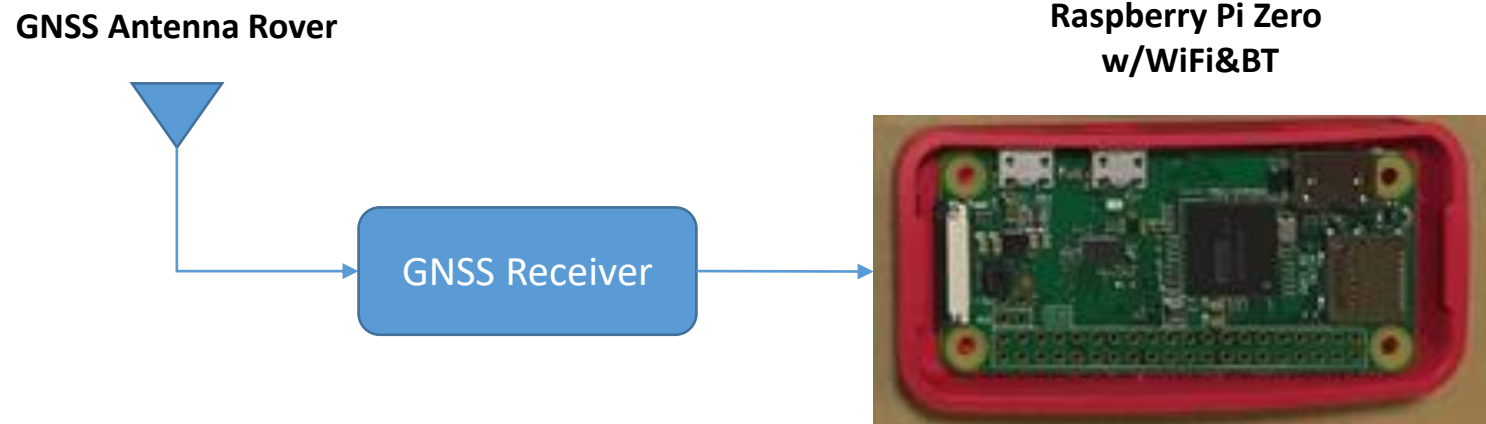
SV	MSG	DATA (* denotes invalid words)
GAL 3 E1B 0 E0	00955555	55555555 55555555 55555555 4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 5 E1B 0 E0	00955555	55555555 55555555 55555555 4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 9 E1B 0 E0	00955555	55555555 55555555 55555555 4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 22 E1B 0 E0	00955555	55555555 55555555 55555555 4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 24 E1B 0 E0	00955555	55555555 55555555 55555555 4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GLO 1 L1OF 1 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 2 L1OF -4 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 8 L1OF 6 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 9 L1OF -2 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 10 L1OF -7 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 11 L1OF 0 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 17 L1OF 4 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 23 L1OF 3 14	1/3156	752856E0 5D706C48 0A4B0000
GLO 24 L1OF 2 14	1/3156	752856E0 5D706C48 0A4B0000
GPS 2 L1C/A 0 2	22C3AE0B	25A34ABB 0E3D5BD5 8D7EF996 B00ED3CB 3DB44210 2EDCDC5A 8402E875 832C83CB 1C909F7C
GPS 5 L1C/A 0 2	22C3AE0B	25A34ABB 033FF65A 8CE7D348 36E920B1 BFF58087 2A4E4660 05792861 831E5F97 1C9093EC
GPS 6 L1C/A 0 2	22C3AE0B	25A34ABB 183CCB64 0BCFF6F7 37D36E26 BD394002 925E8E14 0437A870 037FF228 1C909F2F
GPS 7 L1C/A 0 2	22C3AE0B	25A34ABB 03404DD3 0C196F58 02CFB2D9 802A4174 2A8FDAF4 0523E852 83729150 1C909478
GPS 13 L1C/A 0 2	22C3AE0B	25A34ABB 06002439 8CA2FB8A AD89E7F6 8014C070 328B1F03 03482848 034D7BCA 9C909FF0
GPS 15 L1C/A 0 2	22C3AE0B	25A34ABB 17C07442 8F35037A B9639CDC 0075C135 B9BD06FE 82EBE859 8336425B 1C909F2F
GPS 20 L1C/A 0 2	22C3AE0B	25A34ABB 0A800B59 8E01C218 21702E31 801D0098 149C0D26 8576A85D 8378DEDF 1C909F7C
GPS 29 L1C/A 0 2	22C3AE0B	25A34ABB 01BF15E0 0BDAD92A ADA76857 3F1E8029 90F5C377 01A96847 03220618 1C909478
GPS 30 L1C/A 0 2	22C3AE0B	25A34ABB 0A805139 8D0B6F0B 01C4A960 00238048 246C1FD9 85416853 0343752B 1C909F2F
QZSS 1 L1C/A 0 2	22C0AA24	25A34254 10494F43 067A62DE 8A7BAAB5 84AB49A3 1D0554C4 0AF1F2AF 3BC08DFD 9C585FC7
QZSS 1 L1SAIF 0 50	53CAC767	E0000070 31027FDD FD8FD8FE 502F0000 00000000 00000000 3294C0A6
QZSS 2 L1C/A 0 2	22C0AA81	A5A3524F 107D9E77 037ECC21 BCA9FE77 3F294966 B57BC11D 879B728F 3B22D081 9C585F94
QZSS 2 L1SAIF 0 50	53CAC767	E0000070 31027FDD FD8FD8FE 502F0000 00000000 00000000 3294C0A6
SBAS 128 L1C/A 0 3	530D9FFF	FF9FFDFF C011FFC0 00001FFD FFC007FF 7FF797B9 B95BBA16 B71493A6
SBAS 129 L1C/A 0 25	536611C7	EBFDC05F EC7FFE81 7F9DBA80 00000000 00000000 00000000 0D6D0226
SBAS 137 L1C/A 0 25	536611C7	EBFDC05F EC7FFE81 7F9DBA80 00000000 00000000 00000000 0D6D0226

Type – R1: GNSS Receiver with RaspberryPi-3



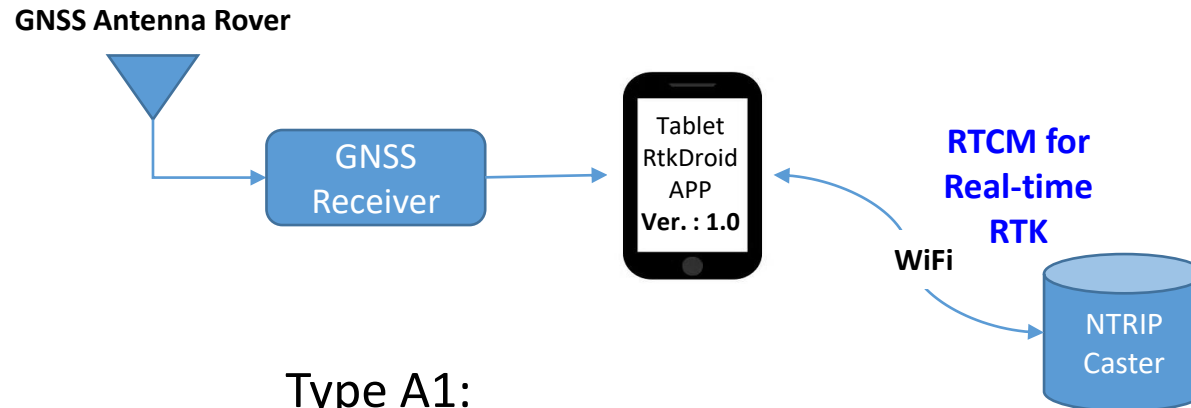
Type R1:
Base or Rover Mode
Real-Time and Post-Processing RTK
Based on RTKLIB Engine

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



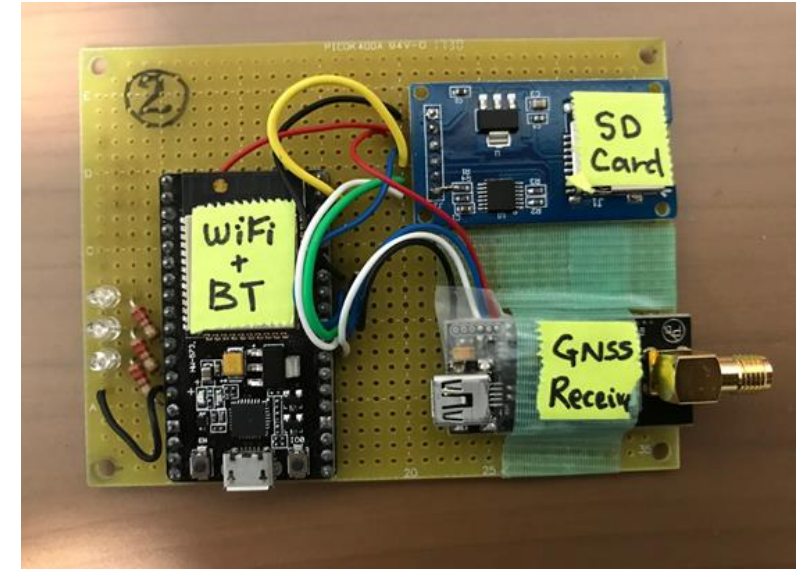
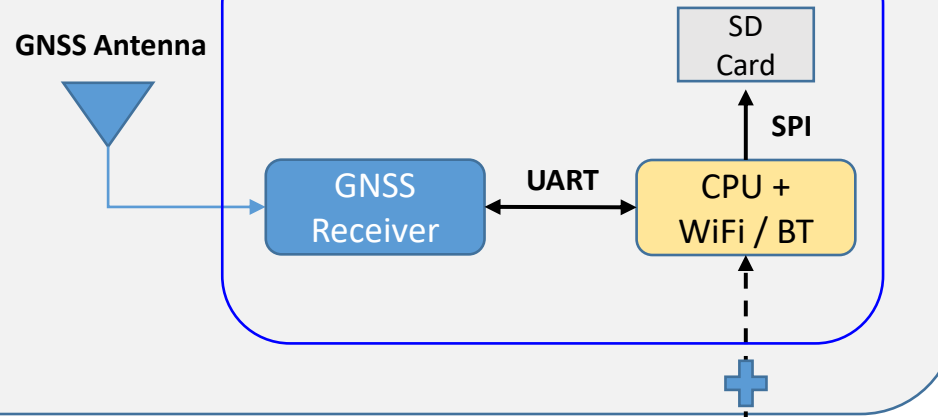
Type A1:
Rover Mode
Real-Time or/and Post-Processing RTK
Based on RTKLIB Engine
Real-time processing in Android Device
APP: RTKDroid



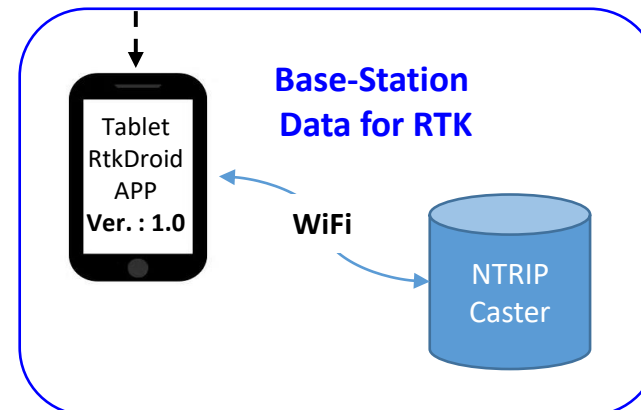
GNSS Receiver Module

Type – W1: GNSS Receiver + WiFi + BT

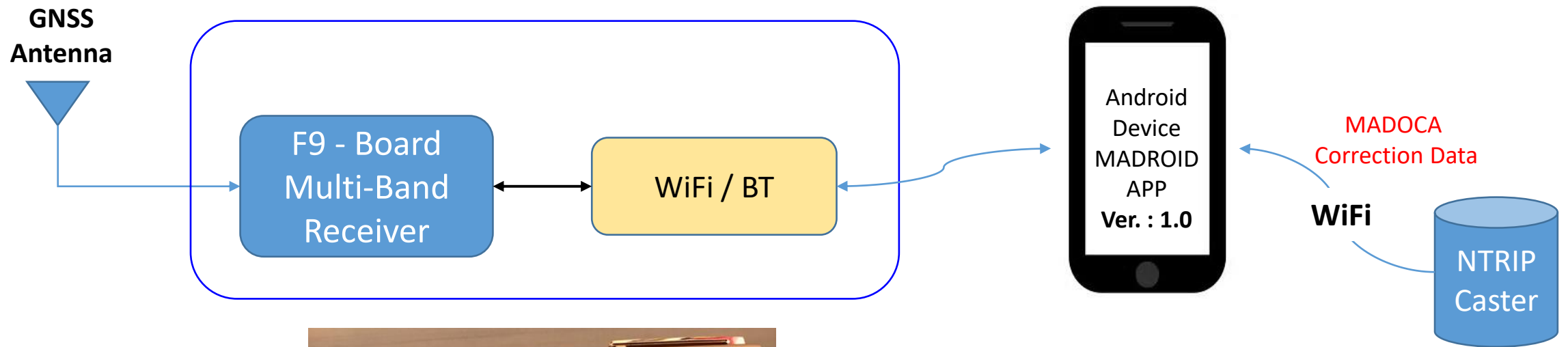
For Post-Processing
Just power-on the device
Data will be logged to SD Card



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)

