

GNSS Low-Cost High-Accuracy Receiver (L-CHAR)

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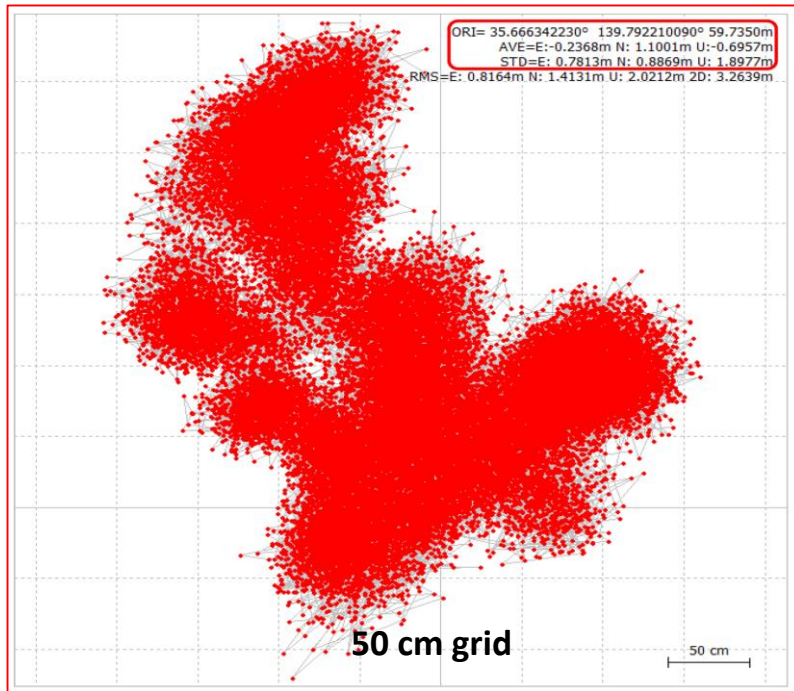
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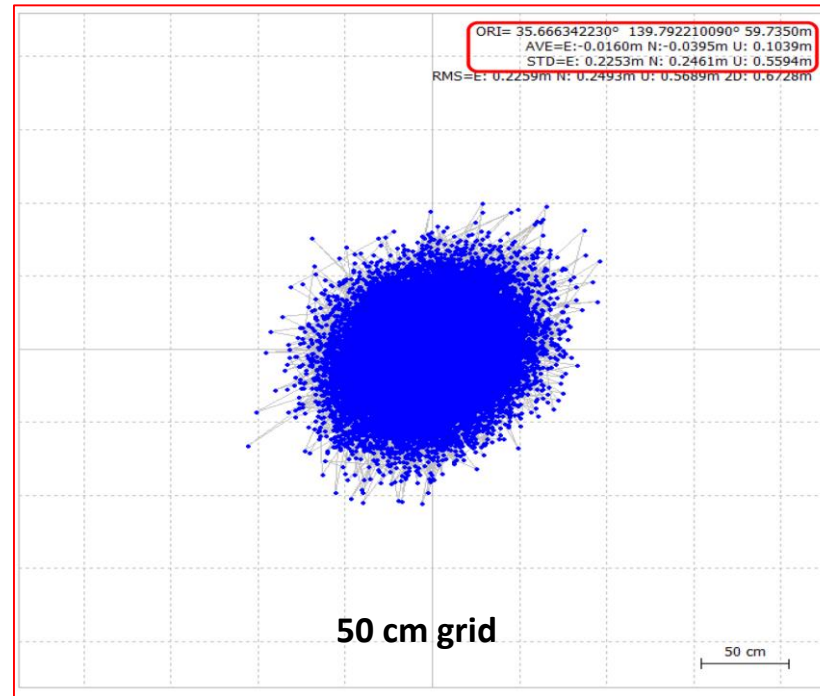
High Accuracy Receivers are Expensive

- 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 \$3, 000 to \$30,000 or more.
- However, Low Cost Receivers are also capable of
 - Multi-System: GPS, GLONASS, GALILEO, BeiDou, QZSS, SBAS etc
 - Basically only in L1-Band Frequency
 - Low Cost: \$300 (Multi-GNSS, L1 Only)
 - Very soon: Multi-System, Multi Frequency, L1/L2/L5
 - Broadcom, u-Blox and ST Micro already announced Multi-System, Multi-Band GNSS Chips for Mass Market

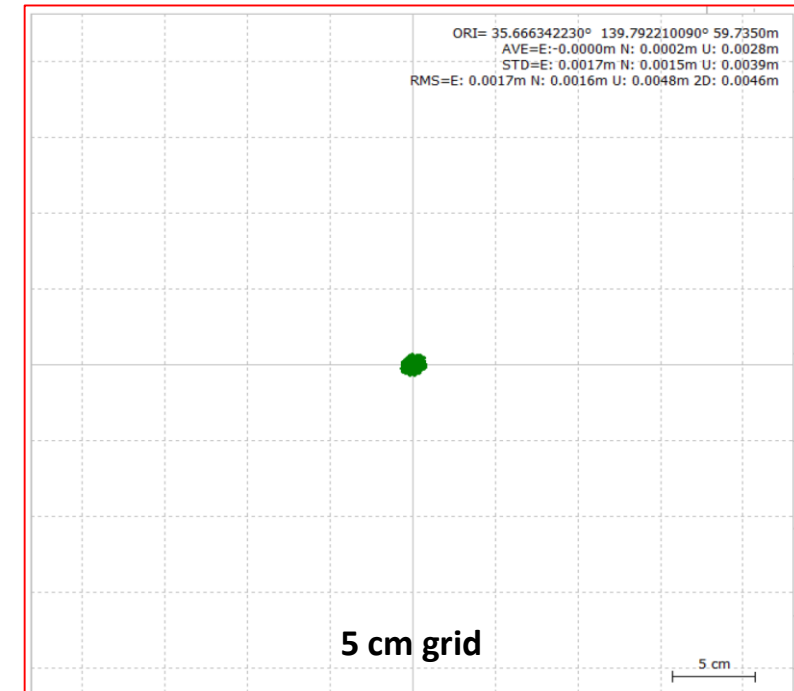
How accurate is GPS Position?



SPP (Single Point Position)



DGPS (Differential GPS)



RTK (Real Time Kinematic)

Errors in GPS Observation (L1C/A Signal)

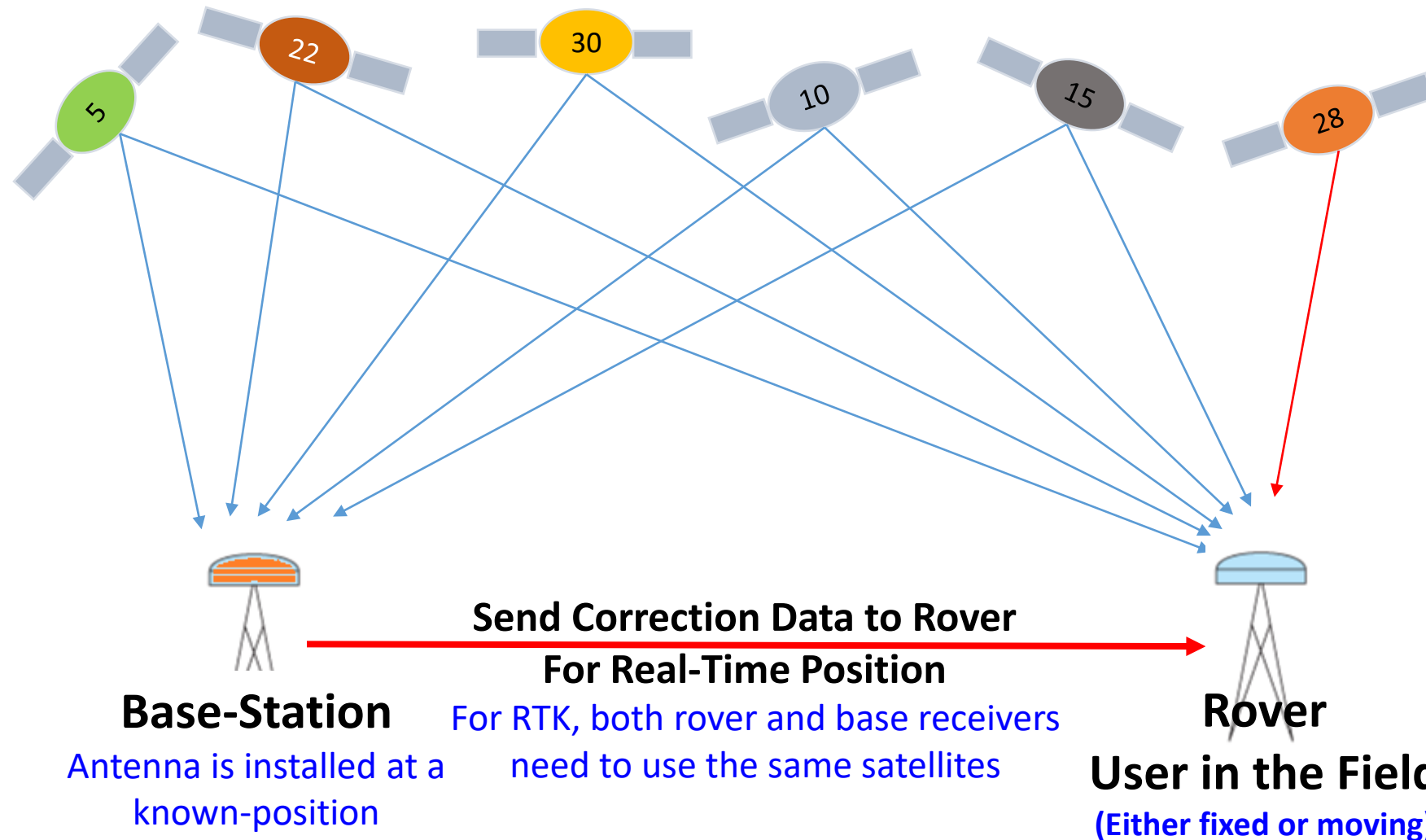
Error Sources	One-Sigma Error , m		Comments
	Total	DGPS	
Satellite Orbit	2.1	0.0	Common errors are removed
Satellite Clock	2.1	0.0	
Ionosphere Error	4.0	0.4	Common errors are reduced
Troposphere Error	0.7	0.2	
Multipath	1.4	1.4	
Receiver Circuits	0.5	0.5	

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

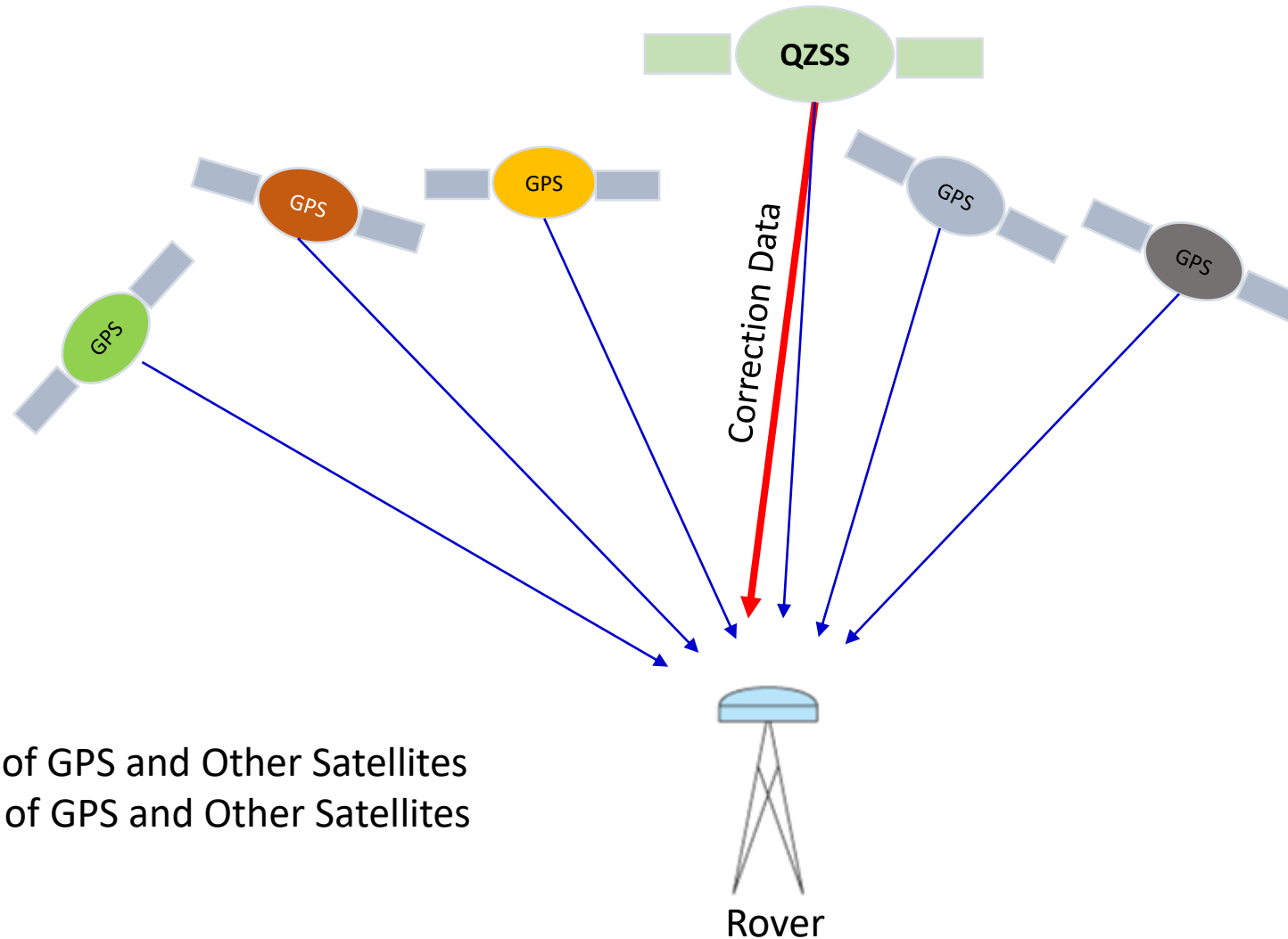
Common errors are: Satellite Orbit Errors, Clock Errors and Atmospheric Errors (within few km)

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

Principle of Differential Correction



Principle of QZSS MADOCA / CLAS Service

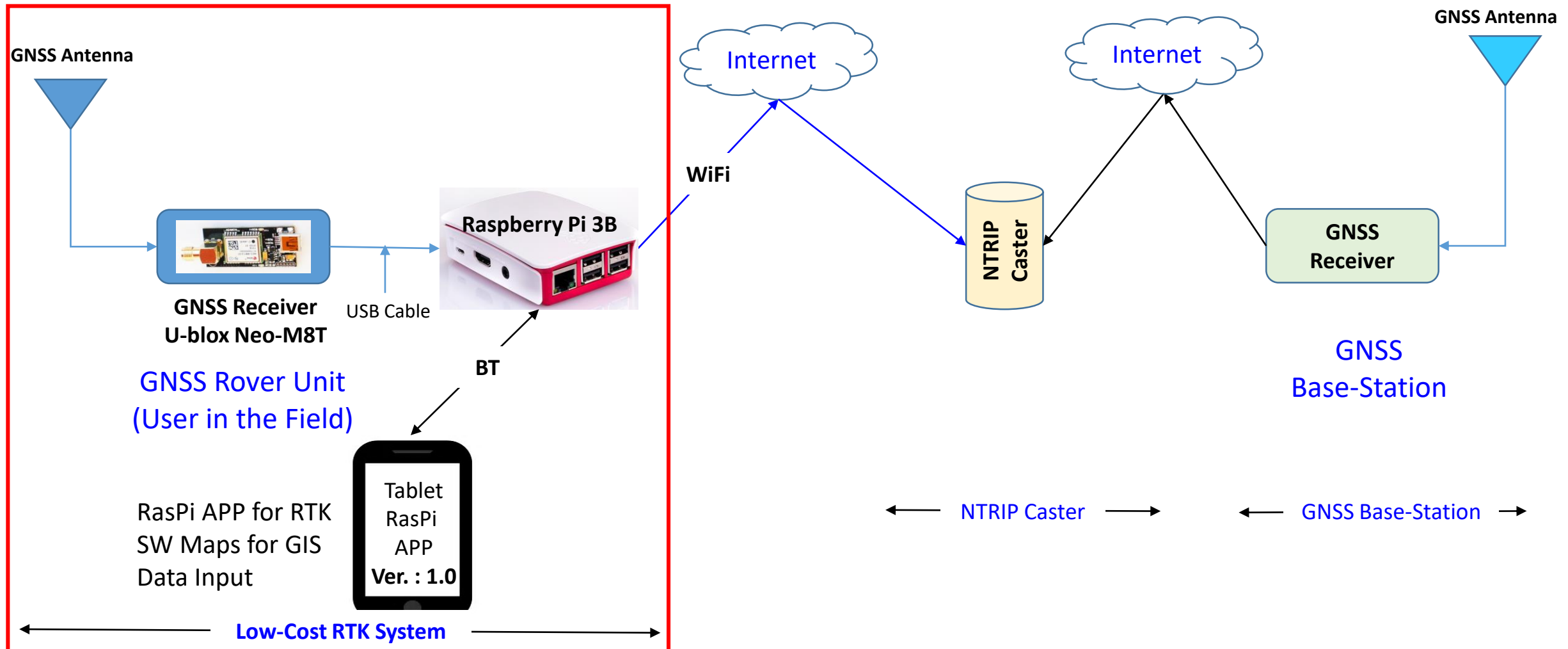


Correction Data:

Satellite Orbit Error of GPS and Other Satellites

Satellite Clock Error of GPS and Other Satellites

Low-Cost High Accuracy System



RTK-Pi 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-pane view, with the left pane showing satellite and NTRIP settings, the middle pane showing rover mode and NTRIP settings, and the right pane showing a signal strength diagram and data logs.

Satellites: The left pane shows three radio button options: GPS + QZSS, GPS + GLONASS + QZSS, and GPS + BEIDOU + QZSS.

NTRIP Settings: The left pane shows the NTRIP Address set to `202.xxx.xx.xx`, Port set to `5000`, Mount Point set to `t1`, and Password set to `1234`.

Base Station Position: The left pane shows fields for Latitude, Longitude, and Elevation, which are currently empty.

Rover Mode: The middle pane shows three radio button options: Autonomous, RTK, and NTRIP.

Satellites: The middle pane shows three radio button options: GPS + QZSS, GPS + GLONASS + QZSS, and GPS + BEIDOU + QZSS.

NTRIP Settings: The middle pane shows the NTRIP Address set to `153.121.59.53`, Port set to `2101`, and fields for Mount Point, Username, and Password, which are currently empty.

Signal Strength Diagram: The right pane shows a circular signal strength diagram with a grid of concentric circles and radial lines. The diagram is labeled with cardinal directions (N, S, E, W) and angles (30°, 45°, 60°, 75°, 90°, 105°, 120°, 135°, 150°, 165°, 180°, 195°, 210°, 225°, 240°, 255°, 270°, 285°, 300°, 315°, 330°). The diagram shows several green dots representing signal strength measurements, with labels 3, 11, 14, 17, 19, 22, 23, 31, 11, 14, 17, 19, 22, 23, 31, 11, 14, 17, 19, 22, 23, 31.

Data Logs: The right pane shows a bar chart with eight bars, each labeled with a number (3, 11, 14, 17, 19, 22, 23, 31). Below the chart, the data logs are displayed: `NMEA: 2017_07_27_22_58_48.nmea, Size: 24KB` and `UBX: 2017_07_27_22_58_48.ubx, Size: 95KB`.

Buttons: The bottom of the interface features three buttons: `START BASE`, `START ROVER`, and `STOP RECORDING`.

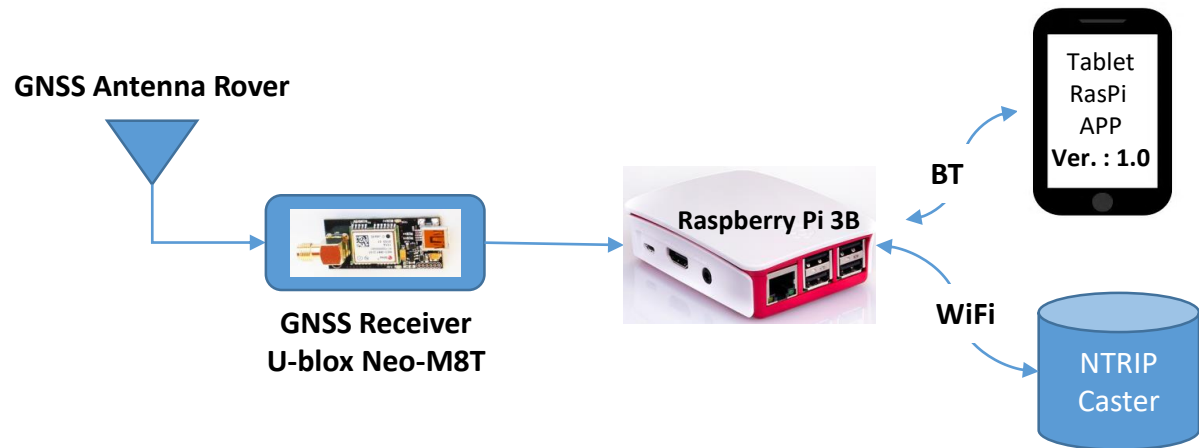
Board Computer for Low-Cost RTK System

**Raspberry Pi 3B for
Realtime and Postprocessing RTK**

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

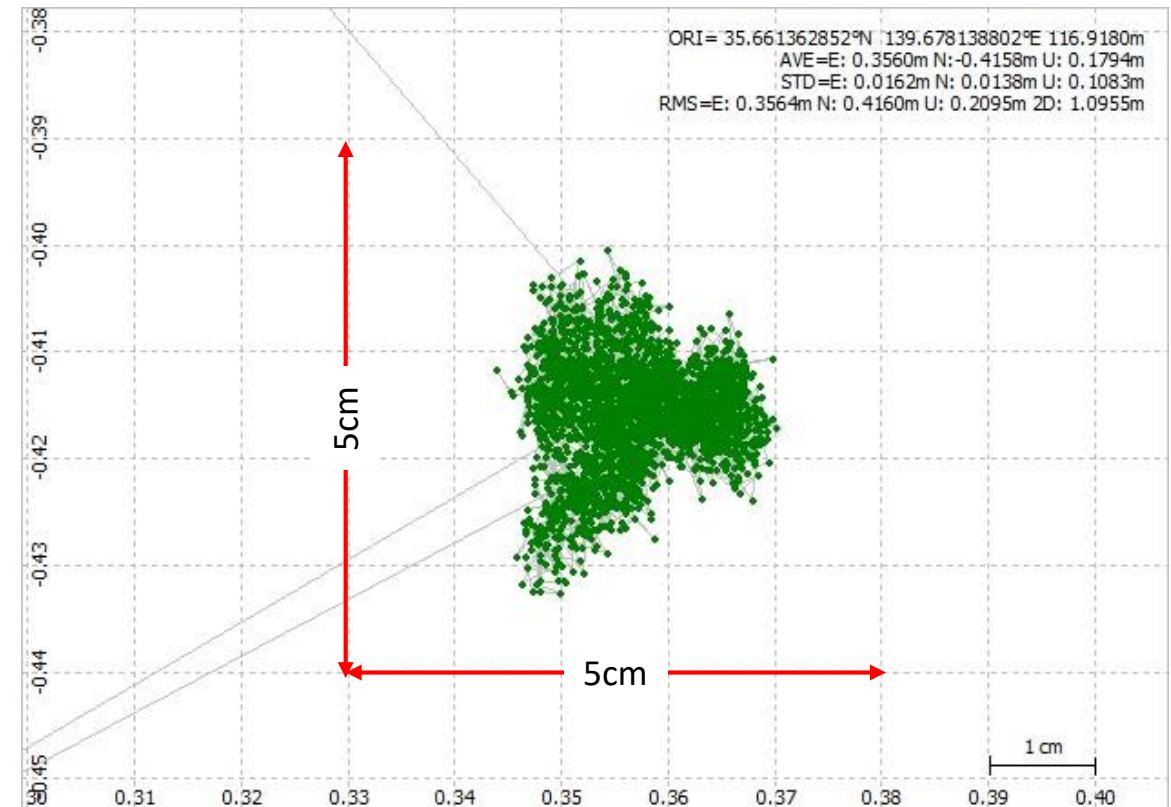


Accuracy from Low-Cost RTK System



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	Y...
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	Y...
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...

Ready

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

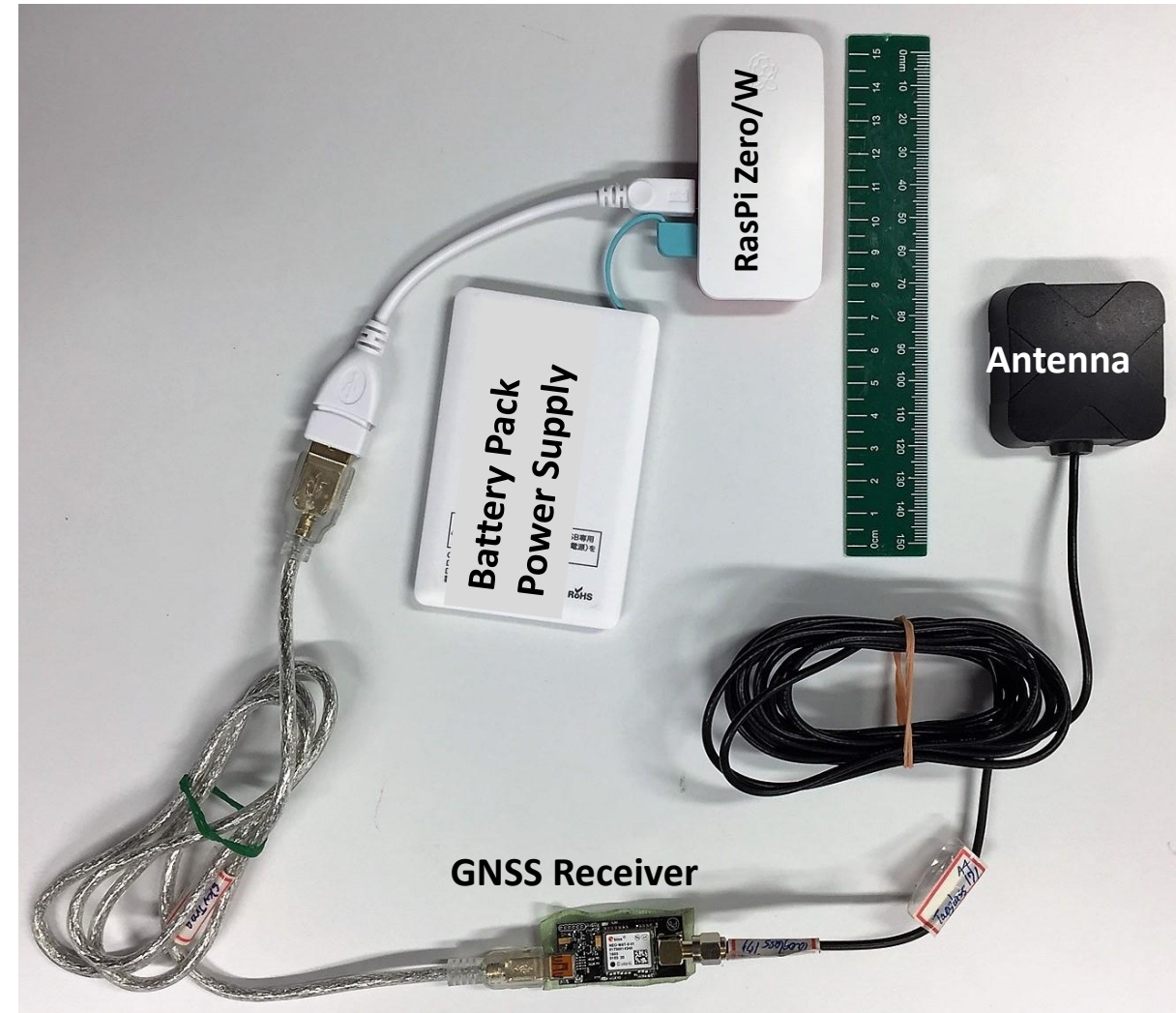
UBX - RXM (Receiver Manager) - SFRBX (Subframe Data NG) 1 s

denotes data received on subChn Strip Parity Bits

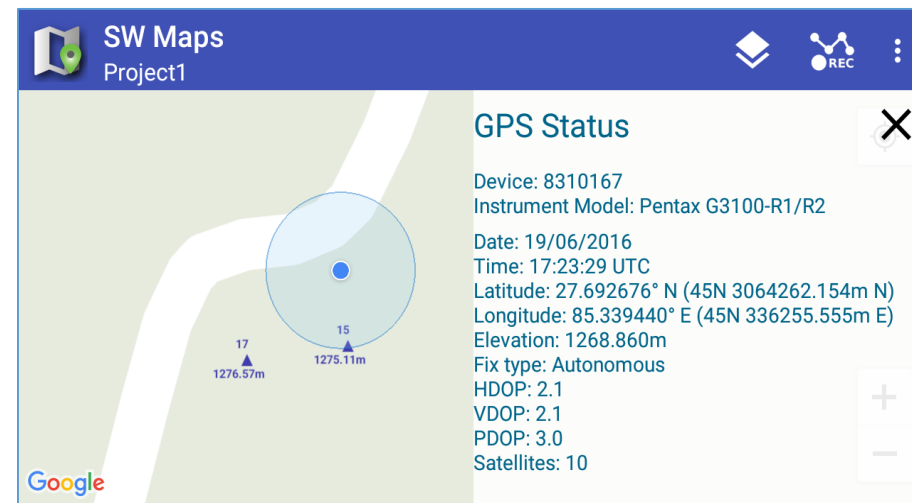
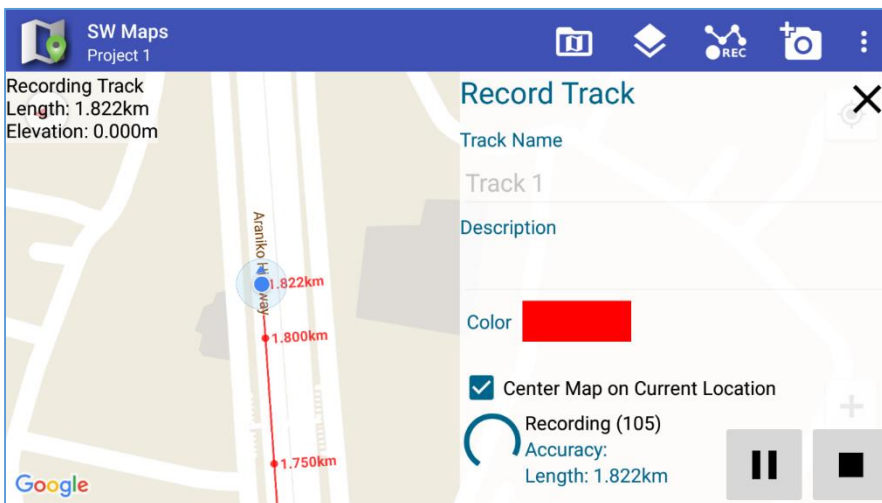
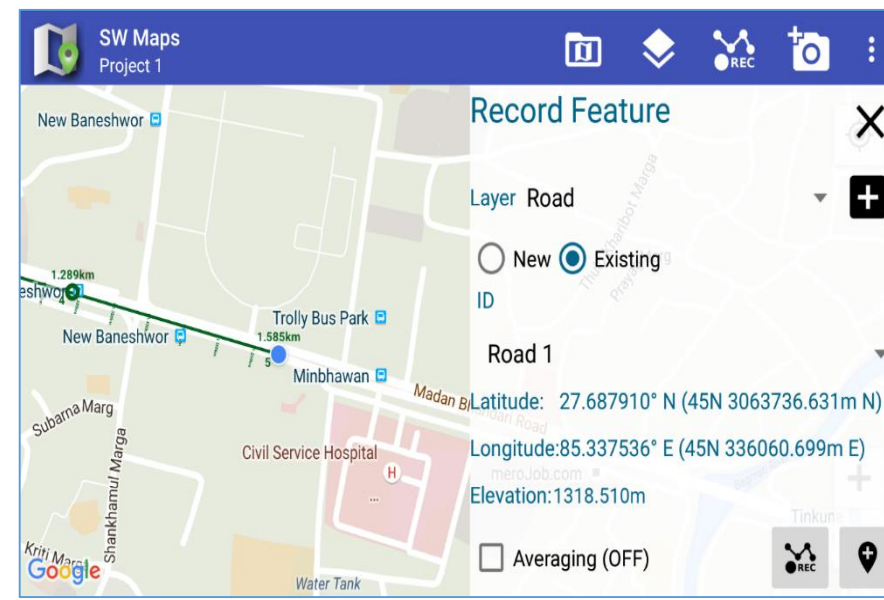
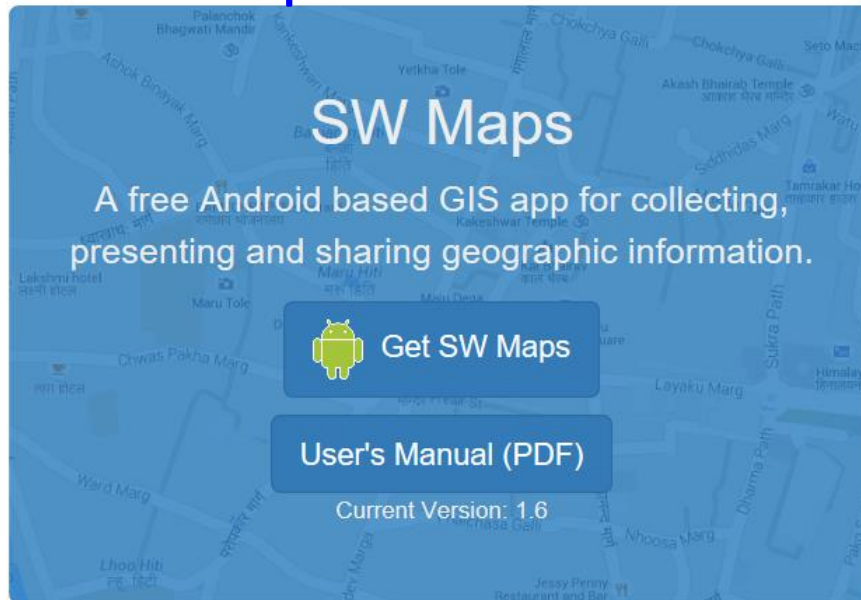
SV	MSG	DATA (* denotes invalid words)
GAL 3 E1B 0 E0	00955555 55555555 55555555	4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 5 E1B 0 E0	00955555 55555555 55555555	4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 9 E1B 0 E0	00955555 55555555 55555555	4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 22 E1B 0 E0	00955555 55555555 55555555	4EB9C000 83A74000 0000002A AAAA632E 87BF4000
GAL 24 E1B 0 E0	00955555 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

Simple to Use, Low-Cost System

Simple to Use, No Commands, Just One Time Setting
Connect Antenna, Receiver and Battery Pack
Device Starts Logging GNSS Raw Data required for RTK Post-Processing



SW Maps APP to Integrate GPS Data into GIS



Conclusion

- Accuracy better than few tens of centimeters using Low-Cost Receiver in RTK mode is possible.
 - Both Base and Rover with Low-Cost Receiver
 - Smaller base length, < 10km
- Accuracy better than few centimeters using Low-Cost Receiver in RTK mode is possible.
 - Base with High-End Receiver and Low-Cost Receiver
 - Smaller base length, < 5km
- Our Target of Low-Cost High-Accuracy Receiver
 - \$100x100cmx100gm (Cost- Accuracy-Weight)

Additional Information

Please visit website at

<http://www.csis.u-tokyo.ac.jp/~dinesh/>

Or Contact:

dinesh@csis.u-tokyo.ac.jp

Sample Raw Data can be downloaded to Check Accuracy of RTK Processing

1. High-End Base (NetR9) Data vs Low-End Rover (u-blox M8T) Data
2. Low-End Base (u-blox M8T) Data vs Low-End Rover (u-Blox M8T) Data