



# Low-Cost High-Accuracy Receiver for Education, Training and GIS Data Collection

**Dinesh Manandhar** 

Center for Spatial Information Science

The University of Tokyo

Contact Information: <u>dinesh@iis.u-tokyo.ac.jp</u>





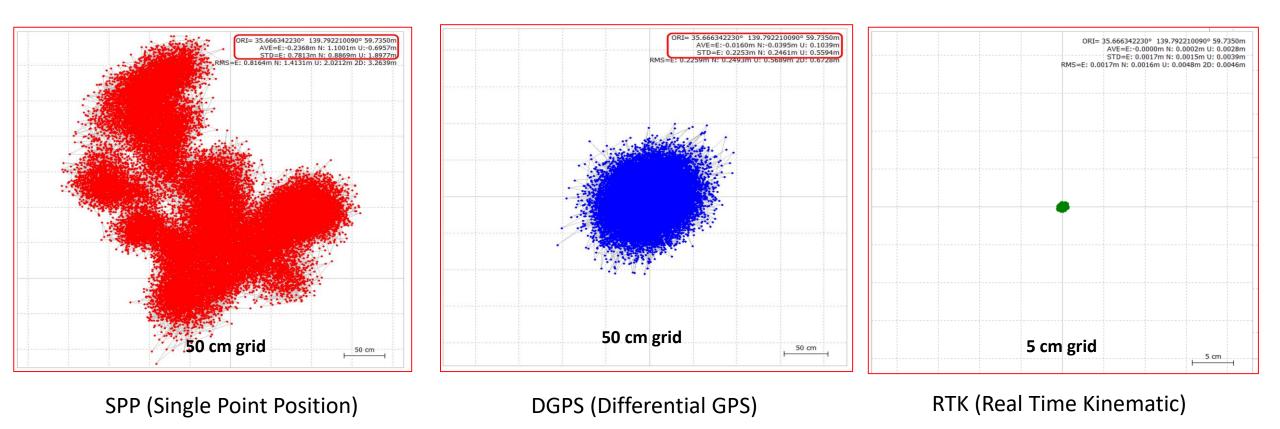
### High Accuracy Receivers are Expensive

- 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 \$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?







### Errors in GPS Observation (L1C/A Signal)

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

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

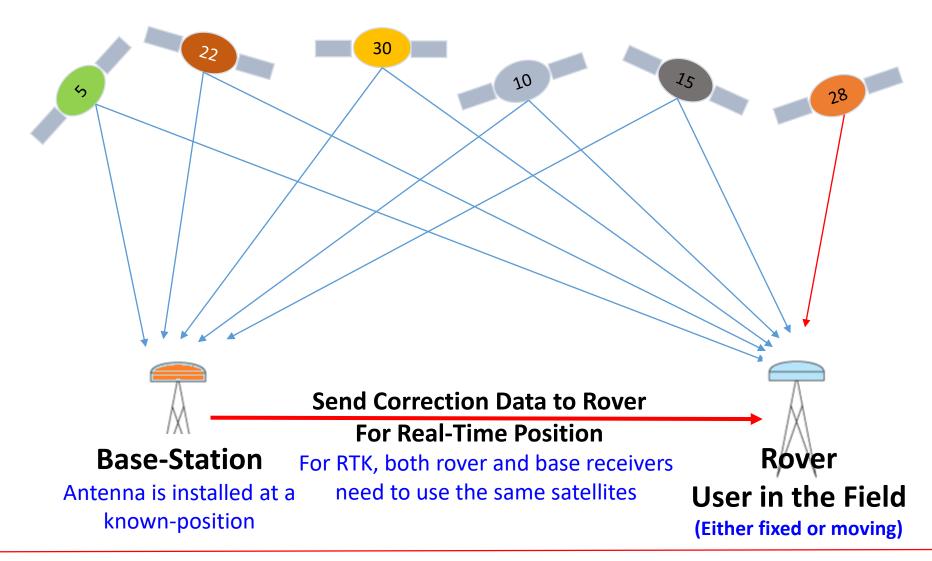
#### Common errors are: Satellite Orbit Errors, Clock Errors and Atmospheric Errors (within few km)

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





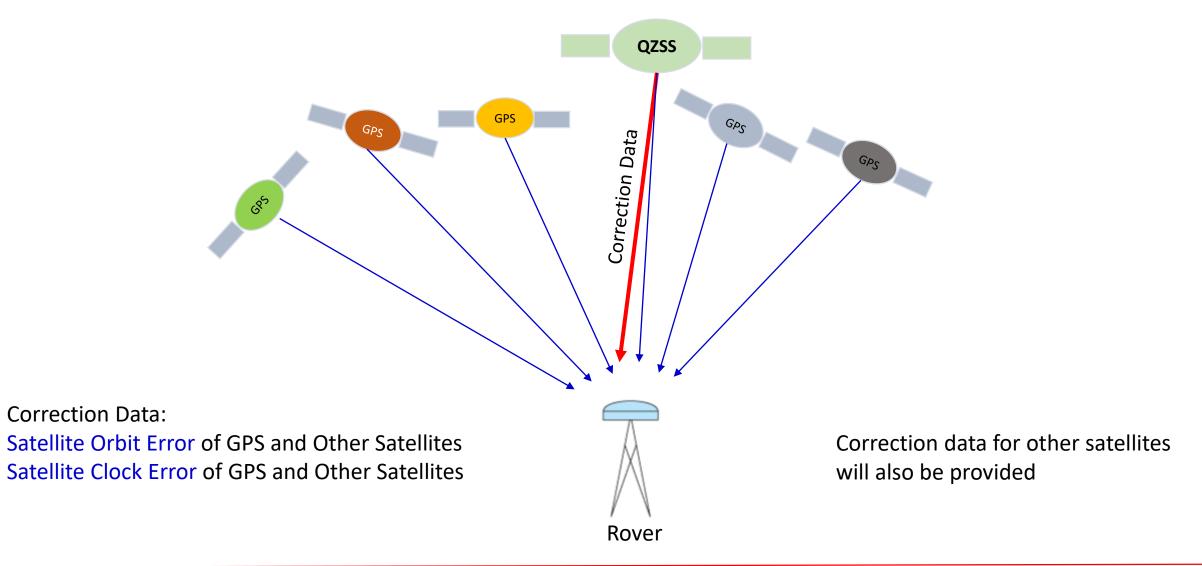
#### Principle of Differential Correction







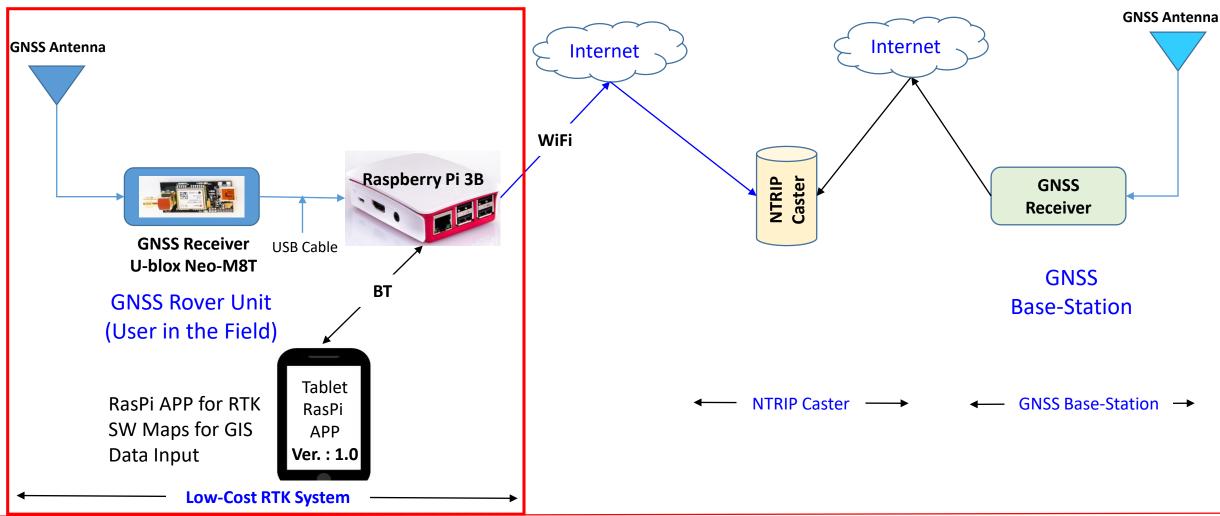
#### Principle of QZSS MADOCA and CLAS Services







### Low-Cost High Accuracy System







### RTK-Pi APP for Low-Cost RTK System

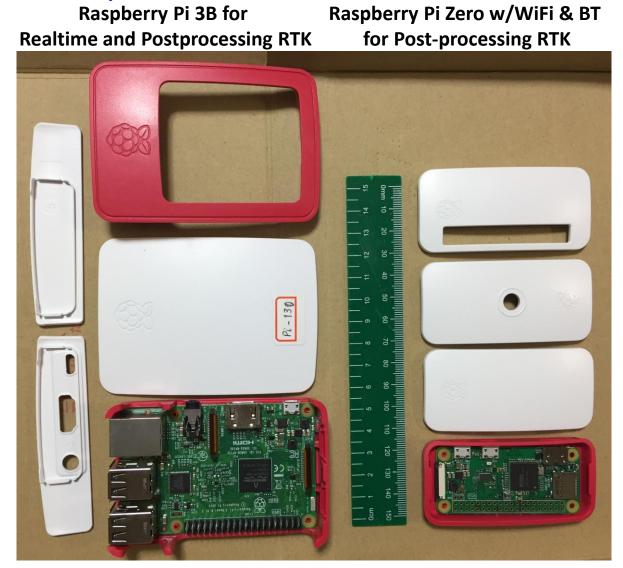
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RtkPi			RtkPi		1	RtkPi			C
CONNECTION	STATUS	SETUP BASE	CONNECTION	STATUS	SETUP BASE	CONNECTION	STATUS	SETUP BASE	SETUP ROVER
Satellites GPS + QZSS GPS + GLONASS + QZSS GPS + BEIDOU + QZSS NTRIP Settings Address 202.xxx.xx.xx Port 5000 Mount Point t1 Password 1234 Base Station Position			Rover Mode Autonomous RTK Satellites GPS + QZSS GPS + GLONASS + QZSS GPS + BEIDOU + QZSS NTRIP Settings Address 153.121.59.53 Port 2101 Mount Point		Elev Fix Sat PDC HD0	itude: 48.873416* igitude: 2.294480* vation: 133.622m type: Autonomous elites: 8 DP: 2.0 DP: 1.0 DP: 1.7 3 w	N 330' 19 19 20' 20' 20' 20' 20'	307 14 607 22 757 607 45 307	E
Latitude Longitude Elevation	START	RASE	Username Password .	STA	N		23 31 48.nmea, Size: 24KB 3.ubx, Size: 95KB	150°	
	START	BASE		STA	RT ROVER		STOP REC	ORDING	
	<  <			$\triangleleft$	О С		⊲ C		

Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@iis.u-tokyo.ac.jp





### Board Computer for Low-Cost RTK System

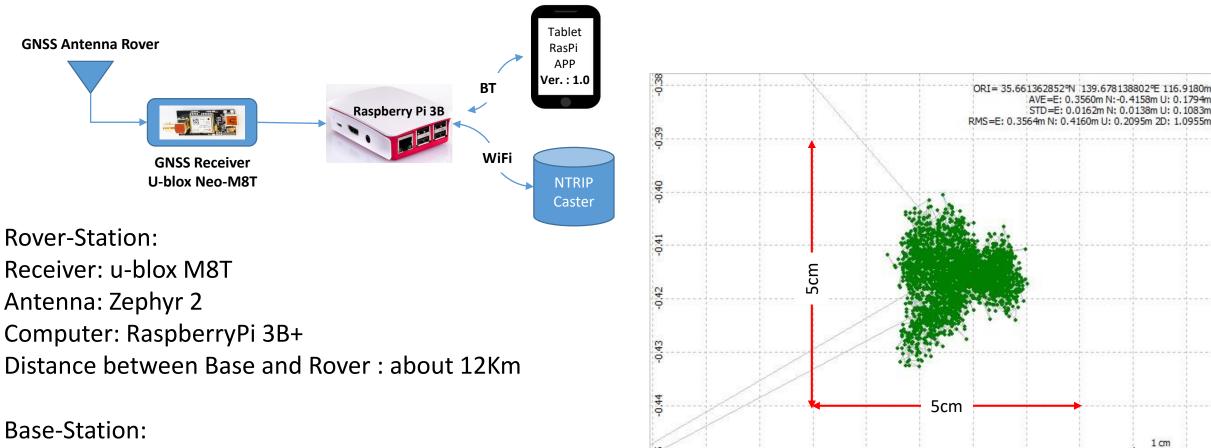


Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@iis.u-tokyo.ac.jp





#### Accuracy from Low-Cost RTK System



Receiver: Trimble NetR9 Antenna: Zephyr 2

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0.31

0.32

0.33

0.34

0.35

0.36

0.37

0.38

0.39

0.40





#### Data from Low-Cost RTK System

🔞 2017_09_15_17_27_13.ubx - u-cen 👰 File Edit View Player Receiver	ter 8.24 - [Messages - UBX - RXM (Receiver Manager) - RAWX (Multi-GNSS Raw Measurement Data)] Tools Window Help	- D ×
	<b>□ ▼ □ ◎ ◎ □ □ ⊕ □ ③ ◎ ◎ ◎</b> ◎ ◎ ◎ ◎ ◎ ● ○ ▼ <i>□</i> ▼ べ 淮 六 档	
RTCM3	UBX - RXM (Receiver Manager) - RAWX (Multi-GNSS Raw Measurement Data)	
⊟- UBX ⊞- ACK (Acknowledge) ⊞- AID (GPS Aiding)	Local Time 1966:462474.993000000 [s] Leap seconds 18 (VALID) [s] Clock reset ■	
<ul> <li>⊕-CFG (Config)</li> <li>⊕-ESF (External Sensor Fusion)</li> <li>⊕-HNR (High Navigation Rate)</li> <li>—INF (Information)</li> <li>⊕-LOG (Data Logger)</li> <li>⊕-MGA (Multiple GNSS Assistance)</li> </ul>	SV         Sign         G.         Pseudo Ra         Carrier Phas         Doppl         Loc         S         PR         C.P         DO         P         C.H.           G05         L1C/A         -         18440103.75         96903400.86         14.7         59000         49         0.32         0.004         0.512         Y. Y. Y         Y           G13         L1C/A         -         18601850.88         97753379.60         1014.6         59000         48         0.32         0.004         0.512         Y. Y. Y         Y           G02         L1C/A         -         18573259.87         97603138.07         -2055.6         59000         46         0.32         0.004         0.512         Y. Y. Y         Y           G30         L1C/A         -         19859876.78         104364373.57         -597.6         59000         44         0.32         0.004         0.512         Y. 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         <	
MON (Monitor)  NAV (Navigation)  RXM (Receiver Manager)  ALM (Almanac)  EPH (Ephemeris)	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           E05         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	$\frac{1}{20}$
– IMES (IMES Status) – MEASX (Measurement C – PMREQ (Power Mode Re – RAW (Raw Measuremen	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       N         R01       L1OF       1       17998955.08       96214678.67       -478.8       57660       49       0.32       0.004       0.512       Y. 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	G5G13G2G30G20G15G29G65129E5 E22 E3 E9 01 R1 R24R8 R23R10R11R17 R2 R9513702 E245128G7 d8       8       2         N       N       7       10         118.400 m       5       8
- RAWX (Multi-GNSS Raw - RLM (Return Link Messag - RTCM (RTCM input statu - SFRB (Subframe Data) - SFRBX (Subframe Data )	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	
SVSI (SV Status Info) SEC (Security)	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	
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Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@iis.u-tokyo.ac.jp





#### Data from Low-Cost RTK System

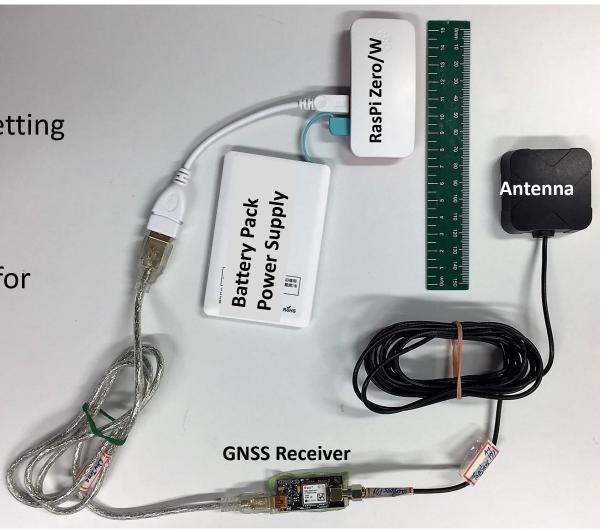
NMEA RTCM3	File Edit View Player Receiver Tools	Nindow Help	_ 8
MMEA ICICMB       UEX-RXM (Receiver Manager) - SFREX (Subframe Data NG)       1 s         # ACK (Achonovledge)       ## denotese data received on subChn       strip Farity Bits         # ACK (Achonovledge)       ## denotese data received on subChn       strip Farity Bits         # ACK (Achonovledge)       ## denotese data received on subChn       strip Farity Bits         # AD (GPS Akting)       ## denotese data received on subChn       strip Farity Bits         # HAR (High Maydation Rate)       ## denotese data received on subChn       strip Farity Bits         # LGG (Config)       ## denotese data received on subChn       strip Farity Bits         # LGG (Lonfig)       ## denotese data received on subChn       strip Farity Bits         # LGG (Lonfig)       ## Life 0       00055555 555555 555555         # NR (High Maydation Rate)       ## 1/3156 7235650 50706646 0A480000       ata 24 #EB 0       0005555 555555 555555 555555         # MAG AM (Allenand)       = 0.1107 6 1 4 1/3156 7235650 50706646 0A480000       ata 1/316 7 235650 50706646 0A480000       ata 1/316 7 123567 523650 50706646 0A4800000       <	🖬 😂 👻   🍜 🖪   X 🖻 🖻   👹 🕴 🕼 🕼 🕻	≝ <sup>1</sup> # ■       ●   ▶ ▼ ₩ H 1	
UICX-R3       UEX-RXM (Recover Hanager) - SFREX (Subtrane Data NG)       15         BX       FX (Acknowledge)       15         FX (D(SP Ading))       15         CFG (Gonfg)       15         FX (Breams Sensor Fusion)       15         HNR (High Navigation Rate)       15         HNR (High Navigation Rate)       15         FX (M (Recover Manager) - SFREX (Subtrane Data NG)       2374000         Global Logger)       12         HNR (High Navigation Rate)       11         HNR (High Navigation Rate)       11         FX (M (Recover Manager) - SFREX (Subtrane Data NG)       2374000         Global Logger)       12         HNA (Minagation)       12         HNA (Minagation)       12         FX (M (Recover Manager) - SFREX (Subtrane Data NG)       13357 523555         Statistics 2 statistic	📸 🖹 🗉 🖸 🗉 👻 🖾 👻 🖬 👻 İ		
MCM3         BX         # AC (Achonowledge)         # AD (GPS Alding)         * CFG (Gonfg)         * CFG (Go	NMEA ^		×
# ACK (Achowledge)       ## denotes data received on subch       Strip Farity Bits         # ACK (Achowledge)       ## denotes data received on subch       Strip Farity Bits         # CG (Confg)       CG (Confg)       CG (Confg)       CG (Confg)         # ACK (Achowledge)       EX B 0 80 0005555 \$555555 \$4585505 \$488500 005020 AAAA622E 70Fx4000       CG (Confg)         # NR (Inframidion)       CG (Confg)       CG (Confg)       CG (Confg)       CG (Confg)         # OG (Multiple CNSS Assistance)       CG (Confg)       CG (Confg)       CG (Confg)       CG (Confg)         # MCA (Multiple CNSS Assistance)       CG (Confg)       CG (Confg)       CG (Confg)       CG (Confg)       CG (Confg)         # MCA (Multiple CNSS Assistance)       CG (Confg)       CG	RTCM3	UBX - HXM (Receiver Manager) - SFRBX (Subframe Data NG)	
AD (GPS Aiding)       +** UnitOrde Late in Polarity Fails gives         C (G, Config)       +** UnitOrde Late in Polarity Fails gives         C (G, Config)	UBX		
AD (GPS Aiding)       +** UnitOrde Late in Polarity Fails gives         C (G, Config)       +** UnitOrde Late in Polarity Fails gives         C (G, Config)	ACK (Acknowledge)	— — — — — — — — — — — — — — — — — — —	
gr       MRX       MRX       Config.       MRX       Resp. (* denotes invalue) works)         gr       MRX       Fills       ED       CO095555       S555555       S55555       S555555       S555555       S555555 </td <td></td> <td>## denotes data received on subChn Strip Parity Bits</td> <td></td>		## denotes data received on subChn Strip Parity Bits	
BSF (External Sensor Fusion)       GAL 5 E1B 0 E0       00955555 5555555 4289C000 83A74000 0000002A ADAA632E 178F4000         B HNR (High Navigation Rate)       GAL 24 E1B 0 E0       00955555 5555555 5555555 5555555 4289C000 83A74000 0000002A ADAA632E 87BF4000         -INF (Information)       GAL 24 E1B 0 E0       00955555 5555555 5555555 5555555 4289C000 83A74000 0000002A ADAA632E 87BF4000         B HOR (Multiple GNS Assistance)       GC 0 1 LIOP 1 14 /13156 7282660 5706C48 0A480000       GAB0000         B MOR (Multiple GNS Assistance)       GC 0 1 LIOP 7 14 /13156 7282660 5706C48 0A480000       GAB0000         B MOR (Multiple GNS Assistance)       GC 0 1 LIOP 7 14 /13156 7282660 5706C48 0A480000       GAB0000         B MOR (Multiple GNS Assistance)       GC 0 1 LIOP 7 14 /13156 7282660 5706C48 0A480000       GAB0000         B MAV (Margidin)       GC 0 1 LIOP 7 14 /13156 7282660 5706C48 0A480000       GAB0000       GC 0 11 LIOP 7 14 /13156 7282660 5706C48 0A480000       GC 0 11 LIOP 7 14 /13156 7282660 5706C48 0A480000         - FLM (Receiver Manager)       GC 2 LIOP 2 14 /13156 7282660 5706C48 0A480000       GC 2 LIOP 2 14 /13156 7282660 5706C48 0A480000       GC 2 LIOP 2 14 /13156 7282660 5706C48 0A480000         - FLM (Receiver Manager)       GC 2 LIOP 2 14 /13156 72826860 5706C48 0A480000       GC 2 LIOP 2 14 /13156 72826860 5706C48 0A480000       GC 2 LIOP 2 14 /13156 72826860 5706C48 0A480000       GC 2 LIOP 2 14 /13156 72826860 5706C48 0A480000         - FLM (Receiver Manager)       GC 2			
HAR (High Navigation Rate)         GAL 9         E1B 0         E0         0.0955555         55555555         4E99000         83,74000         0000002A         AAAA322         67Be4000           -INF (Information)         GAL 24         E1B 0         E0         0.0955555         55555555         4E99000         83,74000         0000002A         AAAA322         67Be4000           GLA 24         E1B 0         E0         0.0955555         55555555         55555555         4E99000         83,74000         000002A         AAAA322         67Be4000           GLA 24         E1B 0         E0         0055555         55555555         55555555         55555555         55555555         5555555         5555555         55555555         55555555         5555555         5555555         5555555         55555555         55555555         5555555         55555555			
H-HNR (High Navigation)       CAL 22 EIB 0 E0       00955555 555555 4EB9C000 03A74000 000002A AAAA632E 07BF4000         OL G (Data Logger)       CL 0 1 LiOF 1 14       1/3156 72258660 50770648 0A4B0000         CL 0 2 LiOF 4 14       1/3156 72258660 50770648 0A4B0000         GL 0 3 LiOF 6 14       1/3156 72258660 50770648 0A4B0000         GL 0 1 LiOF 0 14       1/3156 72258660 50770648 0A4B0000         GL 0 1 LiOF 1 14       1/3156 72258660 50770648 0A4B0000         GL 0 1 LiOF 7 14       1/3156 72258660 50770648 0A4B0000         GL 0 1 LiOF 7 14       1/3156 72258660 50770648 0A4B0000         GL 0 1 LiOF 7 14       1/3156 72258660 50770648 0A4B0000         GL 0 1 LiOF 7 14       1/3156 72258660 50770648 0A4B0000         GL 0 1 LiOF 7 14       1/3156 72258660 50770648 0A4B0000         GL 0 2 LIOF 4       1/3156 72258660 50770648 0A4B0000         GL 0 2 LIOF 4       1/3156 72258660 50770648 0A4B0000         GL 0 2 LIOF 4       1/3156 72258660 50770648 0A4B0000         GL 0 2 LIOF 4       1/3156 72258660 50770648 0A4B0000         GL 0 2 LIOF 4       1/3156 72258660 50770648 0A4B0000         GL 0 2 LIOF 2       1/4         GL 0 2 LIOF 2       2/2C3APOB 25A34ABB 0265155         GL 0 2 LIOF 4       2/2C3APOB 25A34ABB 0265155         GL 0 2 LIOF 2       2/2C3APOB 25A34ABB 0600543 <t< td=""><td>ESF (External Sensor Fusion)</td><td></td><td></td></t<>	ESF (External Sensor Fusion)		
INF (information)       CAL 24 EIB 0 0 00 0055555 5555555 555555 555555 555555	- HNR (High Navigation Rate)		
H LOG (Data Logger)       GLO 1 LLOF 1 14 1/3165 7528560 5770648 0A480000         M Mok (Multiple GNSS Assistance)       GLO 2 1 LLOF 1 14 1/3165 7528560 5770648 0A480000         M MON (Monitor)       GLO 3 LLOF -1 14 1/3165 7528560 5570648 0A480000         P MAV (Navigation)       GLO 1 LLOF 1 14 1/3165 7528560 5570648 0A480000         P MAV (Navigation)       GLO 3 LLOF 1 14 1/3165 7528560 5570648 0A480000         P MAV (Navigation)       GLO 3 LLOF 2 14 1/3165 7528560 5570648 0A480000         - FLM (Almanac)       GLO 3 LLOF 2 14 1/3165 7528560 5570648 0A480000         - FLM (Sinter Data)       GEO 2 LLOF 2 14 1/3165 7528560 5570648 0A480000         - FLM (Sinter S)       GEO 2 LLOF 2 14 1/3165 7528560 5570648 0A480000         - MEAS X (Measurement Data)       GF8 5 LLC/A 0 2       2203808 2533488 0337658 60279348 36892081 BFF5080 7244246 03579261 83125497 12909327         - RAWX (Multi-GNSS Raw Measurement Data)       GF8 5 1 LLC/A 0 2       2203808 2533488 0300598 60102439 60278278 2010070 3226480 134770037872528512 043770 13782631 201099371         - RAWX (Multi-GNSS Raw Measurement Data)       GF8 2 0 LLC/A 0 2       2203808 2533488 030139 60164558 0277824 8014070 03284248 034700205 657563 12099277       0186647 03220618 12909478       0378647 03220618 12909478         - RAW (Raw Measurement Data)       GF8 2 1 LLC/A 0 2       2203808 253488 0405138 6006786 00124396 6027862 0075000138 60067860 0012460000000000000000000000000000000000	INF (Information)		25
HMGA (Multiple GNSS Assistance)       GBD 2 1110 ° 6 1 4 1/3156 7328580 5770cccs 0x480000         HMON (Monitor)       GBD 9 110 ° 7 1 4 1/3156 7328580 5770cccs 0x480000         HNAV (Monitor)       GBD 9 110 ° 7 1 4 1/3156 7328580 5770cccs 0x480000         HNAV (Mavigation)       GBD 2 1110 ° 6 1 4 1/3156 7328580 5770cccs 0x480000         HNAV (Mavigation)       GBD 3 110 ° 7 1 4 1/3156 7328580 5770cccs 0x480000         HAW (Alumanac)       GBO 2 1110 ° 1 14 1/3156 7328580 5770cccs 0x480000         -ALM (Almanac)       GBO 2 1110 ° 1 14 1/3156 7328580 5770cccs 0x480000         -MKM (Secover Manager)       GBO 2 1110 ° 1 14 1/3156 7328580 5770cccs 0x480000         -MKM (Sacurement Data)       GBS 5 111/A 0 2       2233408 2533488 1337664 0ccr57677 7338226 6b394070 3281870 32482564 03778272 1cc939727         -MKAX (Measurement Data)       GBS 5 111/A 0 2       22324808 2533488 1007442       22525376 601001513 8317654 0ccr5787 7338226 60107513 82126376 03262528 1cc99777         -RAWK (Multi-GNSS Raw Measurement Data)       GBS 5 111/A 0 2       22324808 2533488 0109159 05770 0378221 0c105977 0378226 0000070 31281270 7087868 0005780 0104060153 8317880 70002678 314880 7032182 17038278 601002578 10268286 1337788 10268587 03282817 0328286 10097877         -RAWK (Multi-GNSS Raw Measurement Data)       GBS 5 111/A 0 2       22320808 2533488 01091598 0507031218 217078788 268653 307788 12605858 037788 126058587 0328787 10288578 0328788 126058587 0328886 00000000 0000000 03840000         -RAWK (Multi-GNSS Raw Measurement Data)	· · · · · · · · · · · · · · · · · · ·	GLO 1 L1OF 1 14 1/3156 752856E0 5D706C48 0A4B0000	
MON (Monitor)       Guo 9 L10F -2       14 1/3156 75285560 50706C48 0A480000         NAV (Navigation)       Guo 10 L10F -7       14 1/3156 75285560 50706C48 0A480000         Cuo 11 L10F 0       14 1/3156 75285560 50706C48 0A480000         -ALM (Almanac)       -Guo 21 L10F 3       14 1/3156 75285560 50706C48 0A480000         -EPH (Ephemeris)       -ILOF 4       14 1/3156 7528560 50706C48 0A480000         -MAKS (Measurement Data)       -Guo 2 21C3AE0B 25A34ABB 035FB55 807F9658 02FF956 800FD3CB 3D84210 2EECC5A 8402E75 832C83CB 1C909F7C         -MRAC (Power Mode Request)       -Ges 5 L10C/A 0       2       22C3AE0B 25A34ABB 04010D 0C196F59 02CF2958 802A1174 2A8FDA4 0537E562 83728E52 8728150 1C909F7C         -MRAC (Multi-GNSS Raw Measu       -RW (Multi-GNSS Raw Measu       -RW (Multi-GNSS Raw Measu       -RES 1 L1C/A 0       2       22C3AE0B 25A34ABB 040010 0C196F59 02FF206 00000 00000000 0294C6406         -RTCM (Rtch mult Message)       -RIM (Return link Message)       -2       22C3AE0B 25A34ABB 040010 32FF26 8014000 01264560 0075C135 B98D6FT8 81265971 0136467 03228E178 8326525 81706218 8778E178 80080F76       03487586 1700 1209F726       049F76         -RTCM (Rtch mult Message)       -2       22C3AE0B 25A34ABB 0400103 956105 00F7422 170231 8010098 14400008 12400008 12400000 02266       0578561 05796764       04894743 067422 8778 3718629 0075C135 898D6F78 61268 217073 2585650 5705678 0227884 2169877         -RTCM (Rtch mult Message)       -2       22C3AE0B 25A34ABB 04001039			
HOW (Monitor)       GLO       10       Liop 7       14       1/3156       7285660       50706C48       0A480000         HAW (Navigation)       GLO       11       Liop 0       14       1/3156       7285660       50706C48       0A480000         GLO       11       Liop 0       14       1/3156       75285600       50706C48       0A480000         GLO       11       Liop 0       14       1/3156       75285600       50706C48       0A480000         GLO       11       Liop 0       14       1/3156       75285600       50706C48       0A480000         GLO       12       Liop 2       2203A00       25334ABB       03376528       802031       BFF58087       2A474660       0579261       83263CB       1099727         GPS       6       Lic/A       0       2       2203A00       25334ABB       03075723       83202031       BFF58087       73752525       8320312       1099727       1099726       1099727         GPS       1       Lic/A       0       2       2203A00       25334ABB       06002439       60227829       8034072       9378228       810939702       1099726       103402484       30477620       907970       1099726 <td< td=""><td>MGA (Multiple GNSS Assistance)</td><td></td><td></td></td<>	MGA (Multiple GNSS Assistance)		
NAV (Navigation)       CL 0 11 L10 F 0       14 1/315 6 7528560 5D706C48 0A480000         RKM (Receiver Manager)       -ALM (Almanac)       -GL 23 L10 F 3       14 1/315 6 7528560 5D706C48 0A480000         -EPH (Ephemeris)       -GEP 3 L1C/A 0       2       2203AE08 25534ABB 033Fr65A 8cT7D348 36E920B1 BFF5807 2A4E460 05792861 831E5F7 1c9093Cc       160997C         -MKES (IMES Status)       -GFP 5 L1C/A 0       2       2203AE08 25534ABB 033Fr65A 8cT7D348 36E920B1 BFF5807 2A4E460 0579281 50392Cc       160997C       1750035C 550035C         -MKES (IMES Status)       -GFP 7 L1C/A 0       2       2203AE08 25534ABB 033Fr65A 8cT7D348 36E920B1 BFF5807 2A4E460 0579281 50397C2       160997C       1500037C 50037C         -MKEA (Measurement Data)       -GFP 7 L1C/A 0       2       2203AE0B 25534ABB 01051C0 000703 91027FED 0057C37 0136264 0337F52B 102097C       150057C37 0136647 0322061 10509478       150057C37 0136647 0322061 1050977         -RAW (Raw Measurement Data)       -GFP 3 0 L1C/A 0       2       2203AE0B 25334ABB 0105150 0000003 37F52B 01076370 03752BC10B 02563767 000070 31027FDD F05707 017657C 01065407 03220618 105097C       15005727 0146847 0320618 105097C         -RAW (Multi-GNSS Raw Measu       -RIM (Return Link Message)       -2       2203AE0B 25334ABB 0105120 0D035260 0075030 12426647 033752B 1030972F       1600070 31027FDD F05707 03762C21 8A4840 34752B 1030972F       16000000 329400A6         -RIM (Return Link Message)       -1       -2       2200AA24 25	MON (Monitor)		20
RXM (Receiver Manager)       GL0 17 Lior 4 14 1/3156 7328560 SD706C48 0A4B0000         -ALM (Almanac)       GL0 23 Lior 3 14 1/3156 7328560 SD706C48 0A4B0000         -FPH (Ephemeris)       GL0 24 Lior 2 14 1/3156 7328560 SD706C48 0A4B0000         -IMES (IMES Status)       GBS 5 Lic/A 0 2       22C3AE0B 25A34ABB 0235B5B BD75996 B00ED3CB 3DB44210 2EDCDC5A 8402EB75 832C83CB 109097C         -MKASX (Measurement Data)       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 06002439 8C22FB8A AD992FF6 80140070 328E1FG 30342284 034D78C3 037FF228 1090972F       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 06002439 8C22FB8A AD992FF6 80140070 328E1FG 30342584 034D78C3 05909F7C       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 06002439 8C22FB8A AD992FF6 80140070 328E1FG 30342584 034D78C3 05909F7C       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 06002439 8C22FB8A AD992FF6 80140070 328E1FG 30342584 034D78C3 05909F7C       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 06002439 8C22FB8A AD992FF6 80140070 328E1FG 30342584 034D78C3 05909F7C       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 06005439 8C22FB8A AD992FF6 80140070 328E1FG 30342581 02909F2F       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 0600549 8C24FB8 AD992FF6 80140070 328E1FG 30342581 02909F2F       GBS 6 Lic/A 0 2       22C3AE0B 25A34ABB 0A80059 8F01C218 21702E31 801D009E 149CD026 8576855 D 3378EDEP 12909F2F       GBS 6 11c/A 0 2       22C3AE0B 25A34ABB 0A805139 8DD8FFB 502C0000 0000000 0000000 0000000 0000000 0000	-NAV (Navigation)		0.00  m/s = 0.0  km/h
-ALM (Almanac)       -GUO 23 LIOP 3 14 173156 75285E0 5D706C48 0A4B0000         -EPH (Ephemeris)       -GEO 24 LIOP 2 14 173156 75285E0 5D706C48 0A4B0000         -EPH (Ephemeris)       -GES 2 LIC/A 0 2       22C3ARDB 25A34ABB 0E3D5B5 6D7EF996 B0ED3CB 3DB4210 2EDCD5A 8402E875 832C83CB 1C909F7C         -MESX (Messurement Data)       -GES 7 LIC/A 0 2       22C3ARDB 25A34ABB 0E3D5B05 6D7EF996 B0ED3CB 02EF2P3 802A174 2A8FDAF 0437870 037F228 10909F2F         -MEASX (Measurement Data)       -GES 7 LIC/A 0 2       22C3ARDB 25A34ABB 06002439 8CA2FB8A AD99F76 8014C070 32BE150 102099F2F         -RAW (Raw Measurement Data)       -GES 15 LIC/A 0 2       22C3ARDB 25A34ABB 06002439 8CA2FB8A AD95F76 8014C070 32BE150 102099F2F         -RAW (Raw Measurement Data)       -GES 20 LIC/A 0 2       22C3ARDB 25A34ABB 06002439 8CA2FB8A AD95F76 8014C070 32BE150 102099F2F         -RAW (Raw Measurement Data)       -GES 20 LIC/A 0 2       22C3ARDB 25A34ABB 06002439 8CA2FB8A AD95F76 8014C470 32BE150 10209F2F         -RAW (Raw Measurement Data)       -GES 20 LIC/A 0 2       22C3ARDB 25A34ABB 010F15E 0BDAD92A AD766S7 3F1E8029 90F5C377 01A96847 03220618 12099F7F         -RAW (Raw Measurement Data)       -GES 20 LIC/A 0 2       22C0AAB2B 25A34ABB 010F15E 0BDAD92A AD766S7 3F1E8029 90F5C377 01A96847 03220618 12099F7F         -RAW (Ratur Link Message)       -GES 11 LISAIF 0 50       53CAC767 E0000070 31027FDF DFDFPFF 7572496 6B5F1C1B 798F2F3 B322D081 9C585F94         -SFRB (Subframe Data NG)       SBAS 128 LIC/A 0 25       53G6611C7 FEPCO5F EC			
-EPH (Ephemeris)       -IIC/A       0       2       22C3AE0B       25A34ABB       053D5BD5       8D7EP996       800EB75       832c83CB       10909F7C         -IMES (IMES Status)       -MEASX (Measurement Data)       -PM(Request)       -GPS       11C/A       0       2       22C3AE0B       25A34ABB       033F65A       8CETD348       36E920B1       BF58087       2AE4660       05792861       831E5P7       10909F7C         -MESX (Measurement Data)       -PM(Request)       -GFS       11C/A       0       2       22C3AE0B       2SA34ABB       03014D55       02CFE2P9       8024174       2A8FDAP4       0523E652       83729150       1050997F0         -PMREQ (Power Mode Request)       -GFS       11C/A       0       2       22C3AE0B       2SA34ABB       06024975       90263174       2A8FDAP4       0523E652       83729150       105099478       9099750         -RAW (Raw Measurement Data)       -PM(Request)       -GFS       11C/A       0       2       22C3AE0B       2SA34ABB       08005195       8014C070       32206131       109098767       0320613       109098767       0320613       109098767       0320613       109098767       0320613       109098767       0320613       10909877       038042584       03407583       <			10
GPR 5       L1C/A       0       2       22C3AE0B       25A34ABB       033FF65A       ScE7D348       36E920B1       BFF58087       2A4E4660       05792861       831E5F71       129093EC       Filterent and the state and the s	ALM (Almanac)		9
<ul> <li>- IMES (IMES Status)</li> <li>- IMES (IMES Status)</li> <li>- MEASX (Measurement Data)</li> <li>- PMREQ (Power Mode Request)</li> <li>- RAWX (Math-GNSS Raw Measurement Data)</li> <li>- RAWX (Multi-GNSS Raw Measurement Data)</li> <li>- SFRB (Subframe Data)</li> <li>- SFRB (Subframe Data)</li> <li>- SFRBX (Subframe Data)</li> <li>- SFRBX (Subframe Data)</li> <li>- SFRBX (Subframe Data)</li> <li>- SFRBX (Subframe Data)</li> <li>- SFRB (Subframe Data)</li> <li>- SFRBX (Subframe Data)</li> <li>- SFRBX (Subframe Data)</li> <li>- SFRB (Subframe Data)</li> <li>- SFRB (Subframe Data)</li> <li>- SFRBX (Subframe Data)<td>EPH (Ephemeris)</td><td></td><td>ремениеваниеваниеваниеваниеваниеваниеваниев</td></li></ul>	EPH (Ephemeris)		ремениеваниеваниеваниеваниеваниеваниеваниев
-MEASX (Measurement Data)       GPS       7       L1C/A       0       2       22C3AE0B       25A34ABB       03404DD3       0C196F58       02CFB2D9       802A4174       2ABFDAF4       0523E52       83729150       1C909478         PMREQ (Power Mode Request)       GPS       7       L1C/A       0       2       22C3AE0B       25A34ABB       06002439       8CA2FB8A       AD89E7F6       8014C070       32BE1F03       03402848       03407bca       9C909F76         GPS       15       L1C/A       0       2       22C3AE0B       25A34ABB       06002439       8CA2FB8A       AD89E7F6       8014C070       32BE1F03       03402848       03407bca       9C909F76       GPS       GPS       20       L1C/A       0       2       22C3AE0B       25A34ABB       06002439       8CA2FB8A       AD80FF76       825BE35       83729150       1C909478       GPS       GPS       20       L1C/A       0       2       22C3AE0B       25A34ABB       04B0159       8C1C218       21702E31       801D0098       149C0026       8576850       033752B       1C90977C       GPS       30       L1C/A       0       2       22C3AE0B       25A34E8       04B0513       8D0B67B       01C4A960       0228540240       GPS <t< td=""><td>- IMES (IMES Status)</td><td></td><td></td></t<>	- IMES (IMES Status)		
-PMREQ (Power Mode Request)       -GPS 13 L1C/A 0 2       22C3AE0B 25A34ABB 06002439 8CA2F86A AD89E7F6 8014C070 328B1F03 03402848 034D7BCA 9C909FF0         -RAW (Raw Measurement Data)       -GPS 15 L1C/A 0 2       22C3AE0B 25A34ABB 0A00B59 8CA2F86A DB9E7F6 8014C070 328B1F03 03402848 034D7BCA 9C909FF0         -RAW (Rulti-GNSS Raw Measurement Data)       -GPS 20 L1C/A 0 2       22C3AE0B 25A34ABB 0A00B59 8CD1218 2170231 801D0098 149CD26 8576A85D 837BDEFT 1C909F7C         -RLM (Return Link Message)       -RTCM (RTCM input status)       -22C0AA24 25A34254 10494F43 067A62DE 8A7BAB5 84AB49A3 10D554c4 0AF1F2AF 3BC08DFD 9C585FC7         -SFRB (Subframe Data)       50       53cAc767 E0000070 31027FDD FD8FD8FE 502F0000 00000000 00000000 00000000 02394c0A6         -SFRB (Subframe Data)       50       53cAc767 E0000070 31027FDD FD8FD8FE 502F0000 00000000 0000000 02394c0A6         -SFRB (Subframe Data)       50       53cAc767 E0000070 31027FDD FD8FD8FE 502F0000 00000000 0000000 02394c0A6         -SFRB (Subframe Data)       50       53cAc767 E0000070 31027FDD FD8FD8FE 502F0000 00000000 0000000 02394c0A6         -SFRB (Subframe Data)       50       53cAc767 E000070 31027FDD FD8FD8FE 502F0000 00000000 00000000 0226(CA6         -SFRB (Subframe Data NG)       -SFRB (Subframe Data NG)       -SSA611C7 EBFDC05F EC7FFE81 7F9D8A80 00000000 0000000 0000000 0000000 00000			
RAW (Raw Measurement Data)         RAW (Raw Measurement Data)         RAW (Raw Measurement Data)         RAWX (Multi-GNSS Raw Measurement Data)         RIM (Return Link Message)         RICM (RTCM input status)         SFRB (Subframe Data)         SFRB (Subframe Data)         SFRBX (Subframe Data)         SFRBX (Subframe Data)         SFRBX (Subframe Data)         Strage (Security)         TIM (Traina)         25         SSG611C7 EBFDC05F EC7FFE81 7F9DBA80 0000000 0000000 0000000 0000000 000000			
GPS       29       L1C/A       0       2       22C3AE0B       25A34ABB       01BF15E0       0BDAD92A       ADA76857       3F1E8029       90F5C377       01A96847       03220618       1C909478       GPS       30       L1C/A       0       2       22C3AE0B       25A34ABB       01BF15E0       0BDAD92A       ADA76857       3F1E8029       90F5C377       01A96847       03220618       1C909478       GPS       30       L1C/A       0       2       22C3AE0B       25A34ABB       010494F43       067A62DE       8A7BAABS       90F5C377       01A96847       03220618       1C909478       GPS       30       L1C/A       0       2       22C0AA24       25A34ABB       010494F43       067A62DE       8A7BAABS       90F5C377       01A96847       03220618       1C909478       GPS       30       L1C/A       0       2       22C0AA24       25A34254       10494F43       067A62DE       8A7BAABS       84B49433       1D0554C4       0AF1F2AF       3BC0BFD       92F50576       GPS       302D619       92585F67       GPS       302D619       92585F77       3F294966       B57BC11D       879B728F       3B22D081       9C585F94       GPS       SBA5       128       L1C/A       0       25       536611C7       EPFDC05F <td>PMREQ (Power Mode Request)</td> <td></td> <td>6<sup>7011</sup>111114</td>	PMREQ (Power Mode Request)		6 <sup>7011</sup> 111114
- RAWX (Multi-GNSS Raw Measul - RLM (Return Link Message)       GPS 30 L1C/A 0 2       22C3AE0B 25A34ABB 0A805139 8D0B6F0B 01C4A960 00238048 246C1FD9 85416853 0343752B 1C909F2F         - RLM (Return Link Message)       - RTCM (RTCM input status)       - SSCAC767 E0000070 31027FDD FD8FD8FE 502F0000 00000000 3294C0A6         - SFRB (Subframe Data)       - SFRB (Subframe Data)         - SFRB (Subframe Data)       - SFRBX (Subframe Data NG)         - SVSI (SV Status Info)       - SSCAC767 E000070 31027FDD FD8FD8FE 502F0000 00000000 0000000 0000000 0000000 0000	RAW (Raw Measurement Data)		N 118.500 m 5
- RLM (Return Link Message)			<b>K3</b>
- RTCM (RTCM input status)       - SFRB (Subframe Data)         - SFRB (Subframe Data)       - SFRBX (Subframe Data)         - SFRBX (Subframe Data)       - STOP - St	· ·		
SFRB (Subframe Data)         SFRB (Subframe Data)         SFRBX (Subframe Data NG)         SVSI (SV Status Info)         SEC (Security)         IM (Impine)		~	
Shas 128 L1C/A 0       3       530D9FFF FF9FFDFF C011FFC0 00001FFD FFC007FF 7FF797B9 B95BBA16 B71493A6         B SFRBX (Subframe Data NG)       SBAS 128 L1C/A 0       25       536611C7 EBFDC05F EC7FFE81 7F9DBA80 0000000 0000000 006D0226         SVSI (SV Status Info)       SBAS 137 L1C/A 0       25       536611C7 EBFDC05F EC7FFE81 7F9DBA80 0000000 0000000 006D0226         SEC (Security)       SEC (Security)       SEC (Security)       SEC (Security)       SEC (Security)			
E SFRBX (Subframe Data NG)       SBAS 129 L1C/A 0 25       536611C7 EBFDC05F EC7FFE81 7F9DBA80 0000000 0D6D0226         SVSI (SV Status Info)       SBAS 137 L1C/A 0 25       536611C7 EBFDC05F EC7FFE81 7F9DBA80 0000000 0D6D0226         SEC (Security)       TIM (Iming)	SFRB (Subframe Data)	N	
SVSI (SV Status Info) SEC (Security)	🗄 SFRBX (Subframe Data NG)		S125 0 📅 📅 🚽
H-SEC (Security)	SVSI (SV Status Info)		
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	H IIM (liming) ✓		
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### Simple to Use, Plug-And-Record, Low-Cost System Receiver

- 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







#### Conclusion

- Accuracy better than <u>few tens of centimeters</u> using Low-Cost Receiver in RTK mode is possible.
  - Both Base and Rover with Low-Cost Receiver
  - Smaller base length, < 10km
- Accuracy better than <u>few centimeters</u> 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/

### https://www.youtube.com/watch?v=JaicV8egzFo

### 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