GNSS Data Processing for High-Accuracy Positioning using Low-Cost Receiver Systems

UTOKYO/ICG Workshop on GNSS for Policy and Decision Makers
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(Online Workshop)

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Quiz

• What is the Price of a GNSS Receiver?
  • $10? / $100? / $500 / $1,000 / $3,000 / $10,000 or more?

• What is the Accuracy that you can get from a GNSS receiver?
  • mm, cm, dm, few meters or 10 – 30m

• But, what are your requirements?
  • Types of Applications
  • Accuracy Requirements
  • Data Logging Methods
    • Static Mode on a Tripod
    • Dynamic Mode on a Car, Tractor or Machine?
  • Real-Time or Post-Processing
Low-Cost Receiver Systems
High-End Survey Grade Receivers

• Multi-frequency
  • GPS : L1/L2/L5
  • GLONASS : L1/L2/L3
  • GALILEO : E1/E5/E6
  • BDS : B1/B2/B3
  • QZSS : L1/L2/L5/L6
  • NAVIC : L5/S

• Multi-system
  • GPS, GLONASS, GALILEO, BeiDou, QZSS, NAVIC, SBAS etc

• Price varies from $3,000 to $30,000 or more
Low-Cost Receivers

• Multi-System
  • GPS, GLONASS, GALILEO, BeiDou, QZSS, SBAS etc

• Basically Single Frequency
  • L1/E1/B1-Band
  • Very soon: Multi-System, Multi Frequency, L1/L2 or L1/L5
    • Future trend for Mass Market System will be L1/L5
  • Some chip makers have already announced Multi-System, Multi-Frequency GNSS Chips for Mass Market

• Low Cost:
  • Less than $300 (Multi-GNSS, L1 Only) including Antenna and all necessary Hardware, Software
    • Our target is within $100 or less including everything

*Note: Only one signal type from each system is processed
e.g. GPS has L1C/A and L1C in L1, but only L1C/A is used in Low-Cost Receiver
Our Definition of Low-Cost Receiver

- Price: $100 or less
- Accuracy: Better than 100cm
- Weight: 100g or less (Without Battery)

$100 \times 100\text{cm} \times 100\text{g}$

Will it be possible?
Many Applications require Low-Cost, Small-Size & Low-Power Receiver System

But, is it possible to get High-Accuracy with Low-Cost Receivers?
Question?

Although the **Normal Accuracy of GPS is about 10m**, why can we get **Centimeter Level Accuracy**?
GPS Position Accuracy
How to achieve accuracy from few meters to few centimeters?

- **SPP (Single Point Position)**
  - 50 cm grid
  - RTK (Real Time Kinematic)
  - Carrier-phase observation
  - 5 cm grid

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# Errors in GPS Observation (L1C/A Signal)

<table>
<thead>
<tr>
<th>Error Sources</th>
<th>One-Sigma Error, m</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>DGPS</td>
</tr>
<tr>
<td>Satellite Orbit</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Satellite Clock</td>
<td>2.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Ionosphere Error</td>
<td>4.0</td>
<td>0.4</td>
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<tr>
<td>Troposphere Error</td>
<td>0.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Multipath</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Receiver Circuits</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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](http://www.edu-observatory.org/gps/gps_accuracy.html#Multipath)
How to Remove or Minimize Common Errors?

Use Differential Correction

Base-Station
Antenna is installed at a known-position

Base-station Antenna position shall be known in advance

Rover
User in the Field (Either fixed or moving)

Send Correction Data to Rover For Real-Time Position

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

RTCM
RINEX data for post-processing

Base-length < 40Km

\[ \text{error} = \text{known} - \text{measured} \]
How to Remove or Minimize Common Errors?
Principle of QZSS MADOCA and CLAS Services

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

Correction data for other satellites will also be provided

Base-Station not required
Low-Cost RTK Receiver System

**TYPE R1** Type A: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Base and Rover Mode

- GNSS Antenna Rover
- Raspberry Pi 3B
- GNSS Receiver
- Tablet RasPi APP
  - Ver. : 1.0
- NTRIP Caster
- RTCM for RTK

**TYPE R2** Type B: Low-Cost, High-Accuracy Receiver System
For Post-Processing & Rover Mode Only

- GNSS Antenna Rover
- Raspberry Pi Zero w/WiFi&BT
- GNSS Receiver
- NTRIP Caster
- RTCM for RTK

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**TYPE A1** Type C: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Rover Mode Only

- GNSS Antenna Rover
- Android Device
  - RTKDROID
  - Ver. : 1.0
- GNSS Receiver
- RTCM for RTK
- Internet
- NTRIP Caster

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**TYPE MA** Type D: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Rover Mode Only

- GNSS Antenna Rover
- Android Device
  - MADROID
  - Ver. : 1.0
- GNSS Receiver
- RTCM and/or SSR
  - PPP-RTK
  - E.g. MADOCA Service
- Internet
- NTRIP Caster
- MADOCA Correction Server

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# Low-Cost RTK Receiver System

<table>
<thead>
<tr>
<th>Type</th>
<th>Receiver System</th>
<th>Usage</th>
<th>RTK Processing Engine</th>
<th>Mode</th>
<th>User Interface</th>
<th>Base-Station Data</th>
<th>Correction Data Format</th>
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</thead>
<tbody>
<tr>
<td>Type R1 Beta Version</td>
<td><img src="image" alt="Type R1 Diagram" /></td>
<td>Real-time RTK Base and Rover Setting</td>
<td>Raspberry Pi 3B</td>
<td>Base or Rover</td>
<td>Android Device APP: RTKPI</td>
<td>NTRIP Server</td>
<td>RTCM 3</td>
</tr>
<tr>
<td>Type R2 Beta Version</td>
<td><img src="image" alt="Type R2 Diagram" /></td>
<td>Log Raw Data for Post-processing RTK</td>
<td>Raspberry Pi Zero/WiFi&amp;BT Option: RaspberryPi Camera</td>
<td>Rover Only</td>
<td>None</td>
<td>Post-processing</td>
<td>User Defined</td>
</tr>
<tr>
<td>Type A1 Release 1.0</td>
<td><img src="image" alt="Type A1 Diagram" /></td>
<td>Real-time RTK Simultaneous Log of Raw Data</td>
<td>Android Device</td>
<td>Rover Only</td>
<td>Android Device APP: RTKDROID</td>
<td>NTRIP Server or VRS</td>
<td>RTCM 3</td>
</tr>
<tr>
<td>Type MA Release 1.0</td>
<td><img src="image" alt="Type MA Diagram" /></td>
<td>Real-time PPP Based on MADOCA Correction Data from Internet</td>
<td>Android Device</td>
<td>Rover Only</td>
<td>APP: MADROID</td>
<td>MADOCA Correction Data Server</td>
<td>MADOCA Format</td>
</tr>
</tbody>
</table>

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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)
## Low-Cost MADOCA PPP Receiver Systems

<table>
<thead>
<tr>
<th>Type A: MAD-π</th>
<th>Type B: MAD-WIN</th>
<th>Type C: MADROID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver: Dual Frequency Receiver</td>
<td>Receiver: Dual Frequency Receiver</td>
<td>Receiver: Dual Frequency Receiver</td>
</tr>
<tr>
<td>Data Format: UBX, SBF or RTCM 3</td>
<td>Data Format: UBX, SBF or RTCM 3</td>
<td>Data Format: UBX or RTCM 3</td>
</tr>
<tr>
<td>Correction Data: UBX, RTCM3 or JAXA online</td>
<td>Correction Data: UBX, RTCM3 or JAXA online</td>
<td>Correction Data: JAXA online</td>
</tr>
</tbody>
</table>
MADOCA Low-Cost Receiver Systems

Type – A : MAD-π
- GNSS Antenna
- GNSS Receiver
  - L1/L2 GNSS Receiver
  - MADOKA Decoder
- Raspberry Pi 3B or 4B
- WiFi
- MADOKA Correction Data Server
- Use MADOKA correction data from server if GNSS receiver does not have MADOKA decoder

Type – B : MAD-WIN
- GNSS Antenna
- GNSS Receiver
  - L1/L2 GNSS Receiver
  - MADOKA Decoder
- PC
- WiFi
- MADOKA Correction Data Server
- Use MADOKA correction data from server if GNSS receiver does not have MADOKA decoder

Type – C : MADROID
- GNSS Antenna
- GNSS Receiver
  - L1/L2 GNSS Receiver Only
- Android Device
- WiFi
- MADOKA Correction Data Server
- Use MADOKA correction data from server
GNSS MADOCA Receiver and Antenna

Size: W: 55 x B: 55 x D: 15

GNSS and MADOCA Receiver
L1, L2, E5b, L6
GPS, GLONASS,
GALILEO, BEIDOU,
QZSS
Receiver System Architecture

- GNSS Antenna
  - L1, L2, L5, L6

- L1/L2 Antenna

- F9P Receiver
- GNSS Receiver
- L1/L2/E5B

- MADOCA DECODER
  - (QZSS, L6)

- COM Port: 1
  - Baud Rate: 115,200
  - (GNSS Data)

- COM Port: 2
  - Baud Rate: 57,600
  - (MADOCA Data)

- Micro-USB

- Splitter

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GNSS Raw Data, F9P Receiver Output
### GNSS Navigation Data Bits, F9P Receiver Output

#### UBX - RMN (Receiver Manager) - SFRBX (Subframe Data NG)

<table>
<thead>
<tr>
<th>SV</th>
<th>MSG</th>
<th>DATA [* denotes invalid words]</th>
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<tbody>
<tr>
<td>BDS 7</td>
<td>B1D1</td>
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</tr>
<tr>
<td>BDS 7</td>
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<td>BDS 8</td>
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<td>BDS 10</td>
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<td>BDS 11</td>
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<td>BDS 11</td>
<td>B2D1</td>
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<tr>
<td>BDS 13</td>
<td>B1D1</td>
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<tr>
<td>BDS 13</td>
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<td>BDS 14</td>
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<td>BDS 14</td>
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<td>BDS 23</td>
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<td>GAL 26 E1B</td>
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<td>GAL 30 E1B</td>
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<tr>
<td>GLO 1 L1CF</td>
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<td>3/2504</td>
</tr>
<tr>
<td>GLO 2 L1CF</td>
<td>2</td>
<td>3/2504</td>
</tr>
</tbody>
</table>
# GNSS Navigation Data Bits, F9P Receiver Output

## UBX - RKM (Receiver Manager) - SFR8K (Subframe Data NG)

<table>
<thead>
<tr>
<th>SV</th>
<th>MSG</th>
<th>DATA [* denotes invalid words]</th>
<th>Strip Parity Bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLO</td>
<td>2L1OF 4</td>
<td>2 3/2504</td>
<td>1A010022 91 C0C7E5 65214000</td>
</tr>
<tr>
<td>GLO</td>
<td>2L2OF 4</td>
<td>2 3/2504</td>
<td>1A010022 91 C0C7E5 65214000</td>
</tr>
<tr>
<td>GLO</td>
<td>7L1OF 5</td>
<td>6 5/2501</td>
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<tr>
<td>GLO</td>
<td>7L2OF 5</td>
<td>10 1/2501</td>
<td>5D1C698A 5F59885C 3E27DB00</td>
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<tr>
<td>GLO</td>
<td>8L1OF 6</td>
<td>2 3/2504</td>
<td>1A010408 2E2E277F 38082E00</td>
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<tr>
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<tr>
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<td>1L2OF -2</td>
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<td>1L3OF -2</td>
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<tr>
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<tr>
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<td>15L2OF 0</td>
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<td>GLO</td>
<td>17L1OF 4</td>
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<tr>
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<tr>
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<td>22C3C033 1DACE083 000230A7 1FB3DAB61 000145FD 36DA940 07C6477A 6113C462 9FE3C302 0846D75B</td>
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<tr>
<td>GPS</td>
<td>3L2CM 0</td>
<td>45 ??</td>
<td>880C3758 A20C013F 7ECD9935 0F3B800F B1682601 0015E003 2C01F5AD C01C9800 2D3A0EDC 3E6A80D0</td>
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<tr>
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<td>7L2CM 0</td>
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<td>881C3758 A201C723 A285886F 75F9F3EE 6F15CC14 042D2407 E201E58 00307500 2D2AEC35 E8CB1E</td>
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<td>GPS</td>
<td>8L1CA 0</td>
<td>3</td>
<td>22C3C033 1DACE083 0000321F 2A74037 00064906 1FCE85D 1F82227C 10A5752F B653A4A9 827C54E3</td>
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<td>8L2CM 0</td>
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<tr>
<td>GPS</td>
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<td>2</td>
<td>22C3C033 1DA6EAE7 0B69CC0D 9D4B504B 1D4B584F 3F000179 82699939 8917C86C 016A4D45 9695F938</td>
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<td>GPS</td>
<td>17L1CA 0</td>
<td>3</td>
<td>22C3C033 1DAC0A6B 00F39C3B 1F0C8BA9 3F7A285A 85D9A393 0A12F5A 04092F2 9F8A81F 0C7C9D97</td>
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<tr>
<td>GPS</td>
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</tr>
</tbody>
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GNSS Navigation Data Bits, F9P Receiver Output

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</tr>
</thead>
<tbody>
<tr>
<td>GLD</td>
<td>17L10F</td>
<td>2/3/2504</td>
<td>01A16E4 2A1433B8 8384300</td>
</tr>
<tr>
<td>GLD</td>
<td>17L20F</td>
<td>5/2/2504</td>
<td>2A8F0000 0000100 02650000</td>
</tr>
<tr>
<td>GLD</td>
<td>23L10F</td>
<td>3/2/2504</td>
<td>01A16C54 BE884C2C 983C7000</td>
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<tr>
<td>GLD</td>
<td>23L20F</td>
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<tr>
<td>GLD</td>
<td>24L10F</td>
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<td>3</td>
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<tr>
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<td>L1CM0</td>
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<td>88A0678B A26D0313 E7E5D385 6F890D0F B16E2001 001140C3 2C001FA0 C01C0080 2D80A9FD 3EFA8B0E</td>
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<tr>
<td>GPS</td>
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Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
# Satellite System & Signal Settings

## F9P Receiver

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Number of channels available: 60
Number of channels to use: 60

## MADOCA Decoder

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Number of channels available: 60
Number of channels to use: 60
Satellite System and Signal Settings

F9P Receiver

MADOCA Decoder
MADOCA Correction Data Output
Received Directly from QZSS L6E Channel
Type A: MAD-PI

MADOCA PPP based on RaspberryPi / Dual Frequency Receiver + MADOCA Decoder

RaspberryPi 4 with Touch Screen Display

Antenna L1/L2/L5/L6

RaspberryPi 4 Device

GNSS + MADOCA Receiver

GNSS + MADOCA Receiver
Type B: MAD-WIN

The position accuracy improves to cm (10 – 30 cm) level after initialization time of about 15min.
Type B: MAD-WIN

Receiver: Online receiver access in Kashiwa / Correction Data: MADOCA Receiver in Bali

After few minutes observation

After two hours observation

After three hours observation
Type C: MADROID / MADOCA PPP based on Android
Dual Frequency Receiver + Online MADOCA Data

Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
Type C: MADROID / MADOCA PPP based on Android
Dual Frequency Receiver + Online MADOCA Data
Position Data from MADOCA PPP

We walked straight along the concrete tiles (30cmx30cm) and PPP results showed perfect straight line. Accuracy is about 15cm.

Receiver: F9 + Online MADOCA Correction Data
MADROID PPP-AR with Local Correction Data

Test Area: Tokyo
GNSS Receiver Used: u-blox F9P
MADOCA Correction Data: u-blox D9
(Received online via NTRIP Server)
Local Correction Data: Service provided by GPAS
(Received online via NTRIP Server)
Output from MADOCA PPP
Device: RaspberryPi
MADOCA PPP Observation
Time: 2019-12-27 12:53:35
Latitude: 35.9030716°
Longitude: 139.9390085°
Altitude: 93.859m
Solution: PPP
Lat Error: 1.078m
Lon Error: 0.875m
Alt Error: 0.769m

Time: 2019-12-27 12:53:47
Latitude: 35.90393925°
Longitude: 139.93930080°
Altitude: 93.329m
Solution: PPP
Lat Error: 0.911m
Lon Error: 0.736m
Alt Error: 0.644m
**MADOCA PPP at Kashiwa Campus**

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Measured values compared to true values showing minimal differences.
MADOCA PPP at Kashiwa Campus
Part - B
Android GNSS Raw Data Measurement
New Tools for Android
GNSS Measurements

GSA Raw Measurements Workshop, Prague, 26 June 2019

v1.01

Frank van Diggelen
Google

Many slides in this presentation are based on the presentation document from Dr. Frank van Diggelen
Raw Measurement: Lecture Notes by Dr. Frank van Diggelen, Google Inc.

Location APIs, Measurement APIs

- Location APIs, android.gms.location
  - Places
  - Geofencing
  - Fused Location Provider (FLP)
  - Fit
  - Activity Recognition
  - Nearby

- Measurement/Sensor APIs, in android.location
  - Location
  - GnssMeasurement
  - GnssClock

GNSS Raw Measurements
All phones with:
- GNSS chips build date ≥ 2016
- OS ≥ Android N (Nougat)

Download the Lecture Notes from [https://home.csis.u-tokyo.ac.jp/~dinesh/GNSS_Raw.htm](https://home.csis.u-tokyo.ac.jp/~dinesh/GNSS_Raw.htm)
Raw GNSS Measurements

The Android Framework provides access to raw GNSS measurements on several Android devices.

Note: Google has released version 2.6.3.0 of the GNSS Analysis App. For more information, see the [GNSS Analysis app release notes](https://developer.android.com/guide/topics/sensors/gnss).

This article lists Android devices that support raw GNSS measurements as well as tools to log and analyze GNSS data. You can find the tools in the GPS Measurement Tools repo on GitHub, which includes the [GNSS Logger APK](https://developer.android.com/guide/topics/sensors/gnss). and the GNSS Analysis app for Linux, Windows, macOS, and the [Installation and User Manual](https://developer.android.com/guide/topics/sensors/gnss)

Original equipment manufacturers (OEMs), developers, and researchers can make use of the tools in this page to test new phone designs, validate functionality, develop new algorithms, evaluate improvements to the GNSS system.

https://developer.android.com/guide/topics/sensors/gnss
## GNSS Raw Data Compatible Smart-Phones

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</table>

Check ➔ [https://developer.android.com/guide/topics/sensors/gnss](https://developer.android.com/guide/topics/sensors/gnss) for Latest Updates
Android Raw Data Logging APPs

• GNSS Logger
  • Logs Raw Data
  • Some devices also output AGC and Navigation Bit Data
  • Multi Band Compatible

• Geo++ RINEX Logger
  • APP to generate RINEX Observation File
    • Dual Frequency Compatible

• GNSS Compare
  • Compares position accuracy from each type of GPS and GALILEO Signal
Android Raw Data Logging Tool – 1: GnssLogger

GnssLogger

GnssLogger

GnssLogger

GnssLogger

Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@cis.u-tokyo.ac.jp
GNSS Raw Data Output Format from Smart Phone Device

• #
• # Header Description:
• # Version: v2.0.0.1 Platform: 9 Manufacturer: Xiaomi Model: MI 8
• # Raw,
  • ElapsedRealtimeMillis,TimeNanos,LeapSecond,TimeUncertaintyNanos,FullBiasNanos,
  • BiasNanos,BiasUncertaintyNanos,DriftNanosPerSecond,DriftUncertaintyNanosPerSecond,
  • HardwareClockDiscontinuityCount,Svid,TimeOffsetNanos,State,ReceivedSvTimeNanos,
  • ReceivedSvTimeUncertaintyNanos,Cn0DbHz,PseudorangeRateMetersPerSecond,
  • PseudorangeRateUncertaintyMetersPerSecond,AccumulatedDeltaRangeState,
  • AccumulatedDeltaRangeMeters,AccumulatedDeltaRangeUncertaintyMeters,CARRIERFREQUENCYHz,
  • CarrierCycles,CARRIERPHASE,CARRIERPHASEUNCERTAINTY,MULTIPATHINDICATOR,
  • SNRINDB,CONSTELLATIONTYPE,AGCDB,CARRIERFREQUENCYHz
• # Fix,
  • PROVIDER,LATITUDE,LONGITUDE,ALTITUDE,SPEED,ACCURACY,(UTC)TIMEINMS
• # Nav,
  • SVID,TYPE,STATUS,MESSEAGETL,SUB-MESSEAGETL,DATA(Bytes)
GnssLogger: Sample GNSS Raw Data

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GnssLogger: Sample GNSS Raw Data, Header

## Header Description:

## Version: v2.0.0.1 Platform: 8.1.0 Manufacturer: Xiaomi Model: MI 8

## Raw, ElapsedRealtimeMillis, TimeNanos, LeapSecond, TimeUncertaintyNanos, FullBiasNanos, BiasNanos, BiasUncertaintyNanos, DriftNanosPerSecond, DriftUncertaintyNanosPerSecond, HardwareClockDiscontinuityCount, Svid, TimeOffsetNanos, State, ReceivedSvTimeNanos, ReceivedSvTimeUncertaintyNanos, Cn0DbHz, PseudorangeRateMetersPerSecond, PseudorangeRateUncertaintyMetersPerSecond, AccumulatedDeltaRangeState, AccumulatedDeltaRangeMeters, AccumulatedDeltaRangeUncertaintyMeters, CarrierFrequencyHz, CarrierCycles, CarrierPhase, CarrierPhaseUncertainty, MultipathIndicator, SnrInDb, ConstellationType, AgcDb, CarrierFrequencyHz

## Fix, Provider, Latitude, Longitude, Altitude, Speed, Accuracy, (UTC)TimeInMs

## Nav, Svid, Type, Status, MessageId, Sub-messageId, Data(Bytes)

#
GnssLogger: Sample GNSS Raw Data, Raw Data

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<th>Altitude</th>
<th>Speed</th>
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**GnssLogger: Sample GNSS Raw Data, Position and NMEA**

Fix, gps,35.850232,139.862279,37.854518,0.008482,4.000000,1543710718999
NMEA,$GPGSV,4,1,14,02,71,324,32,06,60,115,39,05,43,288,35,09,29,045,25*74
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NMEA,$QZGSV,2,1,05,01,83,285,31,03,41,201,33,02,07,171,22*53
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NMEA,$GPRMC,003159.00,A,3551.013922,N,13951.736758,E,000.0,337.0,021218,,,A*51
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Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
GnssLogger: Sample GNSS Raw Data, Navigation Bit Data

Nav,101,769,1,5,9,76,34,58,55,7,116,-65,67,-77,-42,88
Nav,102,769,1,5,9,76,34,58,55,7,116,-65,67,-77,-42,88
Nav,103,769,1,5,9,76,34,58,55,7,116,-65,67,-77,-42,88
Nav,105,769,1,5,9,76,34,58,55,7,116,-65,67,-77,-42,88
Nav,106,769,1,5,9,76,34,58,55,7,116,-65,67,-77,-42,88
GNSS Raw Data Analysis Tool for GnssLogger

- GNSS Analysis APP
  - Matlab-based Tool
  - Linux, Windows, MacOS
  - Version 2.6.3.0
  - Release Notes: https://developer.android.com/guide/topics/sensors/gnss#releaseGNSS Analysis app v2.6.3.0 release notes.

The GNSS Analysis app is built on MATLAB, but you don’t need to have MATLAB to run it. The app is compiled into an executable that installs a copy of the MATLAB Runtime.
Output from GNSS Analysis Tool, Data Logged by GNSSLogger

Data logged by Mi8 Smart-phone inside the car
Position Output from Android GNSS Receiver, Komaba

- Standard Position Computation
  - No DGPS or RTK Corrections
  - All visible GNSS Satellites are used
  - Frequency: L1/L5/E5
  - Surrounding: Tall Buildings around
Position Output from Android GNSS Receiver, Hongo
Position Output from Android GNSS Receiver

Smart-Phone is kept in an Open Area
Red Circle Radius: 5m
Position Output from Android GNSS Receiver, Melbourne

Smart-Phone is kept on a Bench in the park
Red Circle Radius: 5m
SEE Next SLIDE
Smart-Phone is kept on a Bench in the park
Red Circle Radius: 5m
Output from GNSS Analysis Tool, Data Logged by GNSSLogger

Location: Kennedy Space Center
Florida

Data logged by Mi8 Smart-phone inside the car
Driving from Hotel to Kennedy Space Center
Data logged by Mi8 Smart-phone inside the car
Driving from Hotel to Kennedy Space Center

Output from GNSS Analysis Tool, Data Logged by GNSSLogger
GNSS Position Data from Mi8 Android Device

Yellow Circles : Mi8 Device
White Circle    : 5m Radius

Location: SUVA, FIJI
GNSS Position Data from P20 Android Device

Red Circles : P20 Device
White Circle : 5m Radius

Location: SUVA, FIJI
GNSS Position Data from Mi8 & P20 Android Devices

Red Circles : P20 Device
Yellow Circles : Mi8 Device
White Circle : 5m Radius

Location: SUVA, FIJI
Android Raw Data Logging APP Geo++ RINEX Logger

Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
Geo++ RINEX Logger

Supports both L1 & L5


Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
Android Raw Data Logging APP: RTKDROID

• External GNSS Receiver can be connected to Android Device
• Base-Station is connected via NTRIP Address
• VRS Correction also supported
• Supported File Format
  • ubx (u-blox)
  • Other formats will be included if requested
    • SBF (Septentrio) will be included in near future
• Real-Time RTK
• Raw Data can be logged for Post-Processing
• Output from RTKDROID can be send to other APKs in the device
Android APP to Input GNSS Data for GIS: SW Maps

- Excellent APP to collect GIS Data in the field
- Internal or External GNSS Receiver can be used
  - External Receiver can be connected via BT or USB Cable
- Many Popular File Formats are Supported
  - u-blox
  - Topcon
  - Trimble
  - Septentrio
  - Garmin
  - Or Any Receiver with NMEA output
  - Output from RTKDROID can be send to SW Maps

RTKDROID and SW MAPS run in many Android Devices that has OS 5.0 or later
Contact and Additional Information

• Homepage
  • Main Page : https://home.csis.u-tokyo.ac.jp/~dinesh/
  • Webinar Page : https://home.csis.u-tokyo.ac.jp/~dinesh/WEBINAR.htm
  • Training Data etc. : https://home.csis.u-tokyo.ac.jp/~dinesh/GNSS_Train.htm
  • Low-Cost Receiver : https://home.csis.u-tokyo.ac.jp/~dinesh/LCHAR.htm
  • Facebook : https://www.facebook.com/gnss.lab/

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  • Skype : mobilemap