Receiver Selection Guidelines

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We have no intention to prefer any brand names mentioned in these slides. They are used only for reference. There are many other products in this category from different manufacturers, please search in internet.
Target Usage of the Receiver

• What is the purpose of the receiver?
  • Use as a CORS (Continuous Operating Reference Station)
  • Setup as a local Base-Station for RTK services
  • Field Survey
    • Geodetic Survey, Control Point Survey, Mapping
  • GIS, Facilities Management
  • Drone / UAV
  • Transport Monitoring
    • Tracking of vehicles, public transport for safety and security
    • Tracking of bicycles (Share-riding)
    • Trains
  • Marine
    • Vessels
      • 100tons or more than 300 tons require AIS for VMS
    • Passenger Boats
    • Smaller Fishing Boats, Pleasure boats

• What is the purpose of the receiver?
  • Agriculture
  • Timing Services
  • Space Weather
  • Scientific Applications

We will focus our discussions on High-End GNSS Receivers Because it costs tens of thousands of dollars and should last for more than 10 years of continuous operation
High-End Survey Grade GNSS Receivers

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Antenna for CORS or High-Accuracy Measurement

- Antenna with Choke Ring and Dome is used for CORS
- Choke ring helps to minimize multipath effects
- Dome protects from snow cover and other dusts as well as birds, animals or insects
- A normal base-station may use antenna without choke-ring and dome

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Slide: 4
Different Types of GNSS Antenna

- Patch Antenna
- Antenna for Aviation
- Helical Antenna
- Chip Antenna
- Paper Like Adhesive Antenna

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Antenna for CORS or High-Accuracy Measurement
Select antenna with calibration data

Also Refer:
https://www.ngs.noaa.gov/ANTCAL/FAQ.xhtml
https://igs.org/

- Select an antenna for CORS with technical documents such as Antenna Gain Pattern, Antenna Phase Center Offset (PCO) and Antenna Phase Center Variation (PCV) Data.
- PCO and PCV data for CORS antenna are also available at IGS website.

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# Specification Parameters to be Checked

<table>
<thead>
<tr>
<th>No</th>
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<th>Details</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>GNSS Systems</td>
<td>GPS, GLONASS, GALILEO, BEIDOU, QZSS, NAVIC, SBAS</td>
<td>Select the satellite systems that you would like to use. Normally GPS and GLONASS are already implemented. Other systems may be available with additional cost. QZSS and NavIC are regional systems and hence may not be visible in your region.</td>
</tr>
<tr>
<td>2</td>
<td>GNSS Signal Capabilities</td>
<td>GPS: L1C/A, L1C, L2, L5 GLONASS: L1, L2, L3 QZSS: L1C/A, L1C, L2, L5, L6 Galileo: E1, E5a, E5b, E5AltBOC Beidou: B1, B2, B3 NavIC: L5, S</td>
<td>Depending upon GNSS Systems, select the required signals. Many makers charge separately for each additional signal. RTK and PPP requires dual-frequency signals such as L1C/A, L1P(Y), L2P(Y). It is recommended to include L1, L2 and L5 navigation signals. QZSS L6 provides CLAS and MADOCA correction signals for high-accuracy. CLAS can be used only in Japan. Since QZSS is regional system, it may not be visible in your area.</td>
</tr>
<tr>
<td>3</td>
<td>Signal Processing Capability for High-Accuracy</td>
<td>RTK, PPP L-Band Correction, CLAS, MADOCA</td>
<td>All receivers designed for CORS provide RTK, PPP and many other signal processing technologies required for high-accuracy positioning. L-Band correction, CLAS and MADOCA are satellite and service provider specific.</td>
</tr>
<tr>
<td>4</td>
<td>Performance and Accuracy</td>
<td>SPS, DGPS, RTK, PPP Accuracy</td>
<td>Check the accuracy values the receiver can provide for each type of signal processing method. Also notice the conditions and affecting factors if given in the document with footnotes. Accuracy for RTK or differential observation are mentioned as XX cm + YY ppm. XX cm error is fixed error and YY error varies depending upon base-length (distance between base-station and field receiver (rover unit)). If YY = 1ppm, then every 10Km of base-length will have 1cm of error. If XX is 2cm, the total error is 2 + 1 = 3 cm for a base-length of 10Km.</td>
</tr>
<tr>
<td>5</td>
<td>Physical Data</td>
<td>Size, Weight, Shock, Vibration</td>
<td>If the receiver has to be used in machines such as tractors, excavators, heavy machines, construction machines etc. make sure that the receiver performance well under severe shock and vibration conditions.</td>
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<td>6</td>
<td>Electrical Data</td>
<td>Power consumption, Internal Battery, External Power Supply System</td>
<td>CORS are sometime installed in remote locations where continuous electrical power may not be available or where power outages are very common. In such locations, its better to have a receiver with internal battery. An external power source from Solar panel or battery system is required. Make sure that the receiver also has input port for battery power supply (12volt DC or similar).</td>
</tr>
<tr>
<td>7</td>
<td>Environment</td>
<td>Operating Temperature, Humidity, Dust, IP Rating,</td>
<td>Operating temperature is very important since CORS receivers are installed in various locations, sometimes outdoors (with simple enclosure) where temperature can’t be controlled. Depending upon location, day and night temperature may vary more than 20 degrees. Temperature variation may be as large as 50 degrees Celsius between summer and winter in some locations. Thus, the receiver must perform well even in this large variation of temperature. Though, outside air temperature varies a lot, the receiver temperature may not vary at the same level due to electrical circuits in the receiver. At least a receiver that performs from -20 to +60 deg. Celcius is required and should provide the performance accuracies mentioned in the technical specifications. However, internal battery performance degrades when the temperature goes down to -10C or lower. If your region has severe variation in temperature in winter and summer, -40 to &gt;+60 deg. C is recommended. An IP rating of 67 is recommended to protect from dust and water.</td>
</tr>
<tr>
<td>8</td>
<td>Connectivity</td>
<td>Serial, USB, Ethernet, WiFi, BT, NTRIP, Radio Link</td>
<td>Different types of interface (I/O ports) are available. An USB port will be quite easy to setup the receiver. An Ethernet port is required to connect the receiver to internet for remote access and logging etc. WiFi and BT (BlueTooth) are optional. NTRIP Caster and Server is strongly recommended for CORS receiver for remote data access via NTRIP.</td>
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<td>9</td>
<td>Data Storage</td>
<td>Internal Memory, External Storage Memory</td>
<td>An internal memory is strongly recommended. Select memory size that can accommodate for one month of raw observation data. Better to have also a connection port to an external memory device (USB Drive or Hard Disk).</td>
</tr>
<tr>
<td>10</td>
<td>Data Output Format</td>
<td>NMEA, RTCM., RINEX, BINEX, NAV Data, Proprietary</td>
<td>Normally high-end receivers provide all these output data formats. Need to confirm version for each data output format.</td>
</tr>
<tr>
<td>11</td>
<td>Clock Output</td>
<td>1PPS, 10MHz Clock Input / Output</td>
<td>1PPS output is required to feed timing signal to other devices for clock synchronization. Some, receivers also provide 10Mhz clock I/O.</td>
</tr>
<tr>
<td>12</td>
<td>Other Special Features</td>
<td>Multipath Rejection, Interference protection, Anti-Jamming, Spectrum, Ionosphere Mitigation, RAIM, A-RAIM</td>
<td>Some makers provide various types of proprietary technologies for multipath mitigation, interference mitigation, anti-jamming, IF data spectrum viewing, RAIM, A-RAIM etc.</td>
</tr>
<tr>
<td>13</td>
<td>Maintenance</td>
<td>Remote Logging, FW Upgrade,</td>
<td>Make sure that remote maintenance such as FW Update etc. can be done. This saves lots of time, efforts and money when receivers are installed in remote areas. But, all the receivers may not have this feature. Or it may require additional external systems.</td>
</tr>
</tbody>
</table>
Receiver and Antenna Test Setup

- If possible, setup a test area with four pillars as shown below.
- Measure the pillar reference points by Total-Station with mm-level accuracy
- Log GNSS data by setting antenna on top of the pillar
- Compute position of the pillar reference points using GNSS observation data
- Compute position difference between GNSS and True value for each point
- Also, compute all distance d1, d2, d3, d4, d5, d6, and height of pillar h1, h2, h3, and h4
- By using these pillar control points, various types of receivers and antenna performance can be analysed
- Make sure that the pillars are set in an open area
Exercise

- Download Technical Specification Documents from GNSS Makers for High-End Survey Grade Receivers
  - Such as Trimble, Septentrio, Novatel, Topcon etc.
- Download Technical Specification Document from GNSS Makers for Low-Cost Receivers
  - Such as u-blox, Septentrio MOSAIC etc.
- Compare the technical specifications using Excel file [TechSpec_SampleSheet_R1.xls]
Reference Slides
GNSS Errors
Background Information: Accuracy vs. Precision

- **Accuracy**
  - Capable of providing a correct measurement
  - Measurement is compared with true value
  - Affected by systematic error

- **Precision**
  - Capable of providing repeatable and reliable measurement
  - Statistical analysis of measurement provides the precision
  - Measure of random error
  - Systematic error has no effect

Neither Precise nor Accurate

Precise but Not Accurate

Accurate but Not Precise

Precise and Accurate
## GNSS Measurement Errors

<table>
<thead>
<tr>
<th>Measure</th>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root Mean Square</td>
<td>RMS</td>
<td>The square root of the average of the squared errors</td>
</tr>
<tr>
<td>Twice Distance RMS</td>
<td>2D RMS</td>
<td>Twice the RMS of the horizontal errors</td>
</tr>
<tr>
<td>Circular Error Probable</td>
<td>CEP</td>
<td>A circle's radius, centered at the true antenna position, containing 50% of the points in the horizontal scatter plot</td>
</tr>
<tr>
<td>Horizontal 95% Accuracy</td>
<td>R95</td>
<td>A circle's radius, centered at the true antenna position, containing 95% of the points in the horizontal scatter plot</td>
</tr>
<tr>
<td>Spherical Error Probable</td>
<td>SEP</td>
<td>A sphere’s radius centered at the true antenna position, containing 50% of the points in the three dimensional scatter plot</td>
</tr>
</tbody>
</table>

Commonly Used GNSS Performance Measurements

• TTFF
  • True Time to First Fix
  • Parameter: Cold Start, Warm Start, Hot Start

• Standard Accuracy
  • Accuracy attainable without any correction techniques

• DGPS Accuracy
  • Accuracy attainable by differential correction data
  • Code-phase correction

• RTK Accuracy
  • Accuracy attainable by differential correction data
  • Use both Code-Phase and Carrier Phase correction
TTFF and Typical Example Values

• TTFF
  • Cold Start : < 36 seconds
    • Time required to output first position data since the receiver power is on
    • No reference data like time or almanac are available
  • Warm Start : < 6 seconds
    • Time required to output first position data since the receiver power is on with the latest satellite almanac data in the receiver’s memory
    • Time and almanac related reference data are already known
  • Hot Start : < 1 second
    • Receiver has already output position data
    • Time to reacquire an already tracked satellite due to temporary blockage by buildings or trees
Performance Measurement of RTK Accuracy

• A fix error and a variable error with respect to base-length is given
  • Such as: $x \text{ cm} + y \text{ ppm}$
  • Example: $2\text{cm} + 1\text{ppm}$
    • There is a fix error of 2cm plus 1ppm error due to base-length between the Base and Rover
    • 1ppm $\rightarrow$ 1 parts per million
    • $\rightarrow$ 1cm of error in 1 million centimeter distance between the Base and the Rover
    • $\rightarrow$ 1cm of error in 1000000 centimeter distance between the Base and the Rover
    • $\rightarrow$ 1cm of error in 10000 meter distance between the Base and the Rover
    • $\rightarrow$ 1cm of error in 10 kilometer distance between the Base and the Rover
    • $\rightarrow$ 1cm of error for every 10Km of distance between the Base and the Rover
    • $\rightarrow$ 4cm of error for 40Km of distance between the Base and the Rover
  • Thus the total error is: $2\text{cm} + 4\text{cm due to 40Km of base length}$

• The longer the base-length, the larger the error
  • Do not assume that this error is linear
  • And it may not be valid for longer base-lines
  • Normally the recommended base-length for RTK for a Geodetic Receiver is 40Km