Lowest Power, Smallest Size
RTK Receiver Module

S2525F8-BD-RTK
“S2525F8-BD-RTK” OEM RTK Module

• Support RTK base and rover modes
• GPS L1 + BDS B1 + SBAS
• Tracks up to 28 satellites
• Position accuracy: autonomous 2.5m, RTK cm-level
• Sensitivity: -148dBm cold start, -160dBm tracking
• Receiver Autonomous Integrity Monitoring (RAIM)
• AGPS support
• 25mm x 25mm, 300mW

<table>
<thead>
<tr>
<th>Mode</th>
<th>Output</th>
<th>Output Baud Rate</th>
<th>Input</th>
<th>Input Baud Rate</th>
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<tbody>
<tr>
<td>Rover</td>
<td>NMEA-0183</td>
<td>115200</td>
<td>RTCM-SC104 3.0, 3.1 or SkyTraq-Raw</td>
<td>115200</td>
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<tr>
<td>Base</td>
<td>SkyTraq-Raw</td>
<td>115200</td>
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</table>
Potential RTK Applications

- UAS Mapping
- Agriculture
- Driverless Vehicle
- Surveying
- Construction
Baseline vs Accuracy

Rover Antenna: TW2710
Test Environment: Open Sky
Mode: Real-Time

A. Testing done by road side around 8:50AM with cars passing by or stopping for red light, thus result noisier even with shorter base line

B. Testing done on roof of a 20 floor building around 6:25AM

C. Testing done by road side around 11:20PM without cars passing by

D. Testing done in an empty parking lot around 9:30AM

Baseline 0.5km       TTAF 1 minute Accuracy 0.8 cm R95 (300sec)
Baseline 1km       TTAF 1.5 minutes Accuracy 0.6 cm R95 (300sec)
Baseline 1.5km     TTAF 2 minutes Accuracy 0.7 cm R95 (300sec)
Baseline 6.3km     TTAF 2.4 minutes Accuracy 1.0 cm R95 (300sec)

TTAF: Time To Ambiguity Fixed
Performance Comparison (1/6)

15 meter baseline
HX-CSX601A antenna
Power on 900sec, off 10sec
10 hour testing
S2525F8-BD-RTK GPS/BDS mode

Plot of all RTK fix points
(0,0) is true location

TTAF (sec)

UTC time
Performance Comparison (2/6)

testing another brand single-frequency GPS/GLONASS RTK receiver

2.4 meter baseline
Antenna: TW2710
Power on up to 900sec, off 10sec
12 hour testing

Time-To-Ambiguity-Fixed
(sec, when converged to true location)

1 time no RTK fix solution in 900sec

UTC time

Plot of all RTK fix points
(0,0) is true location
Performance Comparison (3/6)

testing another brand single-frequency GPS/GLONASS RTK receiver

2.4 meter baseline
Antenna: TW2710
Power on 900sec, off 10sec
12 hour testing

<table>
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<tr>
<th>Time (sec) to get FIX solution // UTC 02:00:00</th>
<th>Time (sec) to get FIX solution // UTC 07:00:00</th>
<th>Time (sec) to get FIX solution // UTC 11:00:00</th>
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<td>stable FIX (continuous 30s)</td>
<td>1st FIX</td>
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<tr>
<td>16</td>
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<tr>
<td>11</td>
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<tr>
<td>18</td>
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</tbody>
</table>

1st column: time to get 1st RTK fix solution
2nd column: time that RTK fix solution converged to true location
Yellow color: trials that has RTK fix solution matching true location from beginning
Performance Comparison (4/6)

Testing another brand GPS/GLONASS raw measurement receiver + RTKLIB

17 meter baseline
Antenna: HX-CXS601A
7 hour testing

Plot of all RTK fix points
(0,0) is true location

Time-To-Ambiguity-Fixed
(sec, when converged to true location)

1 time no RTK fix solution in 900sec
Performance Comparison (5/6)

15 meter baseline
Antenna: HX-CSX601A
Power on 900 sec, off 10 sec
10 hour testing
S2525F8-BD-RTK GPS-only mode

UTC time

TTAF (sec)

Plot of all RTK fix points (0,0) is true location

3 time deviation in decimeters

4 time no RTK fix in 900 sec in GPS-only mode due to less available satellite. We are still improving firmware performance to see how much it could be improved.
Performance Comparison (6/6)

- Unlike consumer GPS that works nearly everywhere, RTK receiver works only outdoors under open-sky with very little interference.

- With dual-satellite system, single frequency RTK receiver can have varying TTAF as seen on page-5, page-6, and page-8.

- With GPS-only single frequency RTK receiver, it may sometimes unable to get RTK fix solution or may have deviated RTK fix solution due to too few usable GPS satellites.

- As Beidou (BDS) system is not fully operational yet, users outside Asia will see lesser total number of satellites and performance will be between GPS-only mode and GPS/BDS mode as shown on page-5 and page-9.

- S2525F8-BD-RTK receiver performance will be better than any existing single-frequency GPS RTK receiver on the market due to additional Beidou satellites that it could use.

- GNSS Radar may be used to find out about the satellite situation in your region: [http://www.taroz.net/GNSS-Radar.html](http://www.taroz.net/GNSS-Radar.html)
Accuracy: GPS vs DGPS vs RTK

RTK receiver tested on 3 different days, tracks overlap. Its tracks serve as reference track for comparison.

DGPS result is near reference track, but don’t overlap well.

GPS result deviates on different day due to atmospheric delay error, don’t overlap well.

Other brand GPS result deviates on different pass in a testing on the same day, don’t overlap well.
Performance on Heavy Rainy Day

4.5km baseline, testing on a severe rainy day, getting mostly float solution

Section A: car drove on adjacent 3 lanes separated roughly 2 meters apart
Section B: car drove on the same lane on each pass

Although it’s mostly float solution with small number of fixed solution, the 3 tracks on section A are distinctively on separate lanes running in parallel, and the 3 tracks on section B roughly overlap, nearly as good as from fixed solution

Notice how the tracks look distinctly accurate and different from the GPS results shown in previous slide even when the result is mostly float solution
Dynamic Performance

Max speed 81Km/hr, 1.7Km baseline, blue : single, yellow : float, green : fixed
GPS Receiver

• Most GPS receivers use C/A code to measure position
• A C/A code chip is roughly 300 meters
• GPS receiver can determine position with resolution to fraction of a C/A code chip, resulting in 2.5 meter CEP 50%* accuracy from 4 or more GPS satellites

* 2.5m CEP 50% means 50% of the location points fall within 2.5m radius. It is equivalent to 95% confidence level falling within 5 meter radius
GPS Receiver Error

A rectangular land with 4 corners measured using GPS at different time on different days. When plotted on Google Earth, these 4 measured corners defined rectangular lands may have area shifted by 0 ~ +/-5 meters.

Shifted 10 meters for the worst case +5m and -5m shifts.

This is mostly due to ionosphere and troposphere delays.
RTK GPS Receiver (1/2)

- RTK GPS receiver counts carrier cycles to determine relative position from base station
- Each carrier cycle has wavelength of 19cm
- RTK receiver can determine relative position from base station with resolution to fraction of a carrier wavelength, resulting in centimeter-level position accuracy
RTK Receiver (2/2)

rover’s relative distance from base is accurate to centimeter level

If base position* is accurate to millimeter → rover position* will be accurate to centimeters

If base position* is accurate only to meters → rover position* will only be accurate to meters but relative distance from base is still accurate to centimeters

* position refers to the latitude and longitude numbers reported by base or rover
Usage Configuration 1

- Using S2525F8-BD-RTK as rover
- NTRIP Client
- RTCM 3.x
- NMEA output
- cm-level accuracy
- public free or commercial paid base station service, mm-level accuracy
Usage Configuration 2

- Using S2525F8-BD-RTK as base station
  - Carrier phase raw measurement
  - Wireless transmitter

- Using S2525F8-BD-RTK as rover
  - Carrier phase raw measurement
  - Wireless receiver
  - NMEA output
  - CM-level accuracy relative to base
Usage Configuration 2  2/4

• If a known surveyed point exists with centimeter position accuracy, placing base station S2525F8-BD-RTK antenna there, and enter the location coordinates into S2525F8-BD-RTK, then the rover NMEA output will have cm-level position accuracy.
RTK Usage Configuration 2   3/4

• If no known surveyed point exists, place the base station S2525F8-BD-RTK antenna at some fixed location that is to be later used as *reference point*.

• After base station S2525F8-BD-RTK self-surveyed, take note of the latitude/longitude location reported, to be entered as base station location for future use; also mark the physical location of the *reference point* for future use.

• Using this method, the rectangular land defined by 4 corners measured by GPS receiver that we shown earlier, if measured using RTK receiver over many different days, will only have area shifted in centimeters on Google Earth, not 10 meter!
With base set at a fixed location, the RTK rover determines the other three corner locations as

#1: 3315.78 wavelength to the right
#2: 2052.63 wavelength to the north
#3: 3315.78 wavelength to the right and 2052.63 wavelength to the north

Once base \((X,Y)\) is given a fixed coordinate, when RTK rover measures the other 3 corner coordinates at different days, the results will only differ by fractional wavelength, yielding centimeter-level accuracy relative to the base.

With this kind of rover-to-base relative positioning application, once base is set at a fixed location, accuracy of the \((X,Y)\) coordinate that we measured, meter or centimeter, is not important, so long as the same \((X,Y)\) coordinate number is used for base location, and base antenna is placed at same location afterwards when using rover to measure position.

For short baseline open-sky relative positioning application, lower-cost single-frequency RTK receiver could be used, a considerable cost saving from alternative multi-frequency RTK receivers.
Setup as Rover

- From GNSS Viewer*

Venus8 → RTK → Configure RTK Mode → RTK rover mode

* Using SkyTraq GNSS Viewer V2.0.166 or higher
Setup as Base (1/2)

• From GNSS Viewer

Venus8 \(\rightarrow\) RTK \(\rightarrow\) Configure RTK Mode \(\rightarrow\) RTK base mode
Setup as Base (2/2)

• From GNSS Viewer

1PPS Timing → Configure Timing → Static (input base position)
Application Example 1

• Precision Machine Control
  Once coordinates of the polygon corners are determined by the rover, precision steering of machine can be controlled by the autopilot software using the cm-level accuracy position provided by the RTK rover
Application Example 2

- Precision Aerial Imaging
  - RTK rover equipped UAV can take photo at predefined locations, centimeter-level exact, resulting in images that are always taken at the right spot, always consistent.
  - Acquire same amount of image data when flying against or with the wind.
Known Issue

- BDS is not defined in RTCM 3.x spec yet. Each company has proprietary RTCM 3.x base-station BDS implementation. So limited compatibility with existing base station for BDS initially, but GPS portion is compatible. We’ll provide support for additional different brand BDS base station as more information becomes available.

- GLONASS inter-channel bias is known to cause compatibility issue for different brand base & rover GPS/GLONASS RTK receivers, causing GLONASS portion not working for RTK when using rover with different brand base-station. Thus GPS/GLONASS RTK receiver will only have GPS satellites for RTK when used with different brand public base stations; in same situation as GPS/BDS RTK receiver could only use GPS satellites for RTK in US or Europe when connecting to public base station.

- When same RTK receivers are used for base and rover, then all receivable signals in the two satellite navigation systems can be used.
Lowest Power, Smallest Size

Empower your outdoor machine control, UAV aerial imaging, or GIS data collection applications with centimeter-level accuracy RTK technology!