

Comparing Fugro Satellite Positioning G4+, PPP-RTK, RTK and Network RTK

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Global Navigation Satellite Systems (GNSS) have revolutionized satellite navigation. From GPS with only 30 satellites in the previous century, adding Glonass with 24 satellites from 2000 and 26 Galileo satellites from 2016 to BeiDou3 with 46 satellites from 2020.

Within the field of high-precision positioning, five prominent techniques have emerged.

1. Real-Time Kinematic (RTK) in the 1990's
2. Network RTK from the year 2000
3. GNSS Precise Point Positioning (PPP) from 2009
4. GNSS Precise Point Positioning (PPP-RTK) with fixing of ambiguities from 2016.
5. Adding of regional ionosphere and tropospheric maps to improve converge from 2018 as done by e.g., the Japanese QZSS system.

Each method offers distinct advantages and disadvantages, making them suitable for different applications and scenarios.

Fugro Satellite Positioning G4+ PPP-RTK

GNSS Precise Point Positioning (PPP-RTK) is a technique that enables centimetre-level positioning accuracy for a moving receiver without the need of a nearby reference station. It uses the precise orbits and clocks of GNSS satellites. The error in the ionospheric is eliminated using multiple frequencies. Using satellite bias information (uncalibrated phase delays UPD) the delays in the satellite antennas are removed. This allows to fix the integer number of wavelengths for a global system.

Fugro Satellite Positioning does fix the complete number of wavelengths between GNSS satellite and mobile receiver. So, it also uses an RTK technique. Using 111 reference stations the precise orbit and clock corrections of GPS, Galileo, BeiDou3 and Glonass are broadcast over geostationary satellites. Uncalibrated Phase Delays (UPD's) for difference between two frequencies, the wide line, and the sum of two frequencies (narrow lane) are broadcast.

It takes around 10 minutes to fix ambiguities and get a stable PPP-RTK fixed position.

Advantages of PPP-RTK:

- Global coverage: GNSS PPP can be used anywhere on Earth, making it suitable for applications that require wide-area coverage.
- No infrastructure requirement: Since GNSS PPP doesn't require local reference stations, it is particularly useful in remote or inaccessible areas.
- Single receiver: Only a single GNSS receiver is needed, simplifying equipment setup and reducing costs.
- Continuous positioning: GNSS PPP can provide continuous positioning solutions even during short outages.
- Satellite Lband Communication offers 99.99% availability.

Limitations:

- Convergence time: The convergence time at startup to achieve centimetre-level accuracy in GNSS PPP is 10 minutes for 10 cm and 20 minutes for 5 cm height accuracy in 95% of the starts, making it less suitable for real-time applications needing instant positioning within several tens of seconds.
- L-band Satellites correction signals can be blocked by obstacles as windmill or wheelhouse.
- Precise orbit and clock corrections are required against subscription costs.

RTK (Real-Time Kinematic):

RTK is a real-time positioning technique that provides centimetre-level accuracy by using a base station to transmit correction data to a rover receiver. This method involves measuring the carrier-phase of GNSS signals and resolving the integer ambiguities to achieve high precision.

Advantages:

- Real-Time Accuracy: RTK provides within 1 minute after startup centimetre-level accuracy, making it suitable for applications requiring real-time positioning.
- Local Corrections: The base station provides real-time corrections, reducing the dependence on external data sources.

Limitations:

- Limited range: RTK's accuracy decreases as the distance between the base station and rover receiver increases, limiting its effective range.
- Ionosphere: During higher ionospheric activity at mid day the baseline length for which ambiguities can be fixed can be reduced during local day time.

Reference Station:

- RTK requires a reference station at a fixed base station, which requires a fixed save location and the cost of a reference station.
- It takes time to setup and maintain an RTK reference station.
- Line-of-Sight Requirement:
- RTK performance can be impacted by obstructions that block the line of sight communication between the base station and rover.

Network RTK:

Network RTK is an extension of RTK that utilizes a network of reference stations to provide correction data to rover receivers over a larger area. This approach aims to overcome the limitations of individual base stations.

RTK Baseline accuracy

The longer the baseline the harder it is to fix the correct ambiguities. This does depend on:

- Local phase multipath near the base and mobile antenna.
- Tropospheric weather fronts passing by with heavy rain showers.
- Ionospheric disturbance due to ions in the layer of 100-1000 km depending on solar activity.

The likelihood of fixing the correct wavelengths is reduced with longer baselines. Now it is the decision of the manufacturer how to tune its algorithms. The manufacturer can choose for a conservative approach where the RTK fixed solution is not available at longer distances or have relaxed statistics with a higher likelihood of fixing the incorrect wavelengths.

Advantages:

- Extended Range: Network RTK expands the coverage area by utilizing multiple reference stations, making it suitable for larger projects and regions.
- Reduced Base Station Setup: Rover receivers can access correction data optimized from multiple reference stations, eliminating the need to set up a dedicated base station.
- Improved Reliability: Network redundancy enhances reliability, as the rover can switch to another reference station's correction data in case of outages.

Limitations:

- Infrastructure dependency: Network RTK relies on a network of reference stations, necessitating ongoing maintenance and infrastructure investments, which is normally work for a service provider.
- Subscription costs: Access to network RTK correction data often comes with subscription fees.
- Data communication cost.
- Latency: Network RTK correction data transmission ideally need to arrive in one second. If the age of corrections increases the accuracy degrades and if RTK cannot fix the ambiguities +it becomes inaccurate at the sub decimetre level. The maximum age is 20 seconds with a higher change of not being able to fix the correct ambiguities.

Position accuracies

The Fugro Precise Point Positioning (PPP-RTK) G4+ positioning results do have horizontal accuracies of 6-8 mm standard deviation in east and north. 95% horizontal accuracies are below 25 mm the vertical accuracy is 2-3 cm RMS.

Real-Time Kinematic techniques uses a nearby GNSS base station and broadcasts corrections by UHF Radio or Cell phone to mobile users nearby. With RTK the total number of wavelengths between reference receiver and mobile is estimated and fixed.

Horizontal RTK single baseline

The major RTK manufacturers specify horizontal accuracy of 6-8 mm RMS at zero distance to the reference station. The degradation in accuracy as one travels away from the RTK reference station is horizontally 1 mm per km on a single baseline. This is 16-18 mm at 10 km distance and 32-36 mm at 20 km distance. The horizontal accuracy of Fugro Satellite Positioning is 20-40 mm depending on the location in the world. At 20 km distance Fugro Satellite Positioning and RTK are the same level of accuracy at larger distances it is better to use Fugro Satellite Positioning.

Vertical RTK single baseline

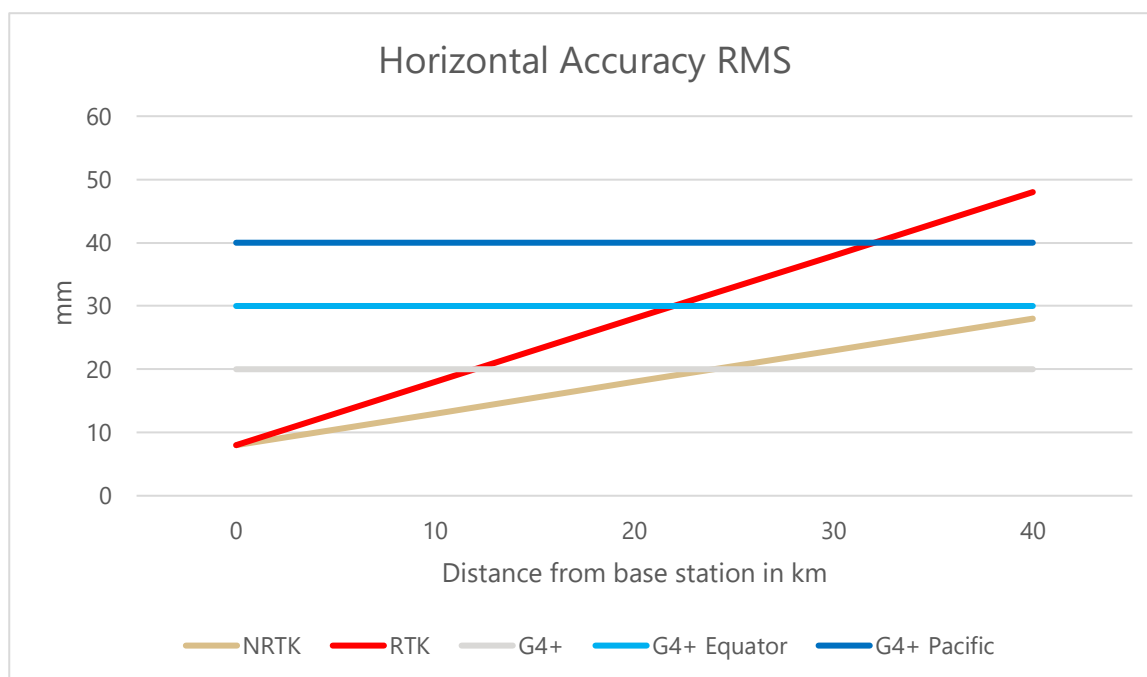
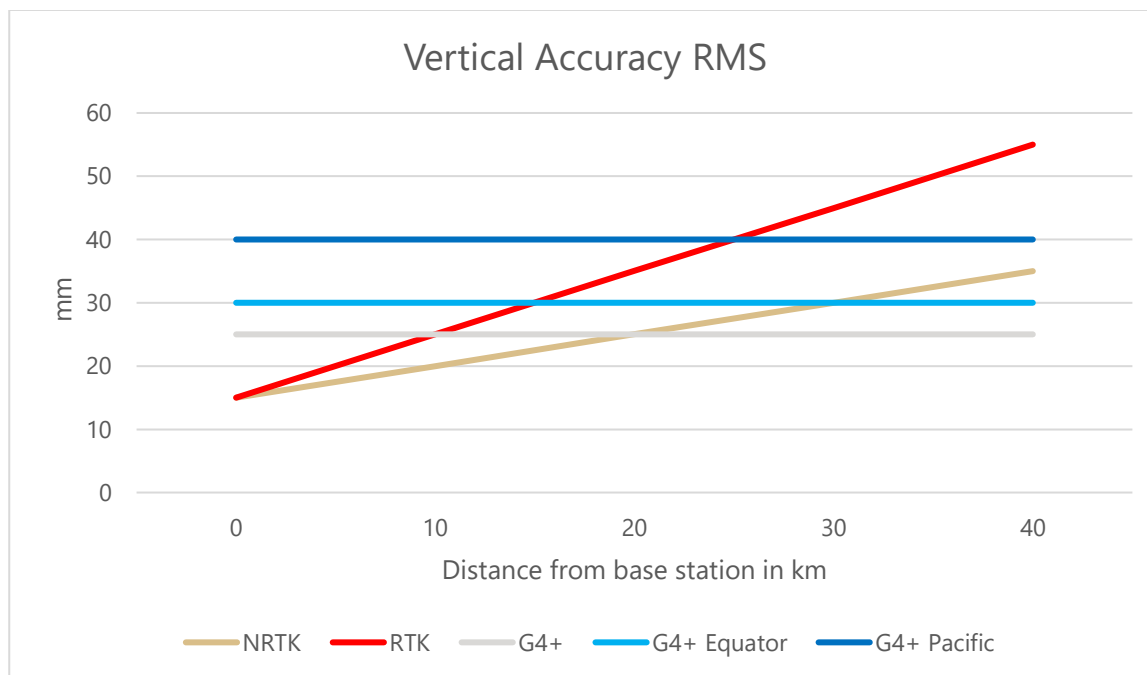
The vertical height accuracy of RTK is 10-15 mm when the reference station is near the base station. When the distance between the base station and the mobile gets larger, the tropospheric variation increases. Especially during heavy rain periods. The ionospheric variations do reduce the ability to fix ambiguities over longer distances. In the previous Solar cycle at maximum solar activity this reduced to a max of 6 km. This is related to sun heating the ionosphere causing higher variations in the total electron content during the local day. Marinestar PPP is not affected because the ionosphere is eliminated using dual frequencies.

RTK Network

Within the RTK Network this is 6-8 mm + 0.5 mm per km from the nearest baseline. Most RTK networks have an inter station distance of 50-70 km, so the maximum distance is 30 km to the nearest reference station than the horizontal accuracy is 6-8 mm+15 mm = 21-23 mm RMS.

Some network providers do have inter distances of 100 km. These distances are too large to allow continuous RTK Fixed positioning with high reliability. The maximum distance within the network is 50 km so that is 6-8 mm+ 50*0.5 mm = 32-35 mm RMS.

When using an RTK Network outside the network the performance is in the order of the single baseline because the network cannot extrapolate the tropospheric and Ionospheric errors. Most RTK Networks are land based. Some RTK networks do have extensions into sea, but at larger inter distances as it is difficult to find platforms for base stations.



Conclusion

At distances further away than 30 km of RTK networks and with baselines which are longer than 20 km, RTK accuracy deteriorates, hence it is better to use in this case Fugro-Marinestar G4+.

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