

ASSESSMENT OF THE INFLUENCE OF GNSS RECEIVER HEIGHT ON RTK MEASUREMENT ACCURACY

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ABSTRACT. This paper presents a comparison of RTK accuracy for two ways of placing a GNSS receiver: on a mini tripod and on a 2 m survey pole with a bipod. The test included 10 control points, three observation sessions, and 180 separate RTK measurements. The results show that the average PDOP value was 1.441 for the mini tripod and 1.390 for the pole with a bipod, while the average number of satellites was 15.844 and 16.222, respectively. The average horizontal precision reported by the controller was 0.007 m for the mini tripod and 0.005 m for the 2 m pole. The average vertical precision was 0.012 m and 0.008 m. The average between-session differences were 0.008 m in plan and 0.012 m in height for the mini tripod, and 0.005 m and 0.008 m for the pole with a bipod. The study shows that a lower antenna height does not seriously worsen satellite geometry, but the 2 m pole provides slightly better repeatability, especially for height.

Key words: RTK GNSS, measurement accuracy, surveying, ground control points, coordinate repeatability.

ОЦЕНКА НА ВЛИЯНИЕТО НА ВИСОЧИНАТА НА GNSS ПРИЕМНИКА ВЪРХУ ТОЧНОСТТА НА RTK ИЗМЕРВАНИЯТА

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РЕЗЮМЕ. Тази статия представя сравнение на точността на RTK при два начина на поставяне на GNSS приемник: върху мини статив и върху 2-метров геодезически стълб с двунога. Тестът включва 10 контролни точки, три сесии на наблюдение и 180 отделни RTK измервания. Резултатите показват, че средната стойност на PDOP е 1.441 за мини статива и 1.390 за стълба с двунога, докато средният брой сателити е съответно 15.844 и 16.222. Средната хоризонтална точност, отчетена от контролера, е 0.007 м за мини статива и 0.005 м за 2-метровия стълб. Средната вертикална точност е 0.012 м и 0.008 м. Средните разлики между сесиите са 0.008 м в план и 0.012 м във височина за мини статива, и 0.005 м и 0.008 м за стълба с двунога. Проучването показва, че по-ниската височина на антената не влошава сериозно геометрията на спътника, но 2-метровият стълб осигурява малко по-добра повторяемост, особено по отношение на височината.

Ключови думи: RTK GNSS, точност на измерване, геодезия, наземни контролни точки, повторяемост на координатите.

Introduction

RTK GNSS is widely used in topographic, cadastral, construction, and mine survey work because it allows surveyors to obtain coordinates quickly with centimetre-level accuracy. However, real RTK accuracy depends not only on the receiver and base corrections, but also on how the antenna is placed above the point.

In field work, a standard 2 m pole is common. At the same time, compact mini tripods are used more often in rough ground, in areas with bushes, or in hard-to-reach places. They are easier to carry and have a fixed height, but a lower antenna may reduce the view of the sky and increase signal reflection. Therefore, it is important to evaluate how receiver height affects RTK measurement accuracy.

The aim of this study is to evaluate how receiver height affects RTK results by comparing two setups: a Rothbucher mini tripod and a 2 m carbon survey pole with a bipod.

The main tasks were to compare the number of satellites and PDOP, assess horizontal and vertical precision from the controller, calculate between-session coordinate differences, and summarize the practical strengths and limits of both setups.

Theoretical part

RTK GNSS positioning is based on real-time processing of carrier phase measurements, allowing centimetre-level accuracy under favourable conditions. The accuracy of RTK results depends on several factors, including satellite geometry, signal quality, multipath effects, and observation conditions (Hofmann-Wellenhof et al., 2008; Misra & Enge, 2011).

Satellite geometry is commonly evaluated using the PDOP (Position Dilution of Precision) parameter, which reflects the spatial distribution of satellites. Lower PDOP values indicate better observation conditions and higher potential positioning accuracy (Leick et al., 2015).

In practical surveying, the placement of the GNSS antenna plays an important role in ensuring reliable signal reception. Obstacles such as trees, buildings, and terrain irregularities may cause signal obstruction and multipath effects, leading to reduced accuracy (El-Rabbany, 2002).

The height of the receiver antenna influences the visibility of the sky and the level of signal reflection from surrounding objects. A higher antenna position generally improves observation conditions, while a lower position may increase the risk of signal interference. However, the extent of this influence under real field conditions requires experimental verification.

Therefore, the analysis of receiver height as a factor affecting RTK measurement accuracy is important for optimizing field surveying techniques and ensuring reliable spatial data.

Methodology

The methodology of this study is based on a comparative experimental approach aimed at evaluating the influence of GNSS receiver height on RTK measurement accuracy under real field conditions.

The study was carried out on 10 control points located within an area of approximately 20 hectares. The points were selected to represent typical surveying conditions, including areas with partially obstructed sky visibility due to trees, buildings, and

terrain features. This ensured that the obtained results reflect practical field situations.

Each control point was measured 18 times: 9 times using a Rothbucher mini tripod and 9 times using a 2 m carbon survey pole with a bipod. The measurements were conducted in three observation sessions (29.01.2026 AM, 30.01.2026 AM, and 31.01.2026 PM), resulting in a total of 180 RTK measurements.

A Trimble R10 receiver was used as the base station, while a Trimble R12 receiver was used as the rover. The maximum distance to the farthest control point did not exceed 400 m, ensuring stable RTK corrections throughout the experiment.

Before each measurement, the equipment was carefully repositioned over the control point, and the antenna height was set according to the selected setup. The RTK solution was reinitialized before every observation to ensure independent measurements. Each observation lasted approximately 15 seconds.

During each measurement, the controller recorded key parameters, including horizontal precision, vertical precision, PDOP, and the number of satellites. These indicators were used to evaluate both positioning accuracy and observation conditions.

For the analysis of repeatability, differences between average coordinates obtained in different sessions were calculated for ΔN , ΔE , and ΔH . The horizontal displacement was determined using the expression $\sqrt{(\Delta N^2 + \Delta E^2)}$. Additionally, statistical indicators such as standard deviation and maximum spread were used to assess the stability of the results.

Results and discussion

The analysis of the observation data showed that both receiver setups operated under nearly identical satellite conditions. The average PDOP values were 1.441 for the mini tripod and 1.390 for the pole with a bipod, while the average number of satellites was 15.844 and 16.222, respectively. This indicates that reducing the antenna height did not significantly degrade satellite geometry, which is consistent with the availability of multiple GNSS constellations.

At the same time, the controller-reported precision demonstrated a clear advantage of the standard 2 m pole. The average horizontal precision was 0.007 m for the mini tripod and 0.005 m for the pole, while the vertical precision was 0.012 m and 0.008 m, respectively. Thus, the higher antenna position provides slightly better positioning accuracy in both plan and height components.

A more detailed analysis by observation sessions (Table 1) showed that the third session was characterized by less favorable satellite conditions.

Table 1. Average RTK values by observation session

Session	Setup	Hz_Prec, m	Vt_Prec, m	PDOP	Satellites
29.01.2026 AM	Mini tripod	0.007	0.012	1.377	16.633
30.01.2026 AM		0.007	0.011	1.420	16.367
31.01.2026 PM		0.008	0.013	1.527	14.533
29.01.2026 AM	2 m pole + bipod	0.005	0.008	1.327	16.967
30.01.2026 AM		0.005	0.007	1.337	17.067
31.01.2026 PM		0.006	0.008	1.507	14.633

Despite these less favorable conditions, the pole with a bipod maintained better precision, confirming its higher stability in more difficult environments.

The comparison of repeatability indicators (Table 2) further supports this conclusion. The average between-session coordinate differences for the mini tripod were 0.008 m in plan and 0.012 m in height, whereas for the pole these values were reduced to 0.005 m and 0.008 m. Similarly, the average standard deviation and maximum spread values were consistently lower for the pole configuration, especially in the vertical component.

Table 2. Summary of accuracy and repeatability

Indicator	Mini tripod	2 m pole + bipod
Number of control points	10	10
Number of RTK measurements	90	90
Average PDOP	1.441	1.390
Average number of satellites	15.844	16.222
Average controller horizontal precision, m	0.007	0.005
Average controller vertical precision, m	0.012	0.008
Average maximum horizontal spread, m	0.022	0.017
Average maximum height spread, m	0.032	0.024
Average horizontal standard deviation, m	0.008	0.006
Average height standard deviation, m	0.011	0.008
Average between-session horizontal difference, m	0.008	0.005
Average between-session height difference, m	0.012	0.008

These results indicate that the increased antenna height improves the stability of RTK measurements, particularly in terms of height determination. This can be explained by a better observation geometry and reduced influence of local obstacles and multipath effects.

From a practical point of view, both setups remain applicable depending on field conditions. The mini tripod is more convenient in rough terrain, forested areas, or locations with limited accessibility. However, when high repeatability and maximum accuracy are required, especially for control networks or deformation monitoring, the use of a standard 2 m pole with a bipod is preferable.

Conclusion

The conducted study showed that reducing the receiver height does not significantly affect satellite geometry, as the PDOP values and the number of tracked satellites remained similar for both setups. At the same time, the standard 2 m pole demonstrated higher positioning precision and better repeatability, particularly in the vertical component. The between-session coordinate differences and statistical indicators confirmed the greater stability of the pole configuration. Therefore, while the mini tripod can be effectively used in difficult field conditions, the 2 m pole with a bipod is

recommended for tasks requiring higher accuracy and reliability of RTK measurements.

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