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Case Report

Evaluation of GNSS accuracy when linked between DOL and RTSD Networks and impacts of SIM card insertion between controller and receiver

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ABSTRACT

This study examines the accuracy performance of GNSS receivers when connected to the continuous reference station (CORS) network managed by Thailand's Department of Lands (DOL) and the Royal Thai Survey Department (RTSD), focusing on the impact of inserting SIM cards between the receiver and controller. Three GNSS receivers were tested: two from the same brand but different models, and one from a different brand. The research investigates how the CORS network's effectiveness and the method of SIM card insertion influence the data accuracy and receiver stability. The results show that data stability improves when connected to the RTSD's CORS network, with more consistent and reliable performance observed when SIM cards are inserted directly into the receiver. In contrast, inserting the SIM card into the controller led to significant instability in the GNSS data. These findings highlight the importance of both network choice and proper SIM card placement for optimal GNSS performance.

1. Introduction

1.1 Origin and importance

In Thailand today, the fields of measurement and surveying are going through a major shift. Traditional methods are being upgraded as modern technology becomes a bigger part of the process. One of the biggest changes is the growing use of advanced tools that make surveying faster, easier, and more accurate. A key player in this transformation is the Global Navigation Satellite System (GNSS) receiver a modern device that has quickly become a favorite among surveyors and engineers. The GNSS receiver works by picking up signals sent from satellites in space and converting them into precise location data here on Earth. Unlike traditional equipment like theodolites or total stations, which require line-of-sight measurements and manual setups, GNSS systems allow users to pinpoint locations with much greater ease. This technology helps overcome many of the limitations of older tools and has become especially popular with professionals in Thailand who are moving toward more modern and efficient ways of working. One of the biggest advantages of using a GNSS receiver is how accurate and fast it is. It can collect reliable data much more quickly than older methods and with far fewer chances for human error. Whether you're marking boundaries, planning a new construction project, or mapping out terrain, GNSS makes the job easier. It's also user-friendly often just requiring a quick setup and the press of a button to start collecting data. This simplicity is especially helpful in real-world conditions, where traditional tools might struggle with obstructions or visibility issues. A major part of using GNSS effectively in Thailand involves tapping into the CORS (Continuously Operating Reference Station) Network, which provides real-time correction data to improve accuracy. This network has been rolled out across the country and supports a wide range of GNSS activities. In practice, however, most engineers connect their receivers to services offered by two key government departments: the Department of Lands (DOL) and the Royal Thai Survey Department (RTSD). Because precise coordinates are crucial for many tasks like land registration, infrastructure development, and construction this research focuses on comparing the accuracy of the GNSS system when connected to the DOL and RTSD networks. The goal is to see if one provides better results than the other. It also looks at how where you place the internet SIM card either directly in the GNSS receiver or in the external controller affects the accuracy of the position data. By studying these factors, this research hopes to give professionals a clearer understanding of what setup delivers the best performance. Ultimately, the insights gained from this work could help improve how surveying is done in Thailand making it more efficient, more accurate, and more aligned with the demands of modern infrastructure and land management.

1.2 Objectives of the research

The main objective of this study is to understand how different GNSS configurations affect the accuracy of location data used in surveying and mapping in Thailand. Specifically, the research focuses on two key variables: the CORS (Continuously Operating Reference Station) network to which the GNSS receiver is connected, and the placement of the internet SIM card whether it's inserted into the receiver itself or into the external controller. In Thailand, most engineers and surveyors typically connect to either the Department of Lands (DOL) network or the Royal Thai Survey Department (RTSD) network. This study aims to compare these two networks in terms of their ability to deliver precise and consistent coordinate data.

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Nomenclature

GNSS	Global Navigation Satellite System	*SIM*	Subscriber Identity/Identification Module
CORS	Continuously Operating Reference Station	*PPP*	Precise Point positioning
RTSD	Royal Thai Survey Department	*PDA*	GNSS receiver Controller
DOL	Department of Lands	*REC*	Receiver
GPS	The Global Positioning System	*RTK*	Real-Time Kinematic
OSCAR	Tersus's receiver	*PA*	Precision Agriculture
BeiDou	BeiDou Navigation Satellite System	$E100$, $E100$	E-Survey's receiver

Additionally, it investigates whether the physical placement of the SIM card makes a measurable difference in performance. The goal is to provide practical guidance to professionals on how to optimize their GNSS setup for better accuracy and efficiency in the field.

1.3 Scope of research

This research was carefully designed to focus on real-world applications while maintaining controlled conditions for reliable comparison. The tests were conducted on the rooftop of a three-story building, a location chosen specifically to ensure a clear, unobstructed view of the sky for optimal satellite signal reception. Three different GNSS receivers were used in the study: two models from the same brand and one from a different brand, allowing for analysis across both similar and varied devices. Each receiver was tested under multiple configurations connected to both the DOL and RTSD networks, and with the SIM card placed either in the receiver or in the controller. Importantly, the same internet SIM card was used throughout all tests to ensure consistent connectivity and eliminate external variables. This controlled approach allowed the research to isolate and evaluate the impact of network choice and SIM card location on GNSS performance[1].

1.4 Research hypothesis

The researchers hypothesized that placing the SIM card directly into the GNSS receiver would result in better data accuracy and stability than placing it into the controller. This is based on the assumption that a direct connection within the receiver would provide a stronger, more stable data link to the correction signal, thereby improving the overall precision of the positioning output. In addition, it was expected that the RTSD network would outperform the DOL network in terms of accuracy, due to potential differences in infrastructure, correction signal reliability, or network coverage. By testing these expectations through a structured set of experiments, the study aimed to determine whether small setup choices—like which network to use or where to place a SIM card can significantly affect the quality of GNSS survey data in practice.

2. Experimental methods

2.1 Review of related research

2.1.1 Role of multi-constellation GNSS in the mitigation of the observation errors and the enhancement of the positioning accuracy

This article explores the use of Precise Point Positioning (PPP) techniques with a single GNSS receiver to achieve centimeter-level accuracy [2, 3]. It evaluates the integration of GPS, GLONASS, Galileo, and BeiDou systems. It was found that combining GPS and Galileo data reduces the integration time, and GPS, GLONASS, and BeiDou have the lowest error values in the north and east directions, while GLONASS, Galileo, and BeiDou have the lowest error values in the upward direction.

2.1.2 Experimental testbed and methodology for the assessment of RTK GNSS receivers used in precision agriculture

This article presents the setup and experimental testing methods for evaluating devices using RTK GNSS technology in Precision Agriculture (PA), [4–6]. Choosing a reliable reference system is essential for assessing positional and directional errors. The study found that the tested devices, especially new models, are exceptional in characterizing and operating in environments with trees. However, issues were found in real agricultural environments, emphasizing the need for reliable wireless signal channels and mobile network coverage. Despite these limitations, RTK GNSS technology devices significantly improve the navigation of machinery and operations in agricultural fields.

2.1.3 Evaluation of the Impact of Ionospheric Anomalies on GNSS Positioning Accuracy and Mitigation Techniques

Ionospheric disturbances affect the accuracy and stability of the Global Positioning System (GPS), especially near the equator, leading to high levels of GPS signal interference and reduced positional accuracy. This article proposes statistical methods using dual-frequency receivers to mitigate the impact of ionospheric disturbances on GPS accuracy and stability [7–10]. It uses the Rate of Total Electron Content Index (ROTI) to classify disturbance levels and evaluate pseudorange error deviations under different groups by combining ROTI with satellite elevation. An improved stochastic model is used to enhance positional accuracy. The tests recommend specific adjustments for each group to reduce errors and prevent hazards caused by ionospheric interference. This approach effectively mitigates ionospheric disturbances on GPS systems and can be appropriately applied to prevent GPS system interference.

2.2 Study area selection

For this study, a corner of the rooftop on a three-story building was chosen as the testing area. This spot was picked because it had a completely clear view of the sky, with no tall buildings, trees, or other obstacles nearby that could block or interfere with satellite signals, [11–14]. Having an open, obstruction-free space is really important when working with GNSS equipment, since it needs a strong and steady connection to satellites to collect accurate data. By using this kind of setting, the researchers could make sure that the results weren't affected by outside factors like signal blockage or interference. It also helped create the same conditions for every test, so any differences in the results could be traced back to the GNSS setup itself not the environment.

2.3 Reference Point Selection

To ensure consistency in the measurements, a fixed reference point was set up right at the corner of the rooftop, Fig. 1. This spot served as the central location where all GNSS receivers were positioned during testing. By using the same reference point for every test, the researchers could fairly compare the results from different devices and configurations. It also helped make sure that any differences in accuracy weren't due to changes in position, but rather to the specific setup—like which network was used or where the SIM card was inserted.

Figure 1. Non-obstruction building.

2.4 Data collection

Each GNSS receiver was used to collect real-time RTK (Real-Time Kinematic) signals once every second, with a total of 1,000 data points recorded per setup. The testing included *three* different GNSS receivers Oscar, E600, and E100 and each was tested under the same set of conditions to ensure consistency.
I) For each receiver, four specific configurations were used to explore how SIM card placement and network connection affected performance:

- PDA-DOL: SIM card inserted in the receiver, connected to the Department of Lands (DOL) network.
- PDA-RTSD: SIM card inserted in the receiver, connected to the Royal Thai Survey Department (RTSD) network.
- REC-DOL: SIM card inserted in the controller, connected to the DOL network.
- REC-RTSD: SIM card inserted in the controller, connected to the RTSD network.

II) The testing configurations for each device were as follows:

- **Oscar**: PDA-DOL, PDA-RTSD, REC-DOL, REC-RTSD.
- **E600**: PDA-DOL, PDA-RTSD, REC-DOL, REC-RTSD.
- **E100**: PDA-DOL, PDA-RTSD, REC-DOL, REC-RTSD.

This structured approach made it possible to directly compare how each factor device model, network choice, and SIM card location impacted the accuracy and stability of the GNSS data.

2.5 Data Analysis

The collected GNSS data was processed and analyzed using Pythagoras software, a professional tool widely used in surveying and geospatial analysis. This software enabled the researchers to visually and statistically assess how tightly the data points clustered around the reference location under each test condition. The analysis focused on three main comparisons: same brand and same model, same brand but different models, and different brands and models [15–17]. By examining the spread and concentration of the data in each scenario, the study was able to evaluate the influence of both hardware differences and configuration settings—such as network connection and SIM card placement on positional accuracy. This clustering analysis was a critical step in identifying which combinations provided the most stable and precise GNSS performance across all tested devices.

3. Results and discussion

3.1 Same brand and same model

From Fig. 2, Fig. 3 and Fig. 4, the performance of a GNSS receiver from the same brand and model under four different setups. Two main variables were changed: the network it connected to (DOL or RTSD), and where the SIM card was placed (inside the receiver or inside the controller). The data showed a clear trend: inserting the SIM card into the GNSS receiver consistently resulted in tighter, more concentrated clusters of coordinate data. This means the receiver was more stable and accurate in collecting position information when the SIM was placed directly inside it. On the other hand, placing the SIM card in the controller led to a broader spread in the recorded data, indicating slightly more error or instability. When connected to the RTSD network, the positional discrepancy between the two setups (SIM in receiver vs. controller) was only about 1.06 centimeters.
In contrast, when connected to the DOL network, the discrepancy between the two setups (SIM in receiver vs. controller) was about 0.08 centimeters. More stable but have more discrepancy than connect to RTSD. This result clearly indicates that both the choice of network and the SIM card placement influence the quality of GNSS data, and the RTSD network paired with SIM-in-receiver setup offers superior precision.

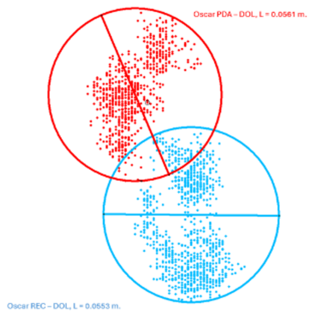

Figure 2. Oscar when connected to DOL.

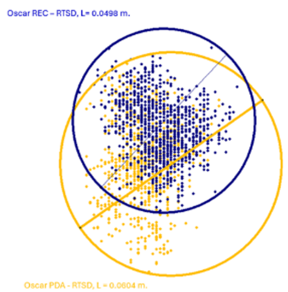

Figure 3. Oscar when connected to RTSD.

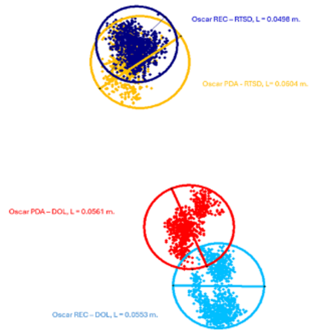

Figure 4. Oscar when connect to both DOL and RTSD.

3.2 Same brand and different model

From Fig. 5 and Fig. 6 a analogize two different models of GNSS receivers from the same brand. The goal here was to see whether newer or alternative models perform differently under the same testing conditions. The trend observed earlier remained consistent: placing the SIM card directly into the receiver resulted in more precise and stable data clusters compared to using the controller as the SIM host. This confirms that the earlier finding isn't model-specific; it's a general performance behavior across models. Moreover, regardless of whether it was the E600 or E100 model, the RTSD network again demonstrated better performance. The data points were closer to the known reference point, which suggests the corrections provided by the RTSD network are more effective or stable than those from the DOL network. This finding is significant for engineers and surveyors because it means even when working with different hardware configurations from the same brand, the best performance still comes from choosing the RTSD network and placing the SIM in the receiver. [18–20].

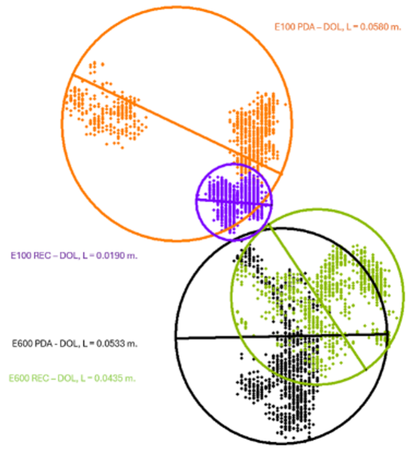

Figure 5. E600 and E100 when connect to DOL.

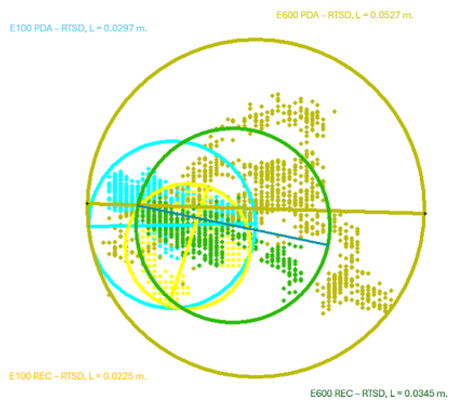

Figure 6. E600 and E100 when connect to RTSD.

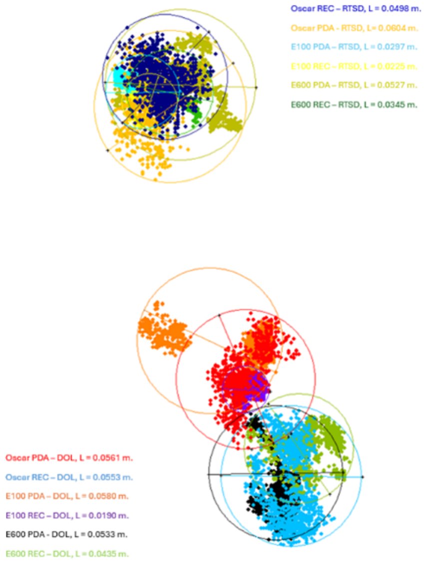

Figure 7. All receivers when connect to DOL and RTSD.

3.3 Different brands and different models

In this final comparison shown in Fig. 7, all three GNSS receivers each from different models and potentially different brands were tested under both network conditions. The results continued to align with earlier findings:

- Connecting to the RTSD network provided consistently closer and tighter groupings of position data, even across different brands and models.
- On the other hand, when connected to the DOL network, the data clusters were generally more spread out, and this trend held true for every receiver tested.
- In simple terms, the RTSD network helped ünify"the data quality across devices, making them more reliable regardless of their make or model. Meanwhile, the DOL network resulted in more variability.

This outcome is especially important for teams using mixed equipment. It suggests that choosing the RTSD network can help standardize accuracy across a project, even when different tools are used. [21–25].

4. Conclusion

This research set out to explore how two practical factors—the placement of the SIM card (in the GNSS receiver vs. the controller) and the choice of CORS network (Department of Lands vs. Royal Thai Survey Department)—affect the accuracy of GNSS-based positioning in Thailand. Through a series of controlled tests using multiple GNSS receivers of different brands and models, the results clearly demonstrated two important takeaways:

- Placing the SIM card directly into the GNSS receiver significantly improves accuracy compared to inserting it into the controller. When the SIM was placed in the receiver, the data points were noticeably more concentrated, leading to more consistent and stable positioning. For example, in tests using the same model (E600 receiver), the distance between PDA and REC was: 0.0527 meters (PDA) and 0.0345 meters (REC).
  This shows a nearly 1.53 times better positional consistency when using the RTSD network and placing the SIM in the receiver.
- The RTSD (Royal Thai Survey Department) network consistently outperformed the DOL (Department of Lands) network in terms of data accuracy. This was true across all devices tested—whether they were the same brand/model or from different manufacturers. The RTSD network produced tighter clustering of points and smaller positional discrepancies, indicating more reliable real-time corrections.

Additionally, when comparing different models (E600 and E100) and even different brands altogether, the pattern held strong:

$$RTSD + SIM\ in\ the\ receiver = Best\ performance$$

In summary, if you're working in the field and aiming for the most precise GNSS results, the evidence strongly suggests that the optimal setup is to use the RTSD network and insert the internet SIM card directly into the GNSS receiver. This combination not only reduces positioning errors but also simplifies the data collection process, saving time and resources while increasing confidence in the results. These insights are especially relevant for Thai surveyors, engineers, and researchers who want to upgrade their practices with minimal cost but maximum impact. Making these simple adjustments can lead to noticeable improvements in accuracy, efficiency, and reliability in any GNSS-based surveying operation.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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