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EECE 5554 Section 2
Lab 3
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Devices Used: RTK receivers 9 and 27, Antenna 17

1. Introduction

Real-Time Kinematic (RTK) GPS is a method to reduce errors in GPS measurements by using a base station to correct measurements made by a rover GPS receiver. The base station can determine its range from a number of satellites and send correction data to a moving GPS receiver. Under the best of conditions, RTK GPS measurements can achieve centimeter-level accuracy. However, there are challenges with setting up RTK GPS that can introduce errors in the process. If there is uncertainty in the position of the base station, bad satellite geometry, or multipath effects, the resulting accuracy of the rover measurements would be limited. This lab explores the effect that setting up RTK GPS equipment in two different locations has on the accuracy of GPS measurements collected at the rover node. The following sections describe the experiments performed, present results after collecting rover GPS data, and provide a discussion on the noise characteristics of the data and the overall accuracy of the measurements.

2. Method

After setting up one GNSS receiver to be the RTK base and the other as the rover node, both nodes were placed in a partially occluded area near ISEC. Stationary data was collected for 10 minutes. After the stationary data was collected, the rover was carried along a path around ISEC while GPS data was collected. The RTK setup was then moved to a new location in an open park area near the Museum of Fine Arts. 10 more minutes of stationary data was collected and them the rover was carried along a path close by to the base station.

3. Results & Discussion

Partial Occlusion, Stationary

The following figure shows the relative easting and northing data collected at a partially occluded location, each direction plotted versus time, and the fix quality for the duration of the trial:

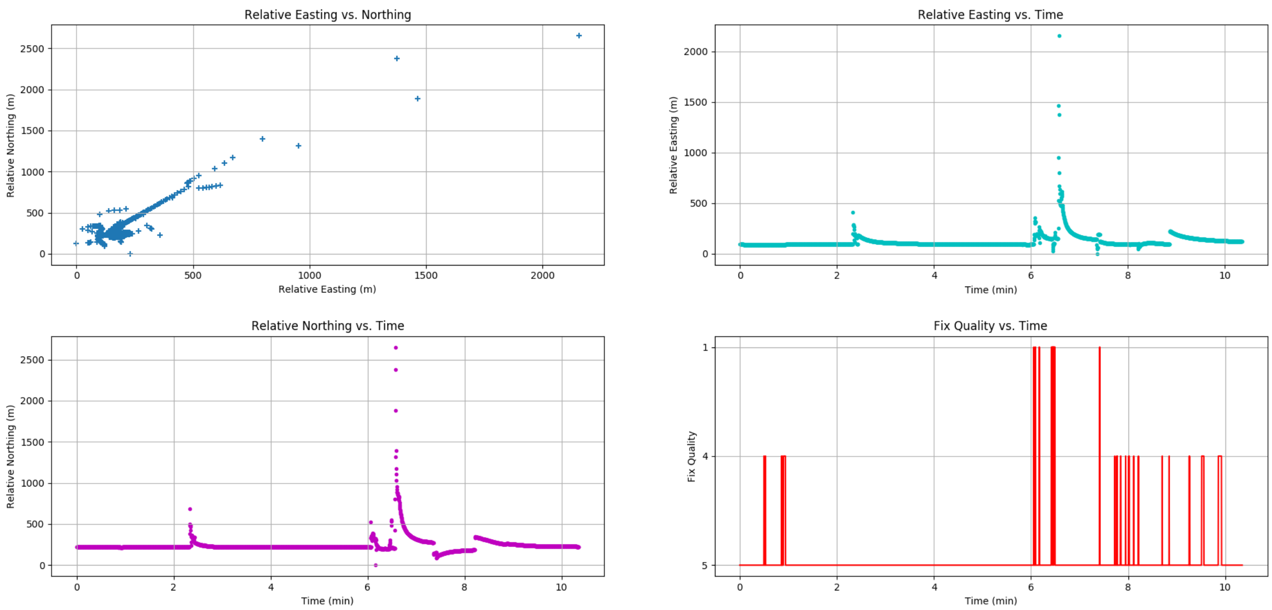

Figure 1: Stationary RTK GPS data at ISEC

To analyze the error in the relative northing and easting data, the mean of each dataset was found after removing outliers in the northing and easting data. The resulting easting and northing means were then subtracted from each sample to obtain error estimates for the dataset. Histograms were plotted from the error estimates to obtain an error distribution for each direction (see figure 2).

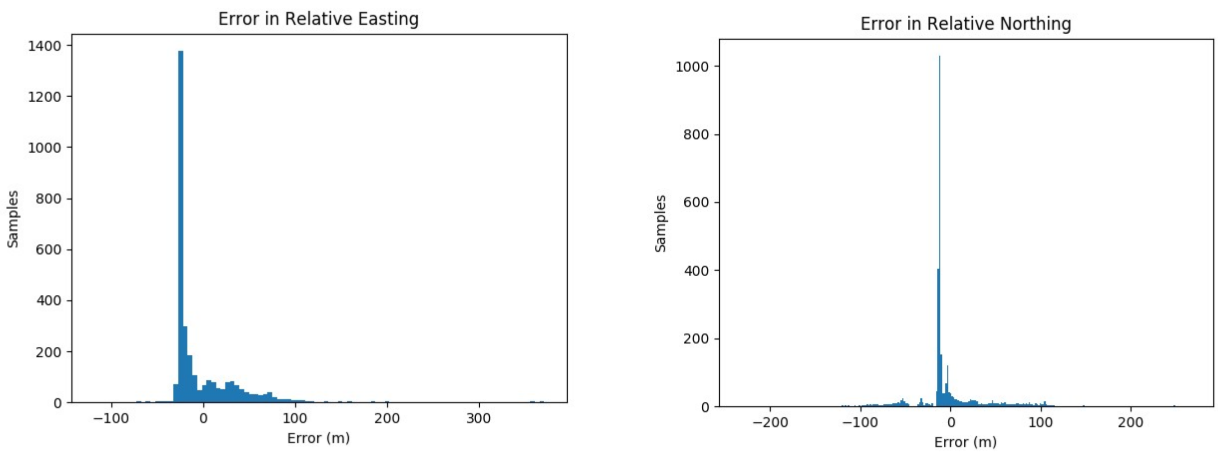

Figure 2: Error histograms for easting and northing stationary data at ISEC

Based on the histograms, the error distributions do not appear to be Gaussian. Also, while most of the samples were drawn from a narrow range, the spread of some of the samples are in the range of tens of meters.

Open Area, Stationary

After collecting stationary data in a open field, the following figure was generated to show the relative easting and northing data along with each direction plotted versus time and the fix quality for the duration of the trial:

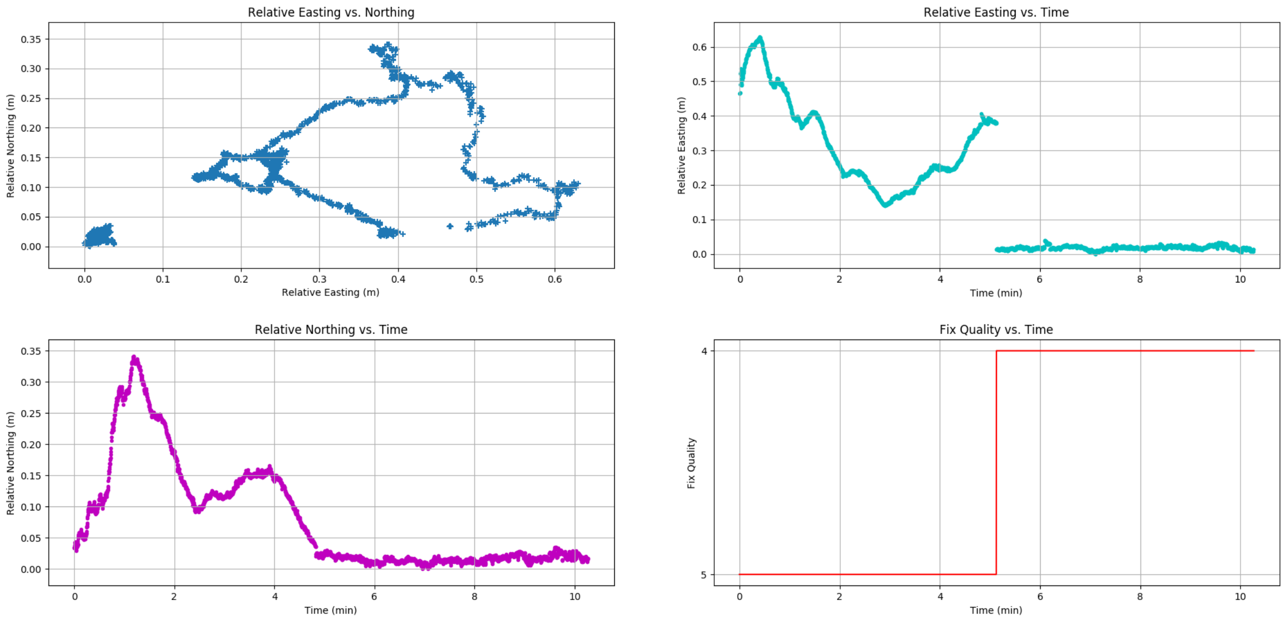

Figure 3: Stationary RTK GPS data at MFA

In the open field, the fix quality moved from RTK float to RTK fixed after approximately 5 minutes and stayed in RTK fixed mode for the rest of the trial. The data shows that the error in the easting and northing data dropped significantly after the RTK setup moved to fixed-point mode. The error estimates were calculated similarly as in the partially occluded area, but in this case, the data was split between RTK float and fixed modes, as shown below:

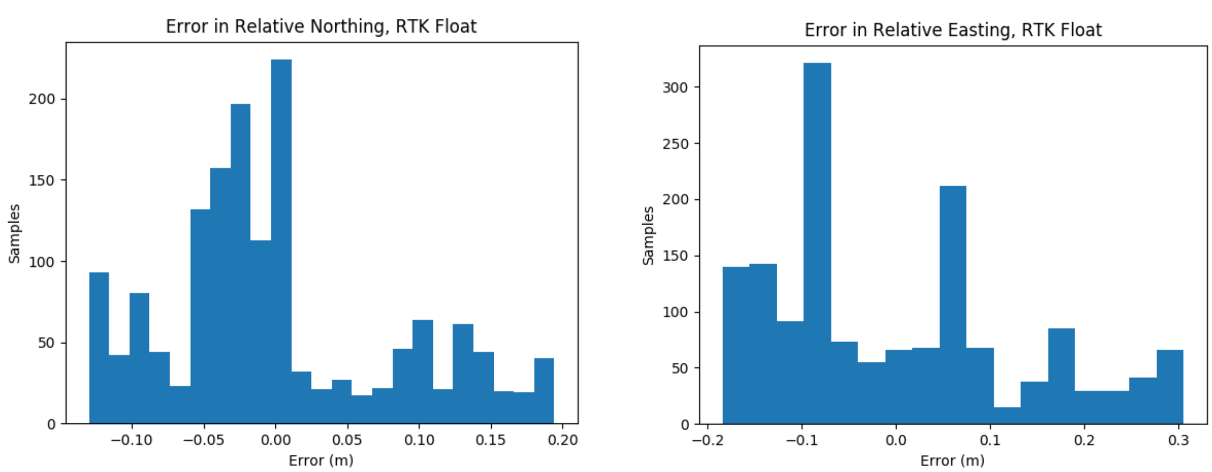

Figure 4: Error histograms for easting and northing stationary data at MFA, RTK Float

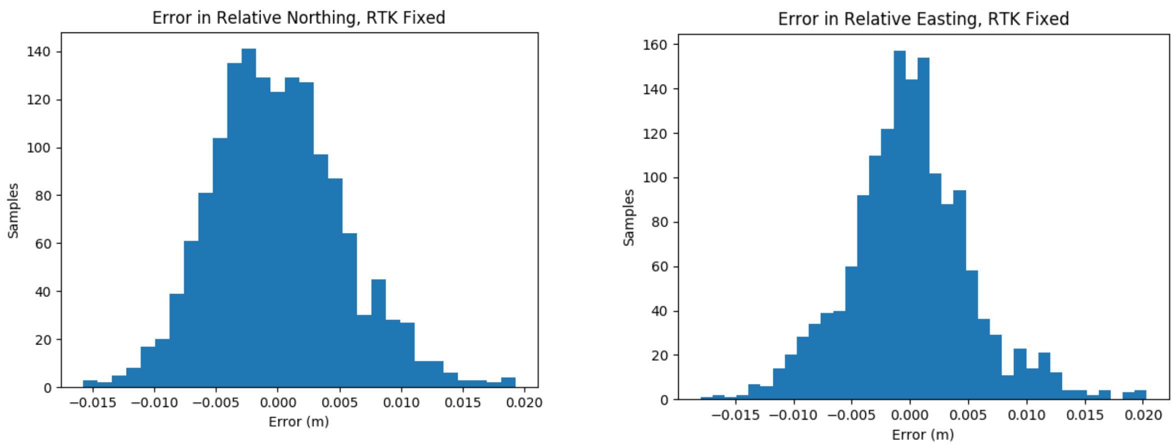

Figure 5: Error histograms for easting and northing stationary data at MFA, RTK Fixed

Comparing the error distributions in the stationary data in RTK float and fixed modes, all of the distributions do not appear to be Gaussian, although the error distribution in the RTK fixed mode is closer to Gaussian than the distribution in RTK float mode. Also, the range in the RTK float error estimates is between -0.15 and 0.20 meters in northing and -0.2 and 0.3 meters in easting. In RTK fixed mode, the range shortened to between -0.015 and 0.02 meters in northing and between -0.02 and 0.02 meters in easting. This result agrees with the specified accuracy in RTK fixed mode, which is approximately centimeter-level, and the specified accuracy in RTK float mode, which is approximately decimeter-level.

Partial Occlusion, Moving

After collecting data near ISEC while moving the rover node, the following figure was generated to compare relative northing and easting, plot each direction versus time, and show the fix quality changes during the trial:

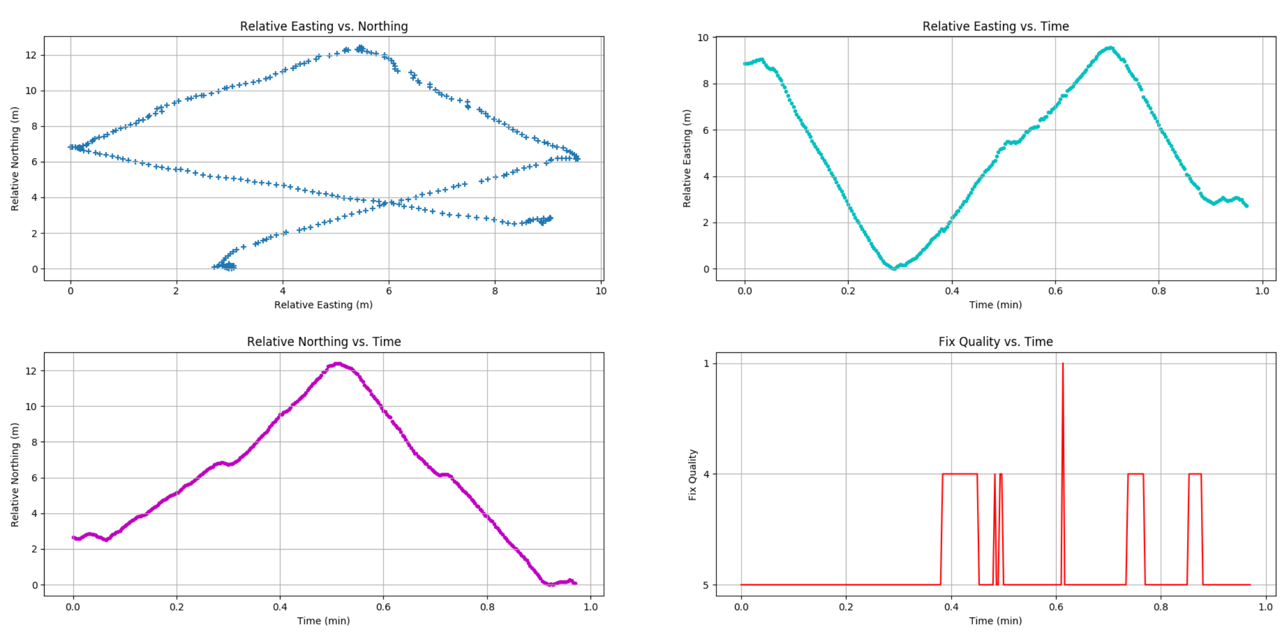

Figure 6: Moving RTK GPS data at ISEC

In order to obtain error estimates for the moving RTK GPS dataset, a section of the data in both directions corresponding to straight walking paths in the route was sliced out and a line was fitted to each section. The easting and northing data were then subtracted by their best-fit lines to obtain error estimates for each direction. The following figure provides histograms for the easting and northing error to highlight their distributions:

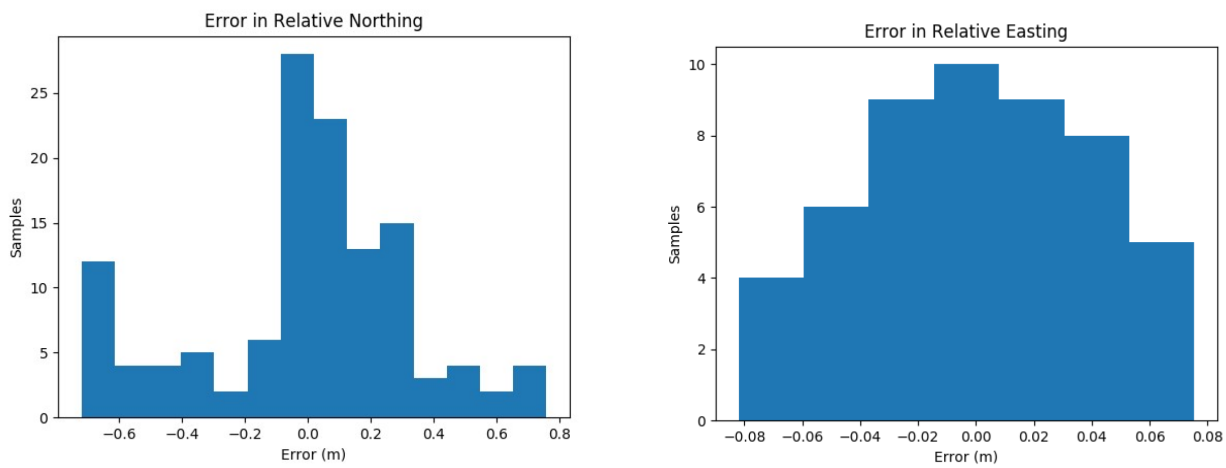

Figure 7: Error histograms for easting (5s to 15s) and northing (5s to 15s) while walking around ISEC

Looking at the distributions of the error in the moving RTK GPS data, the shape of the distributions do not appear to be Gaussian, like in the stationary case, but the error range is much narrower. Comparing the easting and northing error distributions, the range in the easting error is narrower in the interval (-0.821, 0.0755) compared to the northing error in the interval (-0.7203, 0.7588). In the moving case, the rover node does not experience the same multipath effects as the base station, so the resulting measurements should not vary as widely as in the stationary case, which the data shows.

Open Area, Moving

After collecting data near the MFA while moving the rover node, the following figure was generated to compare relative northing and easting, plot each direction versus time, and show the fix quality changes during the trial:

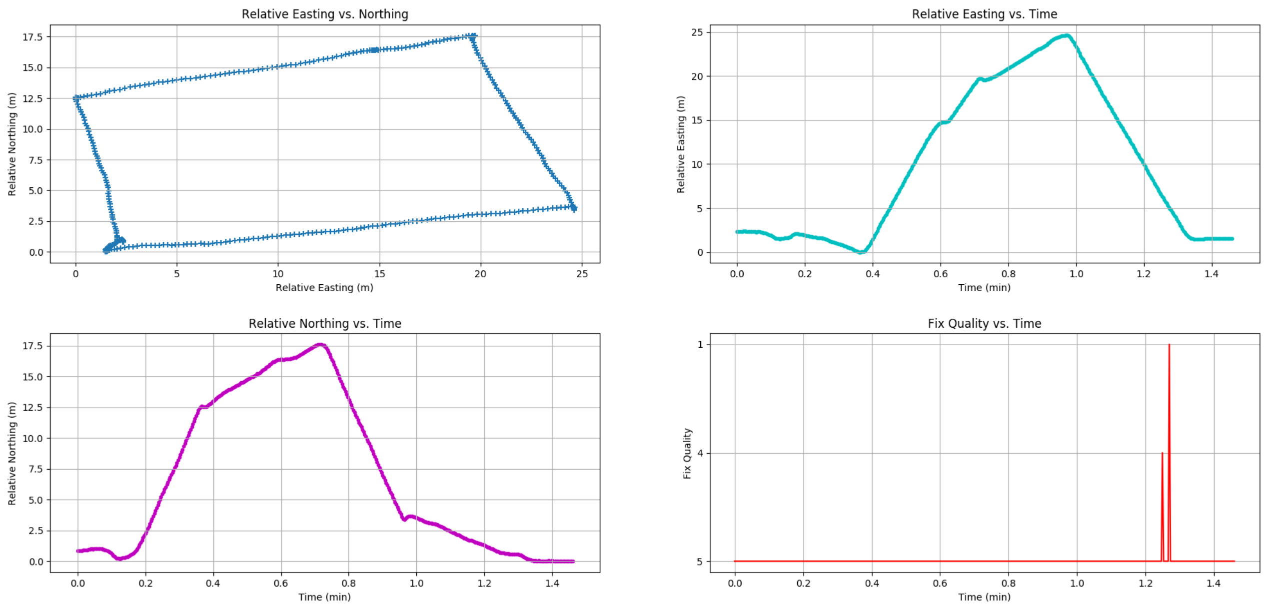

Figure 8: Moving RTK GPS data at MFA

The error estimates in the RTK GPS data in the open-field moving case were calculated similarly to the partially occluded case and the histograms generated to show the distributions in the estimates are shown below:

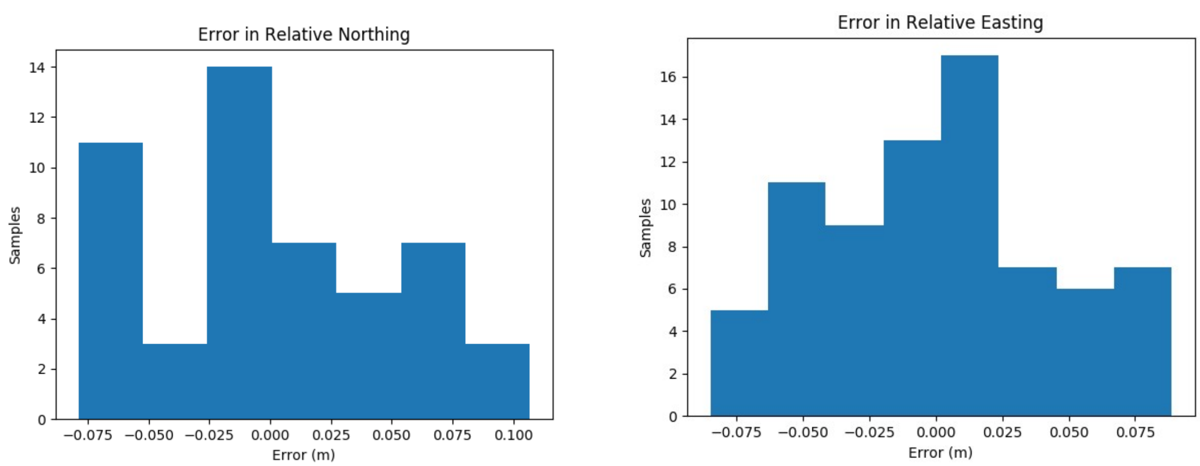

Figure 9: Error histograms for easting (60s to 70s) and northing (45s to 55s) while walking around MFA

The error distributions in the moving RTK GPS dataset in an open field also do not appear to be Gaussian like in the previous cases. But, compared to the moving data in the partially occluded location, both the easting and northing error have similar ranges; the interval for the easting error is (-0.0788, 0.1069) and the interval for the northing error is (-0.0846, 0.0888).

4. Conclusion

One conclusion that can be drawn from this investigation into RTK GPS is that its effectiveness depends on the quality of the GPS fix at the base station. When both the base and rover nodes are located in a partially occluded environment, the resulting GPS measurements would likely not exhibit the centimeter-level accuracy achievable using an RTK GPS setup. When both the base and rover nodes are located in a less obstructed area, the likelihood that the fix quality at the rover node reaches RTK fixed mode increases, which would lead to centimeter-level accurate positioning data. In the partially occluded setting, a moving rover node exhibited more accurate measurements than the stationary node, but the measurements in both directions were not as accurate as the open field case. In the open field case, the moving rover had slight less accurate measurements than the stationary rover, since the moving rover was in RTK float mode for the majority of the trial. Overall, RTK GPS is a valuable technique for increasing the accuracy of position tracking for robot navigation, provided that the base station is in an unobstructed location.

References

[1] https://www.novatel.com/an-introduction-to-gnss/chapter-5-resolving-errors/real-time-kinematic-rtk/

[2] https://www.trimble.com/OEM_ReceiverHelp/V4.44/en/PositionModes_CriticalFactorsRTK.html