Report

Relative position estimation using two GPS modules filtered by EKF2 of PX4 platform

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In this report, the results of tests for measuring the relative position between GPS modules are presented. The raw GPS data of both modules are filtered using the EKF2 of PX4 platform. The following points should be mentioned:

1. The MAVLink message used for logging global position of each module is "GLOBAL_POSITION_INT".
2. The measured global positions of one module is sent to the other module via a UDP connection between them.
3. The relative position between the modules is computed in NED frame by converting the attitude/longitude data of each module to x-y NED data. Here, the conversion method defined in https://en.wikipedia.org/wiki/Geographic_coordinate_system is utilized. Global z-axis position is converted to NED z-axis by just changing its sign.

First round of tests

Six tests are conducted as follows:

- In the four first tests, the two modules are stationary located in a same horizontal plane on the ground. In these four tests, the relative distance between modules are constant as 20cm, 1.5m, 3m and 4m, respectively (Fig. 1to Fig. 4).
- In the fifth test, one module is still stationary on the ground, while the second module is stationary at a 2m altitude above the ground and at 4.5m horizontal distance (Fig. 5).
- In the sixth test, one module is still stationary on the ground, while the second module is moved on almost circular path around the first module, at an altitude of about 1.5m above the ground. The radius of circular path is almost 5m (Fig. 6).

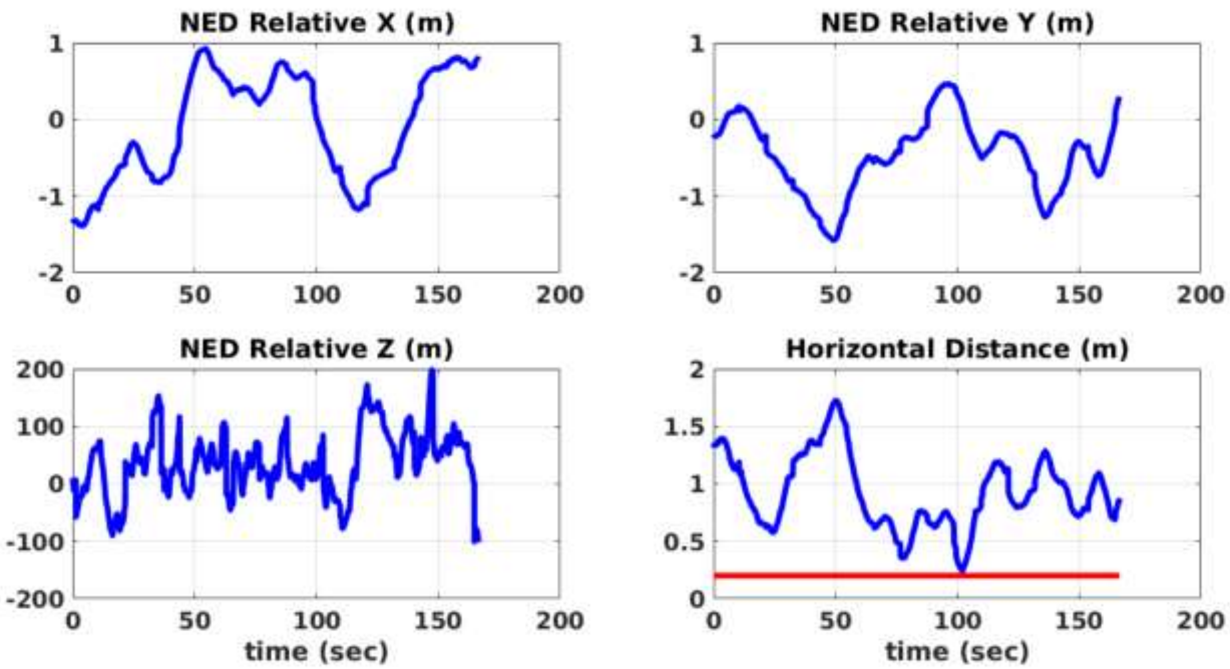

Fig-1. Two GPS modules are stationary on the ground with 20cm distance between them. The fluctuations amplitudes in relative x-y position measurements are $\pm 1m$. The difference between the averaged distance measurement and the correct distance is 0.8m.

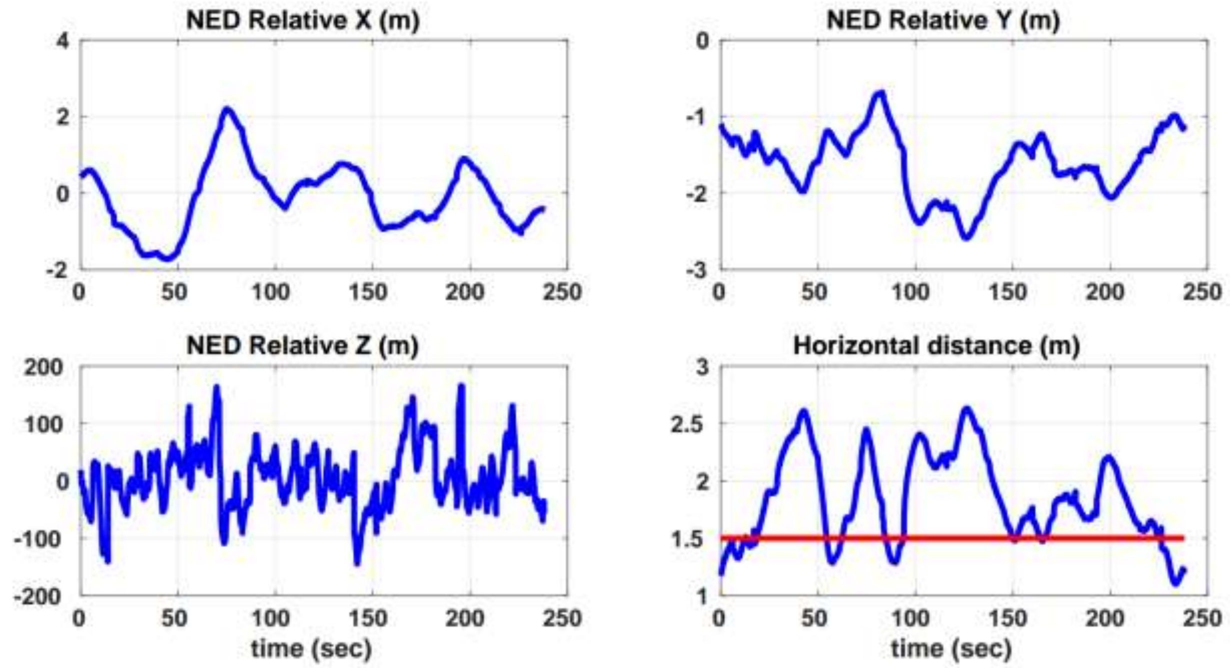

Fig-2. Two GPS modules are stationary on the ground with 1.5m distance between them. The fluctuations amplitudes in relative x-y position measurements are $\pm 2m$. The difference between the averaged distance measurement and the correct distance is 0.6m.

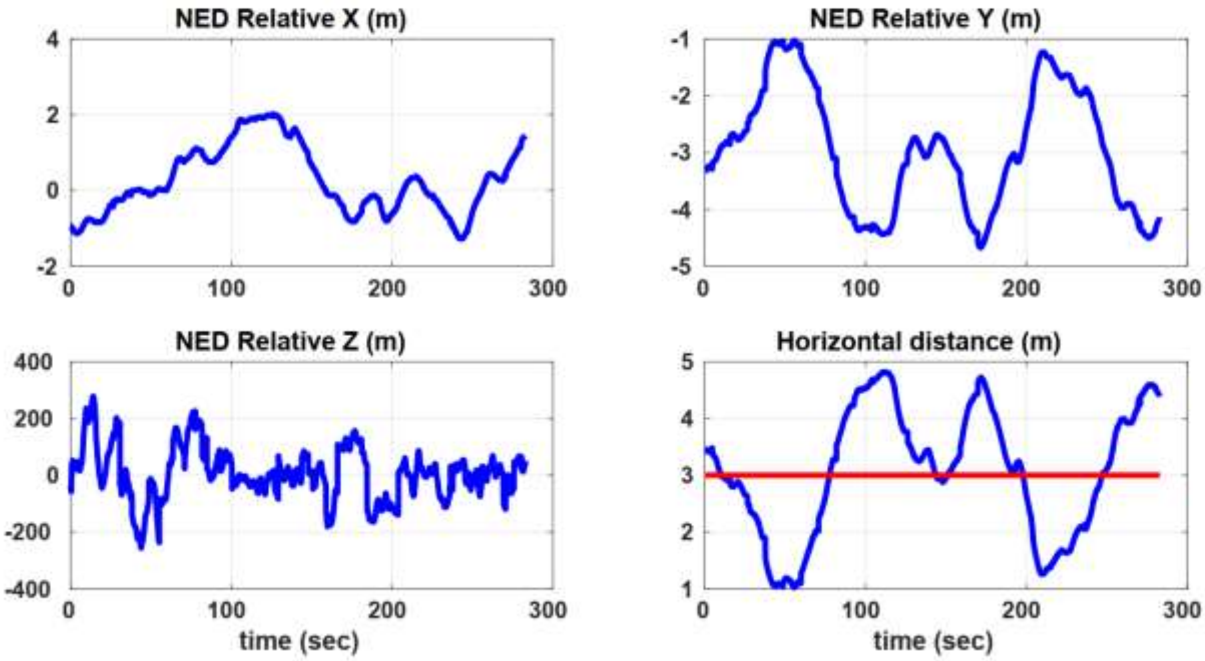

Fig-3. Two GPS modules are stationary on the ground with 3.0m distance between them. The fluctuations amplitudes in relative x-y position measurements are $\pm 1.5m$. The difference between the averaged distance measurement and the correct distance is $0.2m$.

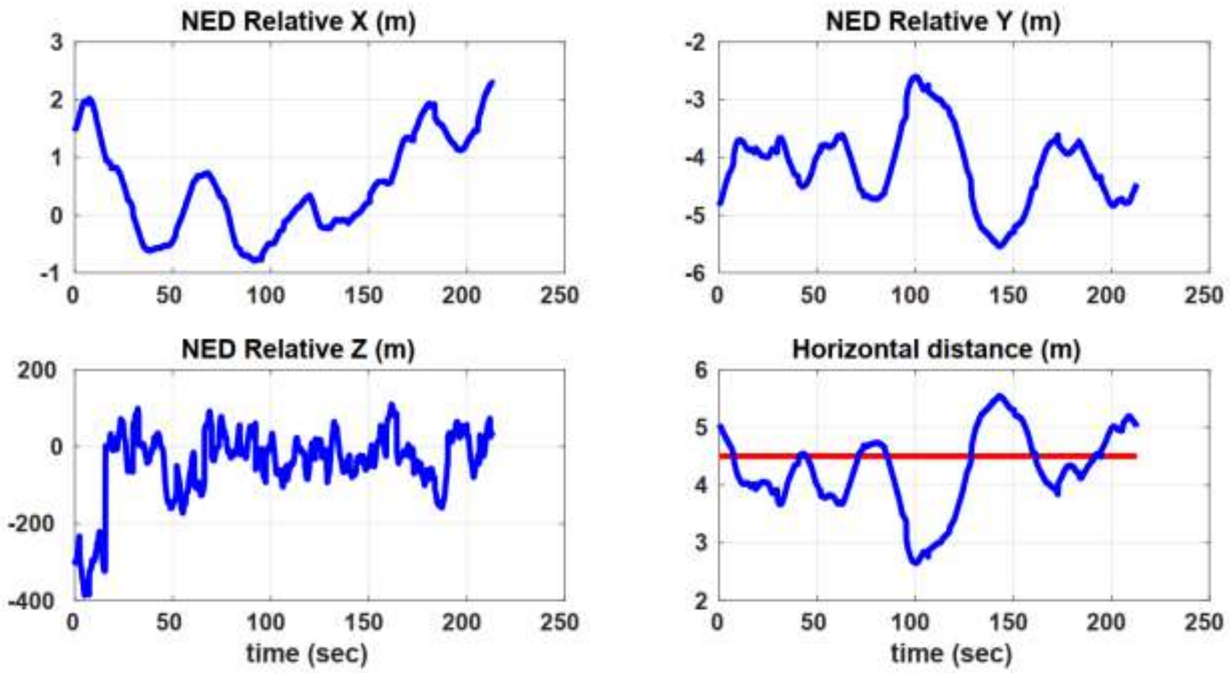

Fig-4. Two GPS modules are stationary on the ground with 4.5m distance between them. The fluctuations amplitudes in relative x-y position measurements are $\pm 1.5m$. The difference between the averaged distance measurement and the correct distance is $0.5m$.

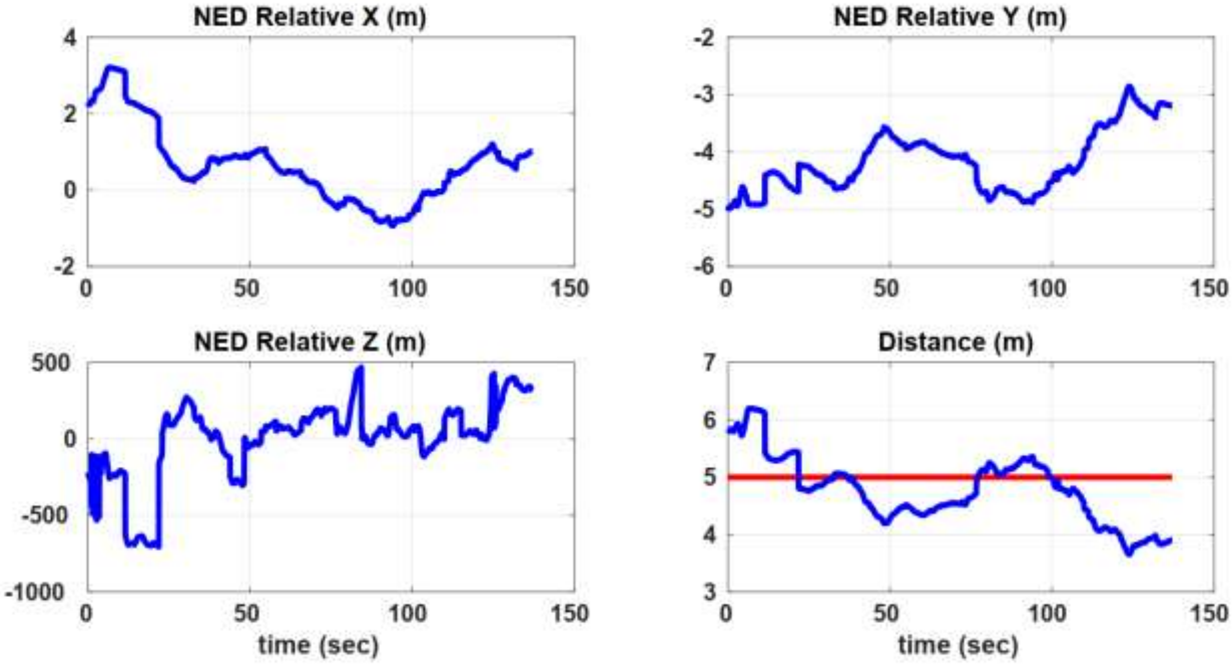

Fig-5. Two GPS modules are stationary with 4.5 horizontal distance and 2.0m vertical distance between them. The fluctuations amplitudes in relative x-y position measurements are $\pm 1.5m$. The difference between the averaged distance measurement and the correct distance is $0.3m$.

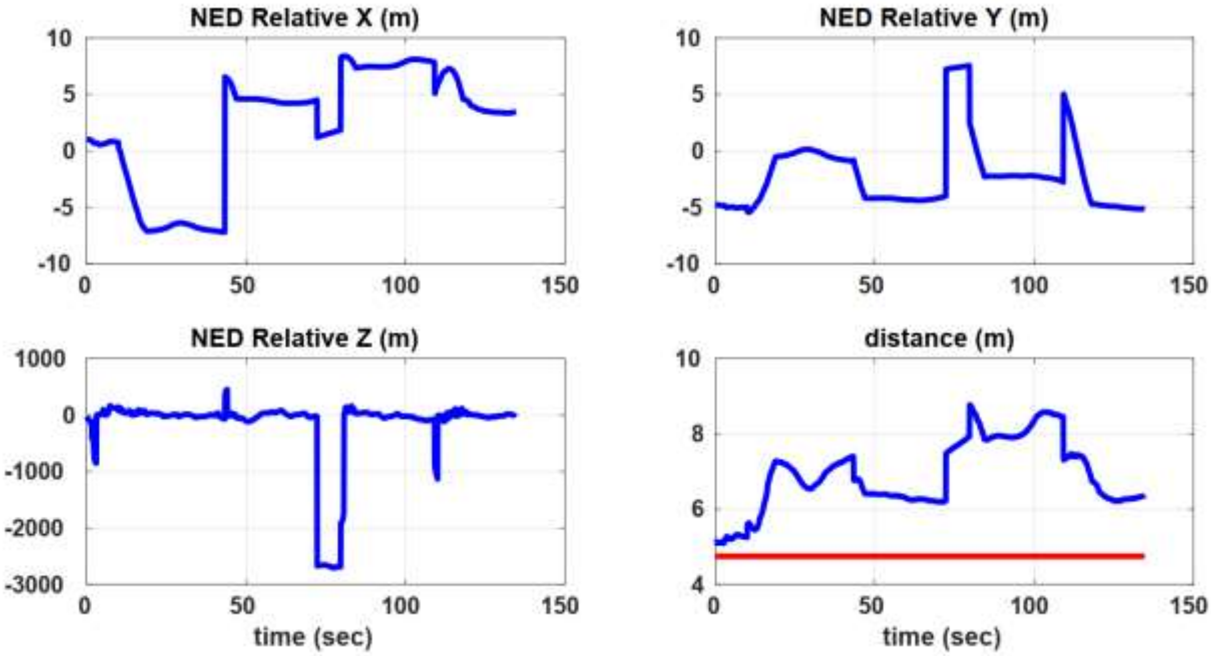

Fig-6. One GPS module is stationary, while the second GPS module is moving in (almost) circular path around it at almost 5.0m horizontal distance and 1.5m vertical distance between them. The fluctuations amplitudes in relative x-y position measurements are $\pm 5m$. The difference between the averaged distance measurement and the correct distance is $2.0m$.

Conclusions

1. The average values for computed distances between the two modules are around 0.5m off from the correct distances.
2. Although the average values for the computed distances between the two modules in test-1 to test-5 are near to the correct distance between them, but there are large magnitude of oscillations around that distances (around $\pm 2m$).
3. In the first five tests, although the two modules are stationary, but we can see high-amplitude fluctuations in relative positions in x-y plane (around $\pm 1.5m$).
4. The relative z-axis position measurements are completely off.
5. In general, the relative position estimations using GPS+EKF2 couldn't be an appropriate solution for the problem of collaborative payload transportation. In that problem, we need cm-level accuracy for 3D relative position estimation between payload and drones.
6. The measured relative values will change via time, as the satellites that provide GPS signal for our modules are switched through time.
7. For the other problems, like autonomous flight of an individual quadrotor or fixed-wing drone, these measurements are fine as the position controller can be designed in a way to operate until the drone reaches at a certain radius (or distance) of the target waypoint. But, in collaborative payload transport problem, we don't have such tolerance.

Second round of tests

In this round of tests, the altitude settings of EKF2 in the pixracer, is set from “Barometric Pressure” to “GPS”. Moreover, the individual GPS measurements of each module in the global coordinate system are logged.

- **Test1:** Two GPS modules are stationary on a bench at 0.5m above the ground, with 1.4m distance between them (Fig. 7 and Fig. 8)

- **Test2:** Two GPS modules are stationary on a bench at 0.5m above the ground, with 3.9m distance between them (Fig. 9 and Fig. 10).

- **Test3:** Two GPS modules are stationary on a bench at 0.5m above the ground, with 5.6m distance between them (Fig. 11 and Fig. 12)

- **Test4:** One GPS module is stationary, while the second GPS module is moving a reciprocating motion around the first GPS module (Fig. 13 and Fig. 14).

Conclusions

1. In test1 to test3, where the GPS modules are stationary, the fluctuations on estimated relative position between the modules are still observed. These fluctuations can be seen in the individual GPS measurement at each module as well.
2. The very noisy measurements on altitude of the modules are still there.
3. In the fourth test, the moving GPS module has fewer fluctuations in the GPS readings and the position measurements of that module, correspond to the its actual movement.

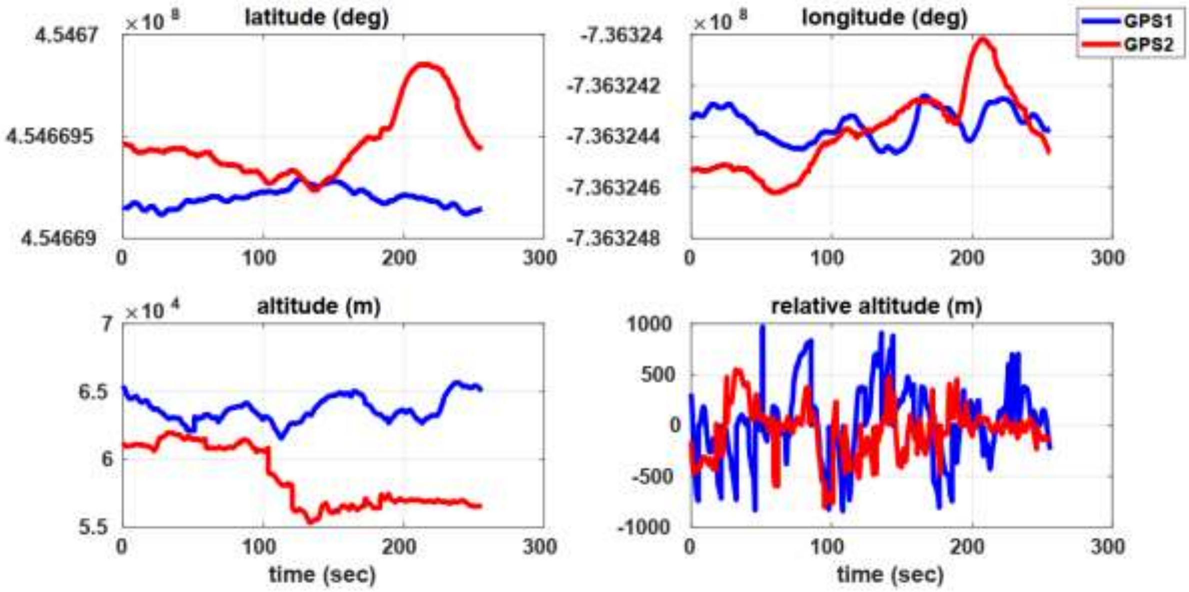

Fig-7. **Test1:** The individual GPS measurements at each module in global coordinate system.

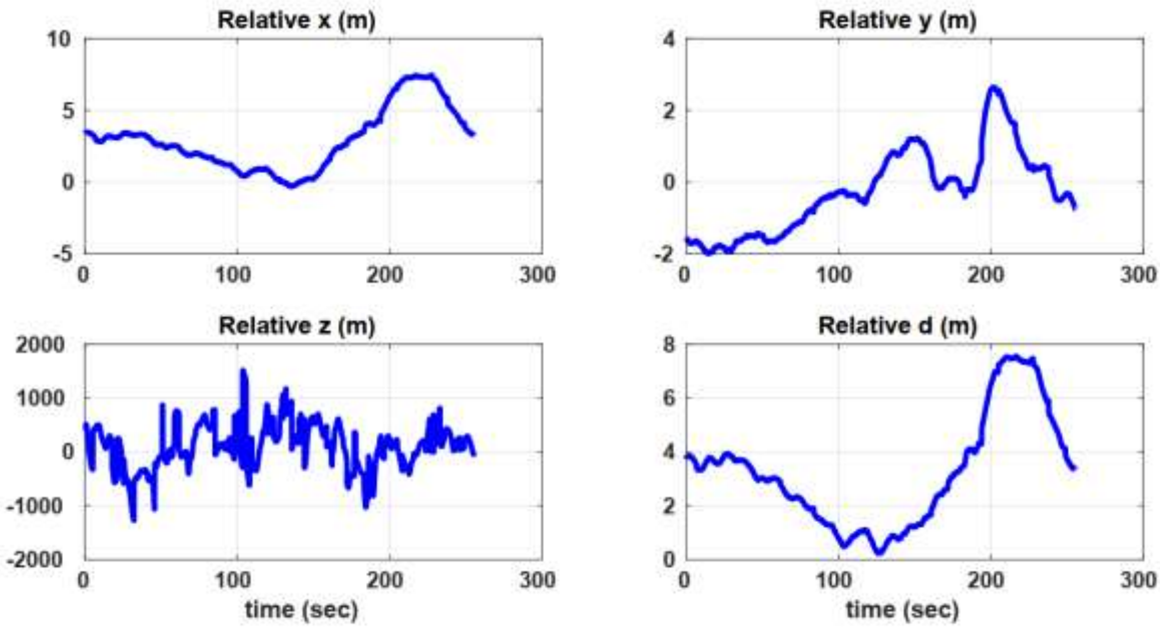

Fig-8. **Test1:** The relative position measurements in NED frame.

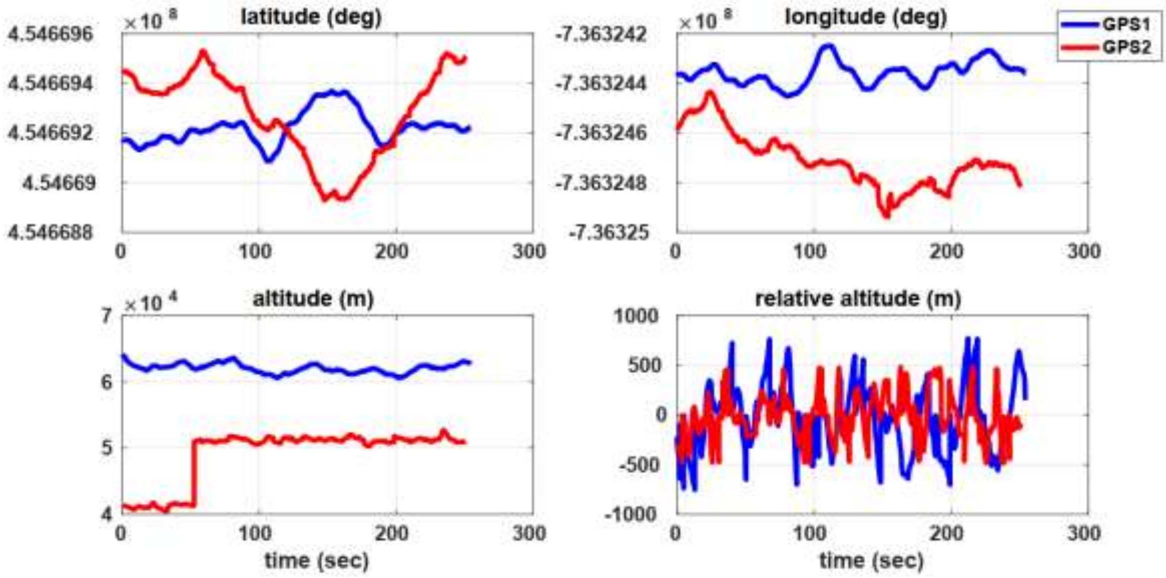

Fig-9. **Test2:** The individual GPS measurements at each module in global coordinate system.

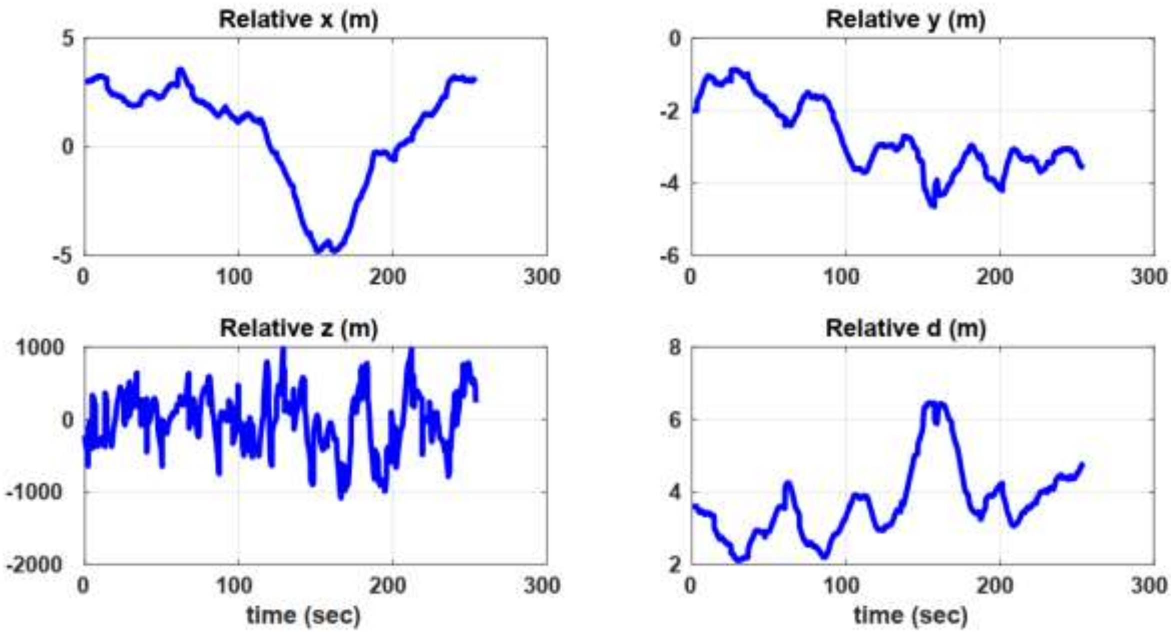

Fig-10. **Test2:** The relative position measurements in NED frame.

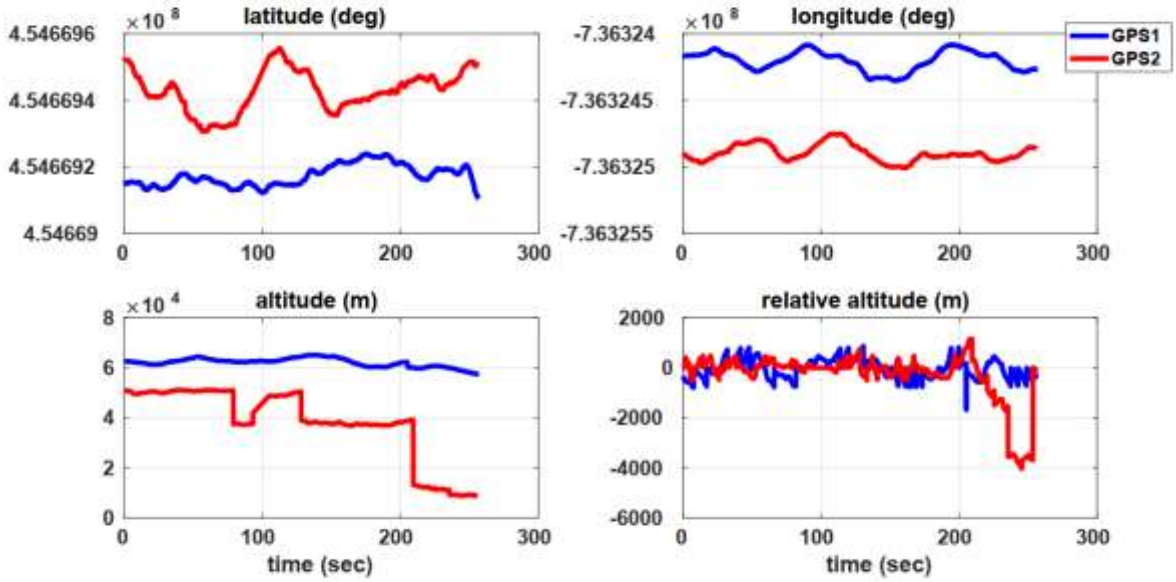

Fig-11. **Test3:** The individual GPS measurements at each module in global coordinate system.

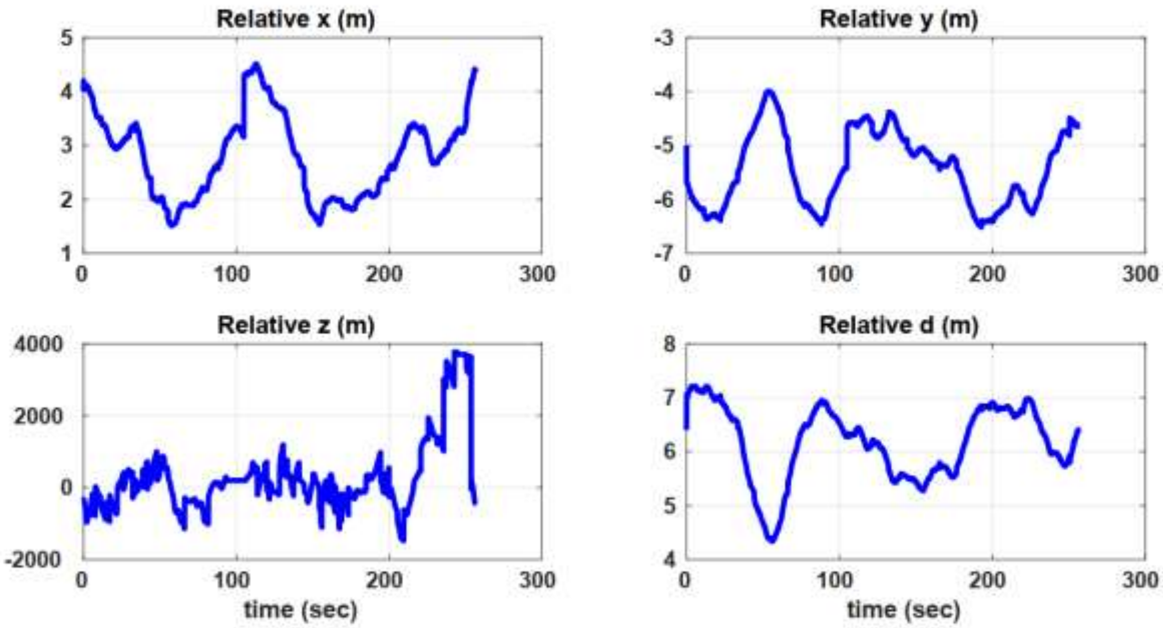

Fig-12. **Test3:** The relative position measurements in NED frame.

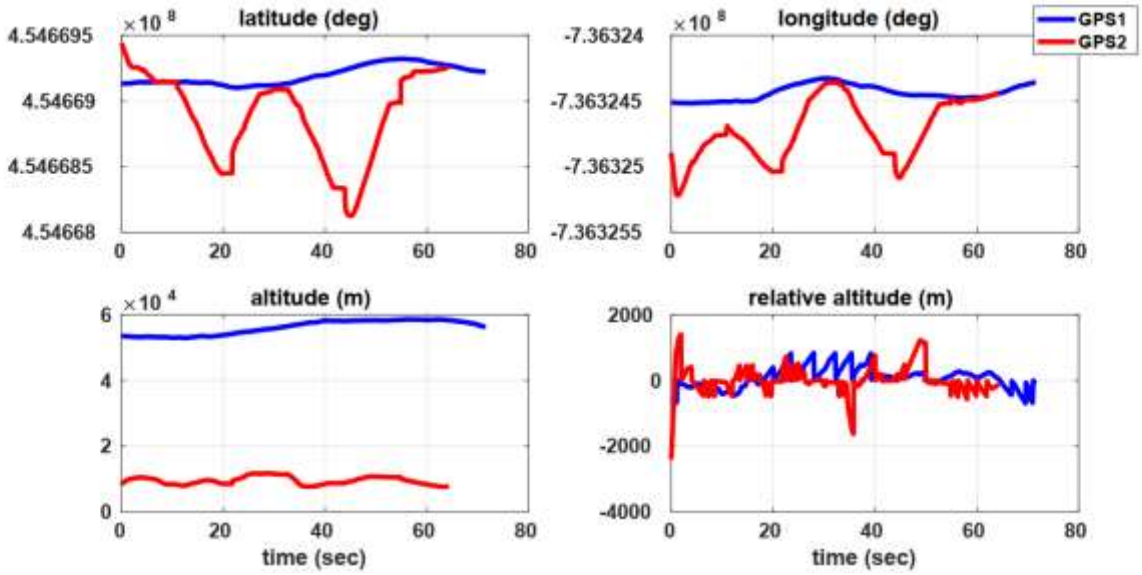

Fig-13. **Test4:** The individual GPS measurements at each module in global coordinate system.

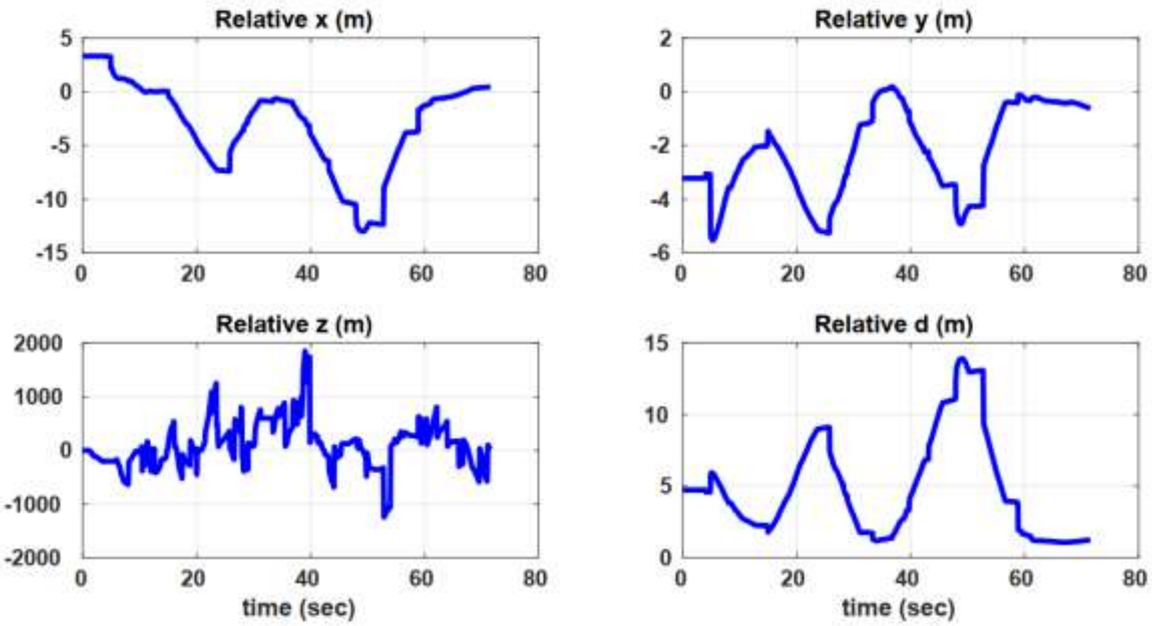

Fig-14. **Test4:** The relative position measurements in NED frame.