POSITIONING

Achieving Centimeter Level Performance with Low Cost Antennas

White Paper

Abstract

In this white paper, u-blox shows how inexpensive patch antennas can be used to achieve centimeter-level accuracies using the u-blox NEO-M8P receiver.

The study identifies critical design information about the antennas and their operating environment, which can be used to gain maximum performance from the system. In particular, we show that it is essential that patch antennas are used with an appropriate ground plane. Ground planes can mitigate multipath effects to a level where the patch antenna performance can reach that of survey-grade antennas.

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Problem description

With the introduction of NEO-M8P, u-blox has laid the grounds for mass market applications to embrace GNSS positioning with centimeter-level accuracy using RTK (Real Time Kinematic) technologies. The introduction of affordable centimeter-level GNSS modules provides applications with a level of accuracy and precision that was once reserved only for high cost applications, such as surveying. In any system attempting centimeter-level GNSS positioning, the GNSS antenna plays a critical part. Existing high precision technologies use expensive survey-grade GNSS antennas because their excellent multipath mitigation properties are critical in providing best performance. However, mass market applications, such as UAVs and robotic lawn mowers, are typically unable to afford the cost of such high performance antennas. This presents the mass market manufacturers with an antenna design challenge that they need to overcome in order to achieve consistent centimeter-level performance.

A significant differentiator between a bad and a good antenna setup is the convergence time, which is defined as the time it takes for the system to fix the integer ambiguities. This is measured as the time-to-first-ambiguity-fix (TTFAF). When using simple patch antenna elements, high levels of code multipath are introduced into the system, which would otherwise be mitigated by using expensive survey-grade GNSS antennas. Such multipath will heavily impact the TTFAF performance and hence great care should be applied to mitigate this effect. Using a ground plane for the antenna is a well-established means and, as shown in this paper, will effectively help in fighting multipath effects on patch antenna setups and can deliver performance levels similar to survey-grade GNSS antennas.

Test description

The following sections describe a set of tests undertaken in order to evaluate the performance that can be achieved using different combinations of base and rover antennas. This was achieved by evaluating the TTFAF for different types of antennas and ground planes in sites with different multipath conditions.

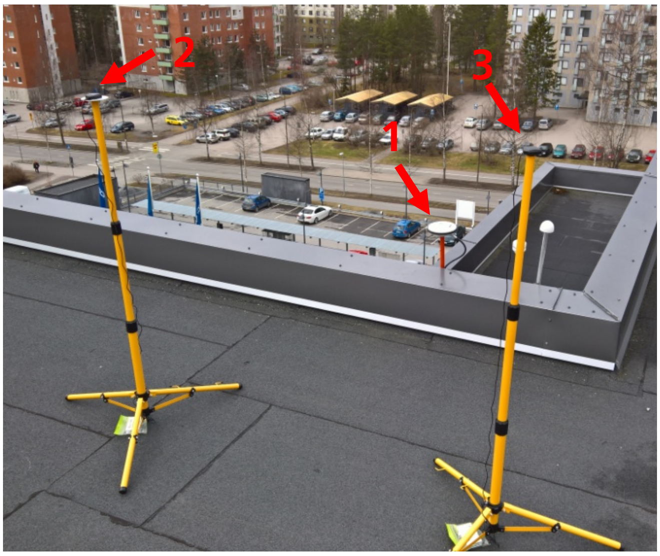
Base antenna installation

Four base antennas connected to NEO-M8P receivers were set up in Tampere, Finland. Three antennas were installed on the roof on an office building and one on the roof of a car, as described below:

1. NovAtel NOV-704-WB pinwheel survey-grade antenna located on a survey pole, on the building roof
2. Patch antenna on a tripod with 10 centimeter diameter metallic ground plane, on the building roof
3. Patch antenna on a tripod without ground plane, on the building roof
4. Patch antenna mounted in the center of a car roof, located approximately 60 meters from the first three antennas

In all cases, the patch antenna is a standard magnetic mount, GPS+GLONASS antenna that is provided with u-blox evaluation kits. The antenna represents a typical low cost antenna that is often used for conventional non-differential GNSS positioning.

Figure 1 shows photos of the antenna locations. All antennas have a good sky view, although there are some obstructions to satellites at low elevations due to air conditioning units. The patch antennas are located on poles that are approximately 1.8 meters high.



Base antennas 1, 2 and 3 looking west

Base antennas 1, 2 and 3 looking north

Base antenna 2 with ground plane

Figure 1 Photographs of the base antennas installed on the office building roof

Figure 2 below shows the location of base antenna 4 that is located in the center of a car roof. The environment is relatively obstructed with a tall tower located to the west, as well as buildings in the north and east directions, which reflect multipath signals onto the antenna location. Such an environment is also not optimal for a base station, since any signals that are obstructed at the base antenna cannot be used by the rover for positioning.

Base antenna 4 on silver car, looking west

Base antenna 4 on silver car, looking north

Figure 2 Photographs of base antenna 4 in a car park

Rover antenna installation

Two separate rover antennas were set up in a open area, 1 kilometer from the location of the base antennas:

A. Patch antenna mounted in the center of a car roof

B. Patch antenna mounted beside the car on a tripod without a ground plane

Some trees without leaves were located to the south-east and south-west of the vehicle, which may cause some signal obstructions due to the test site being located at relatively northern latitude (61.5 degrees latitude).

The baseline length between the base antennas 1-3 and the rovers was approximately 990 meters. Between base antenna 4 and rovers the baseline length was 1020 meters.

Rover A and B antennas looking north

Rover A and B antennas looking south

Figure 3 Photographs of rover antennas, rover A on the car roof and rover B on the tripod

Methodology

In April 2016, a total of 5 hours of data was recorded simultaneously using u-blox NEO-M8P receivers. The time-to-first-ambiguity-fix (TTFAF) metric was used to assess the impact of the antenna setups, because multipath is a critical factor that affects the ability of the receiver to converge and fix ambiguities. The 5 hours of data was divided into 10 minute periods. For each 10 minute period, the TTFAF was measured where the TTFAF is defined as the period of time between the first position fix and the first integer ambiguity fix from the M8P solution.

Results

Rover A (patch antenna on car roof)

Figure 4 shows the cumulative percentage of the TTFAF for rover A (patch antenna on a car roof) using the four different base antennas. Note that the cumulative percentages do not reach 100% for the cases where the ambiguities are not fixed within 600 seconds or, in some cases, if the integer ambiguities are incorrectly resolved.

The figure shows that base antenna 1 (NovAtel NOV-704-WB pinwheel survey-grade antenna) and base antenna 4 (patch antenna located on the car roof) demonstrate the best TTFAF results. For both these base antennas, 50% of the cases have fixed integer ambiguities within 110 seconds as multipath is mitigated by the ground plane. In particular, the car roof provides a large and effective ground plane that reduces the impact of multipath from the surrounding environment and gives a TTFAF performance similar to the survey-grade base antenna 1.

It should also be noted that base antenna 4 is in a sub-optimal location compared to base antenna 1. There will be reduced signal availability due to the obstructions caused by the surrounding buildings, which is expected to have a negative impact on the TTFAF statistics for base antenna 4.

For base antenna 2 (patch with a 10cm ground plane) it is clear that the TTFAF is reduced compared to base antennas 1 and 4. With this base antenna, 50% of ambiguities are fixed within 230 seconds. The importance of the ground plane is highlighted further when these results are compared to those achieved when using a base antenna without a ground plane (base antenna 3) as only 16% of the ambiguities were correctly fixed within 600 seconds with base antenna 3 indicating the significant importance of using a ground plane.

Rover B (patch antenna without ground plane)

Figure 5 shows the cumulative percentage for TTFAF for rover B (antenna without ground plane), which shows a significant reduction in the TTFAF for all combinations of base antenna compared to the rover antenna with a large ground plane (rover A). For example, it takes 470 seconds for 50% of ambiguities to be fixed when not using a ground plane, compared to the 110 seconds reported for rover A using a ground plane. This degradation in performance can be attributed to increased multipath at the antenna when not using a ground plane. The importance of using a ground plane is highlighted further by the fact that the combination of base antenna 3 and rover B, both of which have no ground plane attached, fails to produce any correct RTK fixed positions at all.

These results clearly show the importance of using a ground plane for both base and rover antennas.

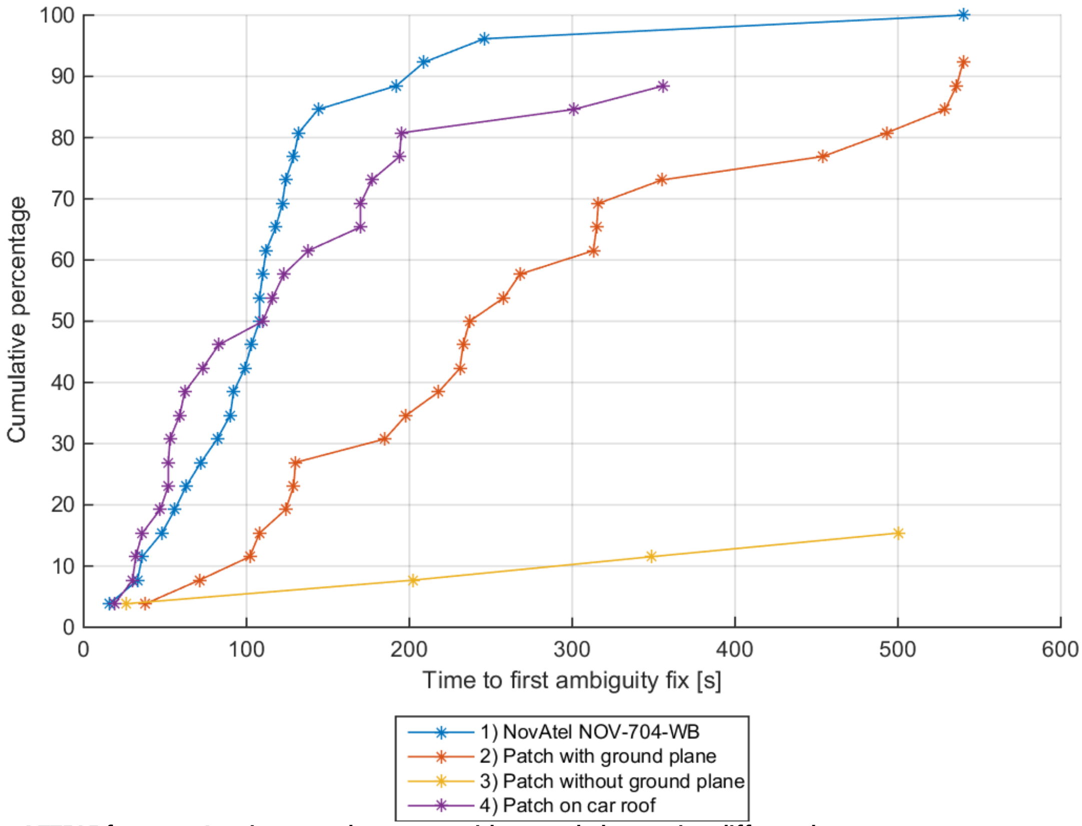


Figure 4 TTFAF for rover A, using a patch antenna with ground plane, using different base antennas

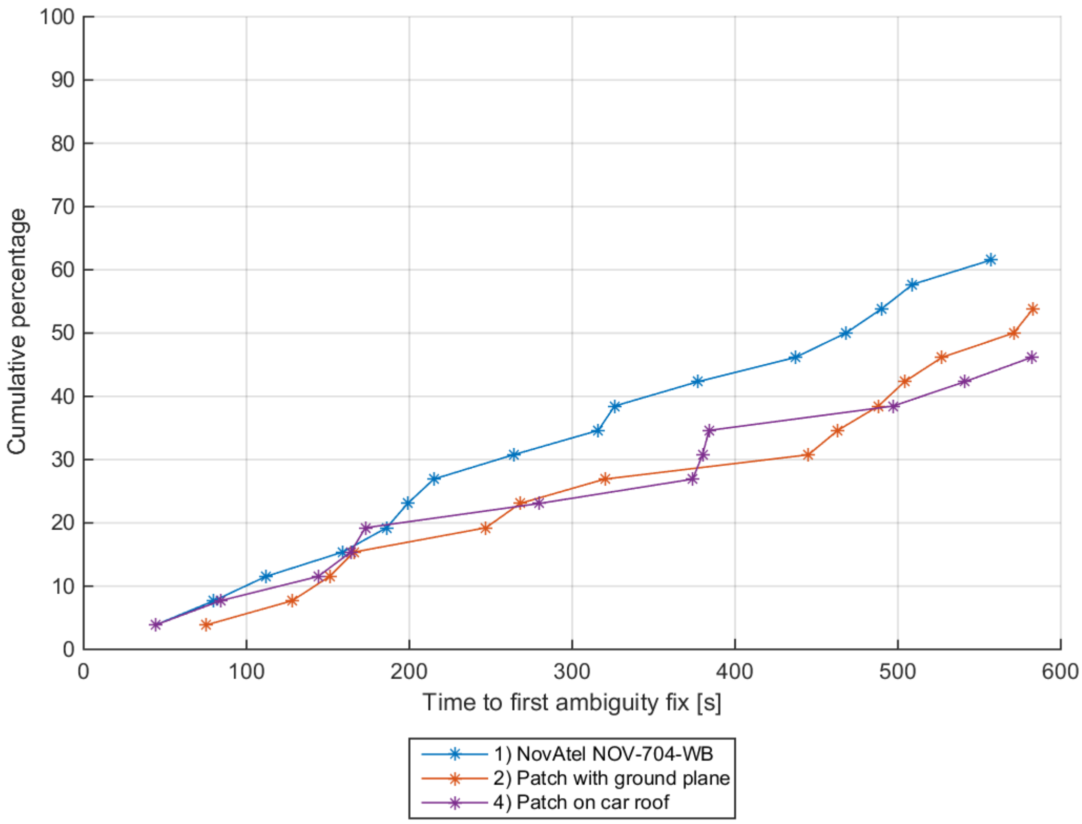


Figure 5 TTFAF for rover B, patch with no ground plane, using different base antennas. Note that no fixes were achieved within 600 seconds for base antenna 3 (Patch antenna without ground plane).

Conclusions

This whitepaper has shown how inexpensive patch antennas can be used to enable centimeter-level performance by using ground planes in the product design. We have investigated the impact of ground planes using different combinations of base and rover antennas. The main conclusions from this white paper are:

- Low cost patch antennas can be used with u-blox NEO-M8P receivers for centimeter-level positioning
- Low cost patch antennas must be used with an appropriate ground plane for any high precision application
- Low cost patch antennas can provide performance levels comparable to professional survey antennas when used with a large ground plane such as a car roof
- A ground plane with 10 centimeter diameter shows a significant performance improvement over an antenna without ground plane.
- The environment in which the base antenna is located is important since any signal obstructions will reduce the availability of satellites at the rover, and any multipath will contribute to the total multipath at the rover.

  Therefore, during the design and evaluation of low cost patch antennas it is recommended that an appropriate ground plane design is considered for applications requiring centimeter level GNSS precision.

Final remark

The antenna design can also impact the absolute accuracy of the RTK system. Such impact originates from phase center variation between antennas. As this effect typically only can be observed on a sub-centimeter level, this effect can be deemed to be of secondary interest to most mass market applications and is not elaborated further in this paper.

NEO-M8P is a high precision module for the mass market. It provides a centimeter-level GNSS solution that has integrated Real Time Kinematics. The module is small, light, and energy efficient. The NEO-M8P is a complete and versatile solution that incorporates world-leading GNSS positioning technology from u-blox.

About u-blox

Swiss u-blox (SIX:UBXN) is a global leader in positioning and wireless semiconductors and modules for the automotive, industrial and consumer markets. Our solutions enable people, vehicles and machines to locate their exact position and communicate wirelessly over cellular and short range networks. With a broad portfolio of chips, modules and software solutions, u-blox is uniquely positioned to empower OEMs to develop innovative solutions for the Internet of Things, quickly and cost-effectively. With headquarters in Thalwil, Switzerland, u-blox is globally present with offices in Europe, Asia and the USA. www.u-blox.com

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