Preliminary Results of Helicopter Navigation Trials with Network RTK GNSS Positioning

Xiaolin Meng[1], Lei Yang[1], Tony Marmont[2], Chris Hill[1], Sean Ince[1], Jose Aptone[1]

[1]Institute of Engineering Surveying and Space Geodesy
The University of Nottingham
University Park
Nottingham NG7 2RD, UK
Email: xiaolin.meng@nottingham.ac.uk

[2]Beacon Energy Ltd
Whittle Hill Farm Buildings
Nanpantan
Loughborough, Leics, LE129YE, UK.
Email: tonym@beaconenergy.co.uk

Biography

Dr Xiaolin Meng is a Research Councils UK Academic Fellow based at the University of Nottingham, UK. He holds a PhD in Highway, Urban Road and Airport Engineering from Tongji University in China, and a PhD in Space Geodesy from the University of Nottingham. Dr Meng has been an overseas peer-reviewer of National Office for Science and Technology Awards of China since 2004. He is chairing three international working groups of the International Association of Geodesy, the International Federation of Surveyors, and the International Association of Bridge Maintenance and Safety. Dr Meng is a guest professor of Wuhan University and a special professor of the Chinese Academy of Surveying and Mapping. His research covers very broad areas, including structural health monitoring, GPS data quality control, integration of GPS and GIS for transportation applications, location based services, network RTK GNSS, and geospatial/geodetic data processing. He has more than 140 publications and is a regular peer-reviewer for more than 12 major international journals. He is currently leading the research on ubiquitous positioning at the University of Nottingham.

Professor Tony Marmont is Founder and Director of Beacon Energy. Beacon Energy's objectives are to demonstrate and promote sustainability, to promote public awareness about global warming and to encourage the reduction of CO2 emissions.

Dr Chris Hill is a Principal Research Officer at the IESSG, specialising in the navigational aspects of the Global Positioning System. He has been involved extensively in the writing of software in the fields of satellite geodesy as well as geodetic datum transformations. He has also acted as the IESSG's project manager on ESA's Low-Cost Navigator (LCN) project.

Dr Lei Yang is a Research Fellow at the Institute of Engineering Surveying and Space Geodesy (IESSG) of the University of Nottingham in the United Kingdom. He holds a PhD degree in Electronic Engineering from the University of Nottingham. His current research interests are Network RTK technology, location based services, GNSS augmentation systems application, algorithm and signal processing in the receiver design, and intelligent transportation systems.

Mr Jose Aponte is a PhD student at the IESSG, the University of Nottingham, performing studies in Network RTK GPS Quality Control. He holds an MSc. in Satellite Positioning Technology from the same university and a BSc. in Civil Engineering from the University of Orient in Venezuela.

Mr Sean Ince is currently an Application Development Officer at GNSS Research and Applications Centre of Excellence (GRACE) at The University of Nottingham. After graduating with a degree in Surveying and Mapping Science (BSc) he spent a couple of years working overseas as a seismic surveyor and 10 years in the Surveying (Geomatics) Department at the University of Newcastle upon Tyne and Newcastle City Council's GIS development team. His work at

GRACE covers all areas of research including precise GNSS positioning, integration of sensors and developments of GIS.

Abstract

Network real-time kinematic (NRTK) GPS positioning has many attracting characteristics over more traditional single reference station based RTK positioning for land applications. However, will this new type of GPS positioning technique of centimetre accuracy be a feasible and reliable tool for precisely navigating a helicopter through integrating a geographical information system (GIS)? What are the constraints and how can we address them?

A feasibility study was carried out recently using a privately owned helicopter. Onboard the helicopter there is a single frequency GPS receiver. Together with a navigation map it is used to navigate the helicopter as daily routine. During the tests, a geodetic type dual frequency GPS receiver with an embedded GPRS modem was used as a rover receiver to acquire real-time RTCM corrections from a network RTK data server situated in the University of Nottingham and these position fixes were fed into a GIS platform as an alternative navigator. Both the real-time NMEA feeds and the carrier phase measurements of this dual frequency GPS receiver were recorded into the receiver's flash card simultaneously. The raw measurements were then post-processed against a nearby reference station to obtain another trajectory of the helicopter. In total, three trajectories of the same helicopter are gained and compared to obtain the statistic parameters such as the percentage of different level positioning solutions of the rover receiver (i.e. standalone solutions, DGPS and network RTK GPS fixes), comparison of 3D distances of different solutions, GPRS connection rate in the middle air, multipath signature level, interference of helicopter blades, etc.

Recently, a fixed IP SIM card has been used to investigate the wireless connection capacity. Different from accessing the Internet via a dynamic IP system as a majority of mobile operators do, the use of a fixed IP SIM card can be of benefit where GPRS is not at its maximum capacity. Road tests have been carried out in the same flying area to verify the wireless signal strength and positioning quality.

The details of these trials are introduced in the paper and the solutions to improve the performance of network RTK GPS positioning for navigating a helicopter are presented in the paper. It demonstrates the attempt of authors' to exploit wider usage of network RTK GNSS positioning.

Keywords: network RTK GPS, precise helicopter landing system, GIS

Introduction

Helicopters are widely used for military reconnaissance and civilian surveillance, emergency service, agricultural inspection and mapping purposes and normally working in difficult operational environments (Wendel et al. 2006). Acquisition of reliable, instant, continuous and accurate attitude information about a helicopter is critical for manoeuvring a helicopter that is hovering in the sky, taking-off or landing. Nowadays, single frequency GPS receiver using pseudorange measurements for navigating a helicopter is a standard onboard configuration for both navigation and control purposes. Helicopter trials have been carried out recently under EC Framework 6 (FP6) to investigate how the European Geostationary Navigation Overlay Service (EGNOS) and future Galileo could provide required safety levels to aviation sector. Due to the space constraint which means that GPS antennas have to be installed in most cases under helicopter rotor blades, the effect of rotors on the reception of GPS signals have been investigated by Brodin et al (2005). However, carrier phase measurements based GPS positioning for helicopter navigation has only been tested on small size unmanned aerial vehicles (UAV) under controlled environments (Conway 1994). This research was carried out more than a decade ago and at that time GPS was not announced as full operational status. Recent progresses in GPS hardware manufacture, software development, wireless communication and real-time data processing have made high accuracy helicopter navigation and control possible, especially network RTK GPS positioning which will inevitably have a profound impact on future manned or UAV navigation. The main objective of this paper is to report the results from an initial network RTK navigation test that was carried out with a Eurocopter AS355 helicopter with FAA tail number as N766AM in Loughborough region on 18th January 2008 (Figure 1). It also aims at the assessment of advantages and disadvantages of using network RTK GPS positioning for manned or future unmanned helicopter navigation and control, precise landing and taking-off in both hostile and calm environments. Since GSM signal availability is critical for NRTK GPS positioning, a test for the acquisition of the GSM signal was also carried out on 23 September 2008 in the same area.

Figure 1. The first author with the Eurocopter AS355 helicopter in a hangar

The instrumentation for the test

In the helicopter test, real-time corrections from the NRTK GPS data server situated at the Institute of Engineering Surveying and Space Geodesy of The University of Nottingham were used with a normal commercial GPRS communication link as it is configured for any land survey. A Leica 1200 dual frequency GPS receiver was onboard the helicopter as the rover receiver and a lightweight GPS antenna was mounted temporarily close the dashboard of the helicopter to avoid any potential mechanical damage to the helicopter (Figure 2). The test consisted of a normal taking off exercise from a landing platform, short flight in the space close to the East Midlands Airport, hovering, and landing for of about one hour.

Figure 2. The antenna installation for the helicopter test

The helicopter has its own GPS navigator and the trajectory data can be downloaded from the log file after the test. Other two trajectories were obtained through post-processing GPS raw measurements that were recorded with the receiver memory card and extracting NMEA data stream that were generated by the receiver in real time and recorded by the same memory card. Overall three sets of 3D coordinate time series are obtained from this test.

Results and analysis

Figure 3 shows the comparison of the post-processed trajectory with the trajectory determined by the onboard GPS navigator. The post-processed one has been offset by 400m in both the E and N directions. It can be found from this figure that the two trajectories match very well for most sections of the flight but there is a systematic offset when the helicopter flew from the West to the East and also two obvious gaps from the post-processed result. Due to the place where the antenna was mounted there was no enough number of satellites for fixing the integer ambiguities during post-processing the raw measurements. However, the onboard GPS receiver could provide much more consistent position solutions due to its capacity to capture weak GPS signals and less obstruction caused by the helicopter itself.

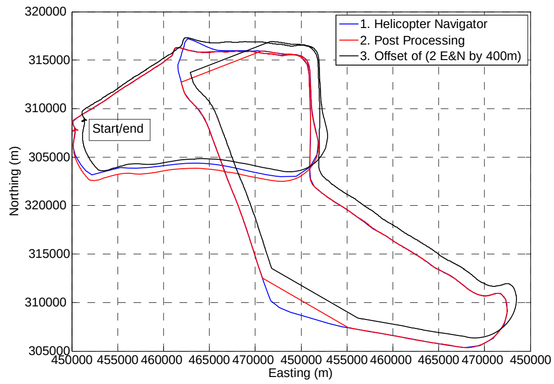

Figure 3. Trajectories obtained by post-processing the recorded GPS measurements (red one for the original trajectory and dark colours for the offset one) and that recorded with the onboard GPS navigator (blue)

A further comparison is made to the height measurements as shown in Figure 4. As it can be seen from this figure, the discrepancies between two height solutions are big in the beginning when the helicopter was ascending but are reduced once the helicopter was hovering in the sky and approaching the land platform. The reason for this needs to be further investigated. From this figure it can also be seen that the highest height the helicopter flew is about 662m.

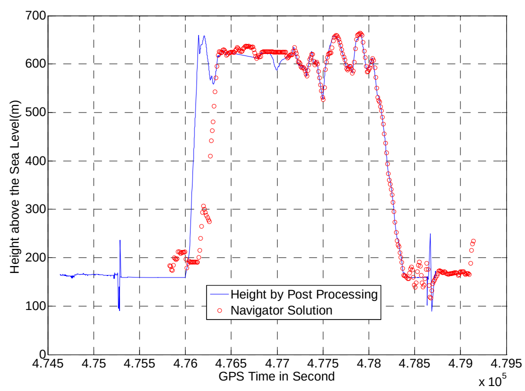

Figure 4. Height components determined with the onboard GPS navigator and through post-processing the raw GPS measurements.

As it is introduced in the abstract, the main purpose of this test was to investigate the feasibility of network RTK GPS positioning for navigating the manoeuvre of a helicopter. There is an established testing reference station network that was jointly developed by the University of Nottingham and Leica Geosystems Ltd. More details can be found from Meng et al (2007). There is a reference station that is situated at the HQ of the Beacon Energy Ltd which was employed to post-process the recorded GPS carrier phase measurements. For achieving high-quality positioning solutions with NRTK GPS positioning, maintaining a continuous data communication link between the NRTK data server that is located at the University of Nottingham for generating precise RTK corrections and the rover is as critical as maintaining the tracking to at least five well distributed satellites. Due to the constraints caused by the local landscape and lack of GSM base stations, access to GPRS signal cannot always be guaranteed. Figure 5 shows the real-time positioning solutions. It is apparent that there are places where even standalone positions could not be achieved due to the lack of GPS measurements. There are about half the positions that are stamped as standalone solutions and one third of the positions are DGPS solutions. Only a few segments of 10% the total positions when the helicopter was ascending from the landing platform and where it was close to turning point OSWED are NRTK GPS solutions. In theory, when the helicopter flew from the North to the South (the middle red trajectory with a break end) there should have more chances to achieve NRTK solutions if the communication link was uninterrupted. However, it looks like this assumption does not exist. A dedicated test was carried out separately to investigate the existence of GPRS signal and their strength.

This signal strength test was carried out on 23 September 2008 on a route chosen as close as possible to the helicopter trail, as shown in Figure 6. The main concern is if the distribution of the GPS solution quality is similar to the helicopter test. If this is the fact, it can confirm that the density of the GSM transmission base stations will be the main reason for the low-level solutions. However, through comparison of Figures 5 and 6, it can be found that the ground test showed a different result from that of the helicopter test. It can be seen that about one quarter of the positions are standalone solution, a half of the positions are DGPS solutions and the other quarter are NRTK solutions, which is generally better than the helicopter test. The distribution of these solutions is also different from that of the helicopter test as well. Therefore the density of the base stations is not the reason for the low-level NRTK solutions. The GPRS signal strength distribution is shown in Figure 7. It can be seen that, the quality of the ground solutions has a correlation with the signal strength. Although in the ground test the local terrain is a different factor with that of the helicopter test, which also affects the received signal strength and then the solution quality, it only deteriorate the solutions and still cannot be used to explicitly explain the difference between the two tests.

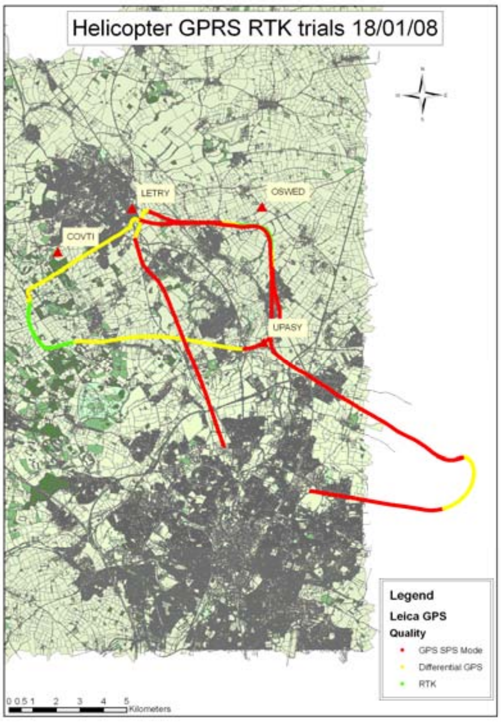

Figure 5. Positioning quality on the helicopter using NRTK GPS positioning (red, standalone positions; yellow, DGPS positions; green, NRTK positions)

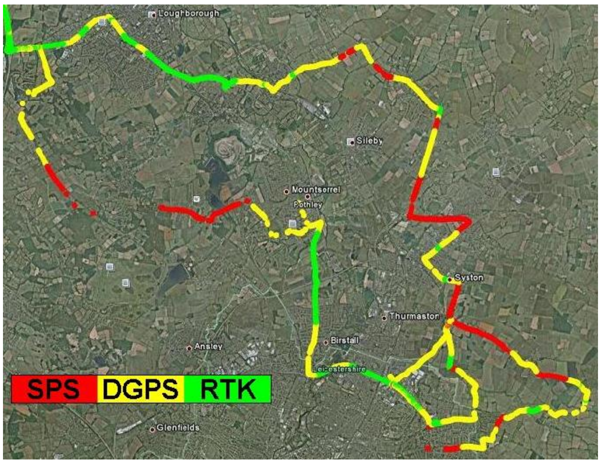

Figure 6. Positioning quality on the ground using NRTK GPS positioning (red, standalone positions; yellow, DGPS positions; green, NRTK positions)

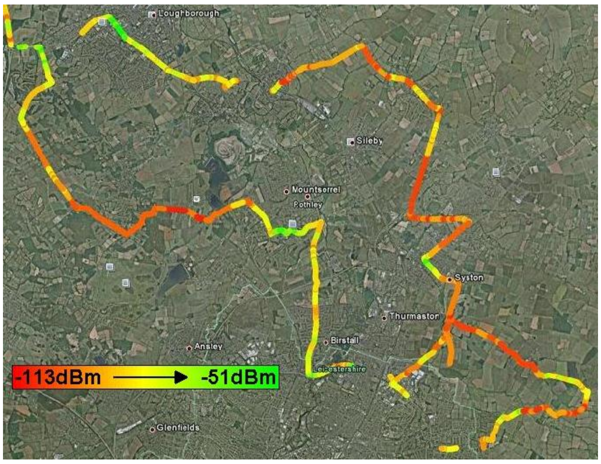

Figure 7. GPRS signal strength on the ground

A reasonable explanation for the low-level solutions in the helicopter test can be related to the gain pattern of GSM base station antenna. This antenna is a directional antenna, and its mainlobe beam is tilting downward to provide a good service to the space lower than it. Therefore the service for a higher position than the base stations, such as the helicopter trial, is possibly not guaranteed. The DGPS solutions in Figure 5 are in the area close to the helicopter hangar. In this area the helicopter is taking off / landing, and is in a relative lower height where may still in the coverage of the GSM antenna sidelobe. The assumption of this explanation is based on that the quality of GPS solutions on a helicopter may relate to its flight height. Further tests are required to confirm this assumption.

Discussions and Conclusions

These two trials aimed at investigating whether network RTK GPS positioning is a feasible technology NOW for navigating the manoeuvre of a helicopter and if the answer is not we tried to interpret the hidden causes. Due to the location of the GPS antenna onboard the helicopter which is not ideal for intercepting GPS signals and the height that helicopter flew (GSM communication link might not be maintained) the success rate of network RTK GPS positioning is very low. Tests have been carried out to investigate the differences between dynamic and fixed IP wireless communications for streaming NRTK corrections and concluded that no apparent effect of them (Aponte et al. 2008). Attempt has also been made using a dedicated survey van and a newly developed GSM signal strength detection software suite to check the GSM signal strength on the ground in the area that the helicopter was flown. No clear pattern can be identified for linking GSM signal strength and the quality of GPS positioning by the helicopter trial. However the correlation between the quality of ground-based NRTK positioning and GSM signal strength is illustrated by Figures 6 and 7. It can be concluded that using current configuration of GPS antenna installation and GSM communication link cannot provide required positioning accuracy and reliability. However, if the GPS antenna could be installed on the tail of the helicopter or any places outside the helicopter with a more open view and satellite mobile phone could be used to stream the NRTK corrections we have no reason to say that NRTK GPS is NOT a feasible navigation technology for aviation applications. One study is currently underway at the IESSG, and amongst many project tasks of it, the investigation of satellite based mobile communication for support NRTK GPS positioning is one important work package (http://www.sister-project.org/), and may contribute to the future network RTK applications to helicopter navigation.

References

Aponte, J., Meng, X., Moore, T., Hill, C., and Burbidge, M. (2008). "Investigating the Impact of the Commercial GSM/GPRS Communications on the Availability of the Network RTK GNSS Service. " GNSS 2008, 16-19 September 2008, Savannah, Georgia.

Brodin, G., Cooper, J., and Walsh, D. (2005). "The Effect of Helicopter Rotors onGPS Signal Reception." *The Journal of Navigation*, 58(2005), 433-450.

Conway, A. (1994). "Autonomous Control of an Unstable Helicopter Using Carrier Phase GPS Only," PhD thesis, Stanford University.

Meng, X., Dodson, A. H., Moore, T., and Roberts, G. W. (2007). "Ubiquitous Positioning: Anyone, Anything: Anytime, Anywhere." *GPS World*, 18(6), 60-65.

Wendel, J., Meistera, O., Schlailea, C., and Tromme, G. F. (2006). "An integrated GPS/MEMS-IMU navigation system for an autonomous helicopter." *Aerospace Science and Technology*, 10(2006), 527-533.