Carrier-Phase Multipath Mitigation in RTK-Based GNSS Dual-Antenna Systems

Abstract

Carrier-phase multipath mitigation in GPS/GNSS real-time kinematic (RTK) mode has been studied for several years, at least since on-the-fly ambiguity resolution techniques were introduced, and receiver hardware improvements to the point that position estimates achieved cm-level accuracies.

This level of accuracy has heralded a new era of applications where the use of GNSS RTK-based techniques can be considered the most reliable navigation tool, especially in the fields of machine automation, industrial metrology, control, and robotics.

However, this incredible surge in accuracy tied with real-time capabilities comes with a cost: one must also ensure continuity, and integrity. Typical users of these systems do not expect heavy machinery drifting from their true paths, caused mostly by changing multipath environments.

In multipath-rich scenarios, phase-multipath reflections can seriously degrade the RTK solutions, and in worst scenarios, integer fixed solutions are no longer available. This dissertation intends to deal with these scenarios, where the rover algorithms should deal with multiple reflections and, in real-time, be able to ameliorate/mitigate their effect.

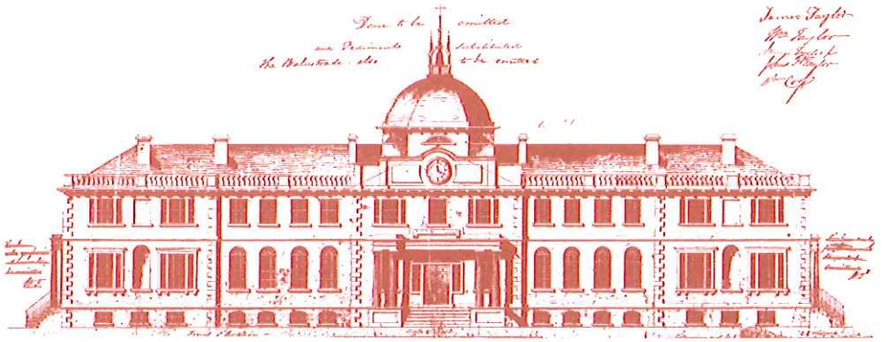
GNSS-based heading/attitude is usually obtained combining the data from two or more antennas (also known as a moving baseline). Many companies provide commercial systems based on this technique, hence this dissertation finds its main applicability here.

Typical heavy construction machinery includes dozers, motor-graders, excavators, scrappers, etc., which usually have GNSS dual-antenna systems to provide positioning and orientation information to the operator. We have not used and collected data from one of these machines, although the author has worked extensively with such machinery and their GNSS-based systems. However, the theory developed throughout this dissertation and the proof of concept through controlled tests that mimic the machinery/installed GNSS dual-antenna systems, are the basis of this dissertation.

Moreover the algorithms developed here are meant to be used independently from the receiver hardware, as well as from GNSS signals. Hence GLONASS, and/or Galileo signals can be processed too. This dissertation is based on the fundamental relationship between multiple multipath reflections from close-by strong reflections, and their effect on GNSS RTK-based dual-antenna systems.

Two questions were answered: Firstly, is it possible to retrieve strong multipath reflectors in kinematic applications? Second, once these strong reflectors are correctly identified, how accurate/reliable are the corrections to the raw carrier-phase multipath, knowing that the host platform performs unpredictable manoeuvres?

Based on the results, we can conclude that it is possible to estimate in real-time multipath parameters based on a strong effective reflector. In most of the tests it takes at least 2 minutes to obtain initial values (after Kalman filter convergence). Once they are determined, multipath corrections can be determined straightforwardly for each satellite being tracked, as long as there are no cycle-slips.



Home of the School of Graduate Studies, Sir Howard Douglas Hall was designed by J.E. Woolford in 1825 and is the oldest university building in Canada still in use.

UNIVERSITY OF NEW BRUNSWICK

SCHOOL OF GRADUATE STUDIES

ORAL EXAMINATION

Luis Serrano

IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

Ph.D. Candidate

Luis Miguel Pina Amaral Serrano

Graduate Academic Unit

Geodesy & Geomatics Engineering

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

September 27, 2013

1:00 p.m.

ADI Studio (Room HC 25)
Head Hall

~~~~~~

Examining Board:

Dr. Richard Langley (Geodesy & Geomatics Eng.)	Co-Supervisor
Dr. Donghyun Kim (Geodesy & Geomatics Eng.)	Co-Supervisor
Dr. Marcelo Santos (Geodesy & Geomatics Eng.)	
Dr. Peter Dare (Geodesy & Geomatics Eng.)	
Dr. Bruce Colpitts (Electrical & Computer Eng.)	Chairperson

External Examiner:
Dr. Kyle O'Keefe, PEng.
Dept. of Geomatics Engineering
Schulich School of Engineering
University of Calgary

The Oral Examination will be chaired by:
Dr. Ed Biden, Dean of Graduate Studies

BIOGRAPHY

Education:

1995-2002	Dipl. Engineering, Surveying Engineering, Dept. of Mathematics, Faculty of Sciences of the University of Lisbon Campo Grande
2003-2004	MScE, Dept. of Geodesy and Geomatics Engineering, University of New Brunswick (transferred into PhD program in January 2004)
2004-2013	Ph.D. Candidate in GNSS/Geodesy and Geomatics Engineering

Publications:

Serrano, L., D. Kim, R. B. Langley, K. Itani and M. Ueno (2004). "A GPS Velocity Sensor: How Accurate Can It Be? – A First Look." Proceedings of NTM 2004, the 2004 National Technical Meeting of The Institute of Navigation, San Diego, CA, 26-28 January 2004; pp. 875-885.

Serrano, L., D. Kim, and R. B. Langley (2004). "A Single GPS Receiver as a Real-Time, Accurate Velocity and Acceleration Sensor." Proceedings of GNSS 2004, the 2004 GNSS of The Institute of Navigation, Long Beach, CA, 21-24 September 2004; pp. 2021-2033.

Serrano, L., D. Kim, and R. B. Langley (2005). "A New Carrier-Phase Multipath Observable for GPS Real-Time Kinematics Based on Between Receiver Dynamics." Proceedings of The 61st Annual Meeting of The Institute of Navigation, Cambridge, MA, 27-29 June 2005.

Serrano, L., D. Kim, and R. B. Langley (2005). "A New Approach for Mitigating Low-Frequency Carrier-Phase Multipath in GPS-RTK, Based on Between-Receiver Dynamics and an Effective Reflector". Proceedings of The ION GNSS Meeting of The Institute of Navigation, Long Beach, CA, September 13-16, 2005.

Kim D., L. Serrano and R. B. Langley (2005). "Compensating Phase Wind-up Effects for Improving the Performance of a GPS RTK-Based Vehicle Navigation System". Proceedings of The ION GNSS Meeting of The Institute of Navigation, Long Beach, CA, September 13-16, 2005.

Beran T., R. B. Langley, S. B. Bisnath and L. Serrano (2005). "High-Accuracy Point Positioning with Low-Cost GPS Receivers: How Good Can It Get?" Proceedings of The ION GNSS Meeting of The Institute of Navigation, Long Beach, CA, September 13-16, 2005 **(Best Paper Award).**

Serrano, L., D. Kim and R. B. Langley (2006). "Performance Analysis of the NovAtel OEM4-G2L Receiver for Low Earth Orbit Satellite Tracking". Report for the Canadian Space Agency (CASSIOPE Project), May 2006, 18 pp

Kim D., L. Serrano and R. B. Langley (2006). "Phase Wind-Up Analysis: Assessing Real-Time Kinematic Performance". Innovation Column, GPS World, September 2006, pp. 58-64.

Serrano, L., D. Kim, and R. B. Langley (2006). "Near Real-Time Carrier-Phase Multipath Mitigation in Kinematic Applications, Using a Dual-Antenna System and Effective Close Range Reflectors". Proceedings of The ION GNSS Meeting of The Institute of Navigation, Fort-Worth, TX, September 26-29, 2006.

Beran T., R. B. Langley, S. B. Bisnath and L. Serrano (2006). "High-Accuracy Point Positioning with Low-Cost GPS Receivers: How Good Can It Get?" Accepted for publication at "Navigation", Journal of The Institute Of Navigation

Serrano, L., D. Kim, and R. B. Langley (2007). "Real-time Multipath Calibration of a GPS-Based Heading Reference system". Proceedings of TimeNav'07, European Navigation Conference GNSS 07, Geneva, Switzerland.

Serrano, L. (2007). "Leica Geosystems New Technologies". Presented at European CGSIC/ISC Meeting, TimeNav'07, European Navigation Conference GNSS 07, Geneva, Switzerland

Serrano, L., D. Kim, and R. B. Langley (2008). "Carrier-Phase Multipath Calibration in GPS-RTK Machine-Guidance Applications". Proceedings of The ION / IEEE PLANS Conference, Monterey, CA, May 3-5 **(Best Paper Award).**

Serrano, L., C. S. Dixon, and R. Haas (2009). "Pseudolite Augmentation for GNSS-based Monitoring Systems". Proceedings of ENGA 09 (Encontro Nacional de Geodesia Aplicada), 12-13 October, LNEC, Lisbon, Portugal

Serrano, L. (2010). "Multipath Adaptive Filtering in GNSS/RTK-Based Machine automation Applications". Proceedings of the ION/IEEE PLANS Conference, 3-6 May 2010, Indian Wells/Palm Springs, CA.