International Journal of Innovative Computing, Information and Control
Volume **4**, Number **1**, January **2008**

ICIC International ©2008 ISSN 1349-4198
pp. 127–141

FURTHER STUDY ON PPP BASED ON GR MODELS WITH MULTIPLE ANTENNAS

Seigo Fujita, Yukihiro Kubo and Sueo Sugimoto

Department of Electrical and Electronic Engineering
Ritsumeikan University
1-1-1, Noji-Higashi, Kusatsu City, Shiga, 525-8577, Japan
sugimoto@se.ritsumei.ac.jp

Received February 2007; revised July 2007

Abstract. *In this paper, we present the new carrier-phase-based Precise Point Positioning (PPP) algorithm based on GR models (GNSS Regression models) by using multiple antennas. Previously, we introduced GR equations such that a PPP algorithm was derived. In the single frequency case, the derived PPP algorithm achieved a positioning accuracy at the decimeter error level without any external information, such as from wide area augmentation system (WAAS). After showing the GR models which contain the so-called receiver's and satellite's hardware biases, we extend our PPP algorithm for using multiple antennas and present a new positioning method called Very Precise Point Positioning (VPPP). VPPP algorithms are derived by using two or more PPP antennas with common clock errors and known distances among antennas. We formulate estimation algorithms with the constraints of the distances among antennas so that the recursive VPPP algorithms are derived. Finally, we show the experimental results of the present VPPP algorithms using real receiver data collected in the static environments.*

Keywords: Precise point positioning, GNSS regression models, Kalman filter, Multiple antennas

1. **Introduction.** In this paper, we will introduce new carrier-phase-based Precise Point Positioning (PPP) algorithms with multiple antennas based on GR models (: GNSS Regression models), which have been developed in [1]-[6]. PPP is an ultimately desirable technology in the GPS/GNSS positioning community [7]. In the single frequency case, our derived positioning algorithm achieves the positioning accuracy in decimeter level [3]-[5] without any external transmitted information, such as information from the WAAS. Furthermore, in order to achieve rapid and accurate positioning, we extend our PPP algorithms for using multiple antennas and developed a new positioning method called Very Precise Point Positioning (VPPP).

According to [6], we present GR equations which contain the receiver's and satellite's hardware biases such that VPPP algorithms are derived by using multiple antennas which are disposed with solid geometrical distances and common receivers' clock errors. The measurement data is obtained from L1, L2 band carrier phases, as well as the pseudoranges based on C/A and P(Y) codes, respectively. The regression matrix in a GR model is given by computing the gradient vector of the geometric distance between the receiver, u, and the satellite, s, with respect to the j-th estimated value $\hat{u}^{(j)}$ and $\hat{s}$.

In this next section, we will show the GR models and use them to derive a PPP algorithm. In section 3, the PPP algorithm is extended to VPPP using two or more GNSS antennas with common clock errors and known distances among receivers [8]. We then developed he algorithms for estimating the mid-position of the antennas with the constraints of the distances among antennas, based on recursive Kalman filtering. Finally,