IMPROVING ACCURACY OF REAL TIME KINEMATIC POSITIONING BY USING PPP WITH IGS-RTS CORRECTIONS

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ABSTRACT

The accuracy of real time single point positioning using the broadcast ephemeris is at the meter level, thus it is usually only used for low accuracy applications. Applying IGS-RTS corrections to real time precise point positioning (the so-called RTPPP) has improved the accuracy significantly. When compared with the results of RTK techniques for kinematic cases in Vietnam, the accuracy of RTPPP in East, North, Up components is (0.19, 0.25, 0.23) m respectively. These accuracies are improved in East (78%), North (75%) and Up (89%) components compared with single point positioning using the broadcast ephemeris (0.87, 1.01, 2.14) m. With the accuracy of RTPPP it can be applied in precise navigation or bathymetric surveys.

Keywords: *RTPPP, PPP, IGS-RTS Corrections, Real time kinematic positioning*

1. INTRODUCTION

Currently, Global Navigation Satellite System (GNSS) has become an important part in construction and surveying services. GNSS can provide accurate position, velocity and time. The information can be obtained using several different GNSS techniques, where the technique used depends on the specific accuracy requirement and the efficiency.

Since 2013, contributing to improved accuracy in real-time positioning, the International GNSS Service (IGS) has assisted users through the transmission service of the GNSS satellites orbit and clock corrections in real time. These corrections are formatted according to the RTCM-SSR standard and are transmit to the users via the Internet protocol [12].

Real Time Precise Point Positioning (RTPPP) is a relatively new technique of absolute positioning. Basically, RTPPP is the development of the Precise Point Positioning (PPP) technique. RTPPP uses carrier phase and pseudo range in ionospheric-free linear combination. In order to get high accuracy of survey point positions, RTPPP needs satellite orbit and clock corrections which can be got from the Real Time Service (RTS) of the IGS.

According to our previous research [16], the accuracy of single point positioning using RTS in real time static positioning cases of the North, East and Up components is 0.26 (m), 0.21 (m) and 0.40 (m), respectively. This accuracy improves about 75% in horizontal and 81% in vertical components compared to single point positioning using broadcast ephemeris, and is about 50% less than post-processing results using the IGS Final precise ephemeris and 30s clock corrections (0.11, 0.10 and 0.21m).

This paper will present the concept and algorithms of RTPPP as well as its performance in real time kinematic positioning cases in Vietnam, by comparing them with the RTK technique.

2. ALGORITHM FOR RTPPP USING IGS-RTS CORRECTIONS

The RTPPP technique uses the pseudo range and carrier phase observation from a single dual-frequency receiver. RTPPP can use ionospheric-free linear combinations in order to eliminate the ionospheric effects on satellite signals [6].

$$P_{i,3}^{k}(t)=\alpha_1 P_{i,1}^{k}(t)-\alpha_2 P_{i,2}^{k}(t)=\rho_i^k(t)+c\left[dt_i(t)-dT^k(t)\right]+T_i^k(t)+\varepsilon_{i,3}^{-k}(t) \quad (1)$$

$$\Phi_{i,3}^{k}(t)=\alpha_1 \Phi_{i,1}^{k}(t)-\alpha_2 \Phi_{i,2}^{k}(t)=\rho_i^k(t)+c\left[dt_i(t)-dT^k(t)\right]+T_i^k(t)+b_{i,3}^{k}+\varepsilon_{i,3}^{k}(t) \quad (2)$$

Where:

- $\Phi_{i,1}^{k}(t)$ and $\Phi_{i,2}^{k}(t)$ are phase measurements of f_{L_1} and f_{L_2} respectively
- $P_{i,1}^{k}(t)$ and $P_{i,2}^{k}(t)$ are pseudo range measurements of f_{L_1} and f_{L_2} respectively
- $\rho_i^k(t)$ is the geometric distance between receiver and satellite
- $T_i^k(t)$ is the tropospheric delay
- $dt_i(t)$ and $dT^k(t)$ are the receiver and satellite clock corrections respectively
- $\varepsilon_{i,3}^{k}(t)$ and $\varepsilon_{i,3}^{-k}(t)$ are the relevant measurement noise components, including multipath
- $b_{i,3}^{k}$ is the iono-free ambiguity parameter (non-interger)
- c is the speed of the light
- The coefficients :

$$\alpha_1=\frac{(f_{L_1})^2}{(f_{L_1})^2-(f_{L_2})^2}\approx 2.545728 \text{ and } \alpha_2=\frac{(f_{L_2})^2}{(f_{L_1})^2-(f_{L_2})^2}\approx 1.545728 \quad (3)$$

The RTPPP estimates four types of parameters:- the receiver position, the receiver clock error, the tropospheric zenith path delay and the ambiguity.

The accuracy of the broadcast ephemeris is 1 m for satellite's orbit and 5 ns for satellite's clock [5, 11], these shall be corrected to improve positioning accuracy. In such cases, IGS-RTS can be used as correction values to broadcast ephemeris. Information related to satellite orbit corrections is provided via message type 1057 and information related to satellite clock corrections is provided via message type 1058 [4].

The GPS satellites orbit correction δO include three position component: radial (δO_r), along-track (δO_a), cross-track (δO_c), and three velocity component: $\delta\dot{O}_r$, $\delta\dot{O}_a$, $\delta\dot{O}_c$ respectively. Calculate the orbit correction for time t according to time t_0 [4, 12, 16].

$$\delta O(t)=\begin{bmatrix}\delta O_r\\ \delta O_a\\ \delta O_c\end{bmatrix}+\begin{bmatrix}\delta\dot{O}_r\\ \delta\dot{O}_a\\ \delta\dot{O}_c\end{bmatrix}.(t-t_0) \quad (4)$$

Calculate the direction unit vectors: e_r, e_a, e_c

$$e_a=\frac{\dot{r}}{|\dot{r}|}\ ;\ e_c=\frac{\dot{r}\times r}{|\dot{r}\times r|}\ ;\ e_r=e_a\times e_c \quad (5)$$

where: r is the satellite broadcast position vector and $\dot{r}$ is the satellite broadcast velocity vector at time t.

Transform the corrections to geocentric corrections

$$\delta r(t) = \begin{bmatrix} e_r & e_a & e_c \end{bmatrix} . \delta O(t) \quad (6)$$

Correct the geocentric corrections $\delta r(t)$ to broadcast orbits $r(t)$ to obtain precise orbits

$$r_p(t) = r(t) - \delta r(t) \quad (7)$$

The GPS satellites clock correction includes three parameters: C_0, C_1, C_2. Calculate the clock correction for time t according to time t0 [4, 12, 16].

$$\delta C(t) = C_0 + C_1.(t - t_0) + C_2.(t - t_0)^2 \quad (8)$$

Correct the clock correction $\delta C(t)$ to broadcast clock

$$dT^s(t) = dT_b^s(t) + \frac{\delta C(t)}{c} \quad (9)$$

where: c is the speed of light.

We have estimated the precision of the GPS satellites orbit and clock corrected by RTS corrections [15]. The result has shown that the precision of the GPS satellites orbit is about 0.3m, while the precision of the GPS satellite clock corrections is about 1.2ns.

3. DATA COLLECTION AND PROCESSING

Basic flowchart for this research can be seen on **Figure 1**:

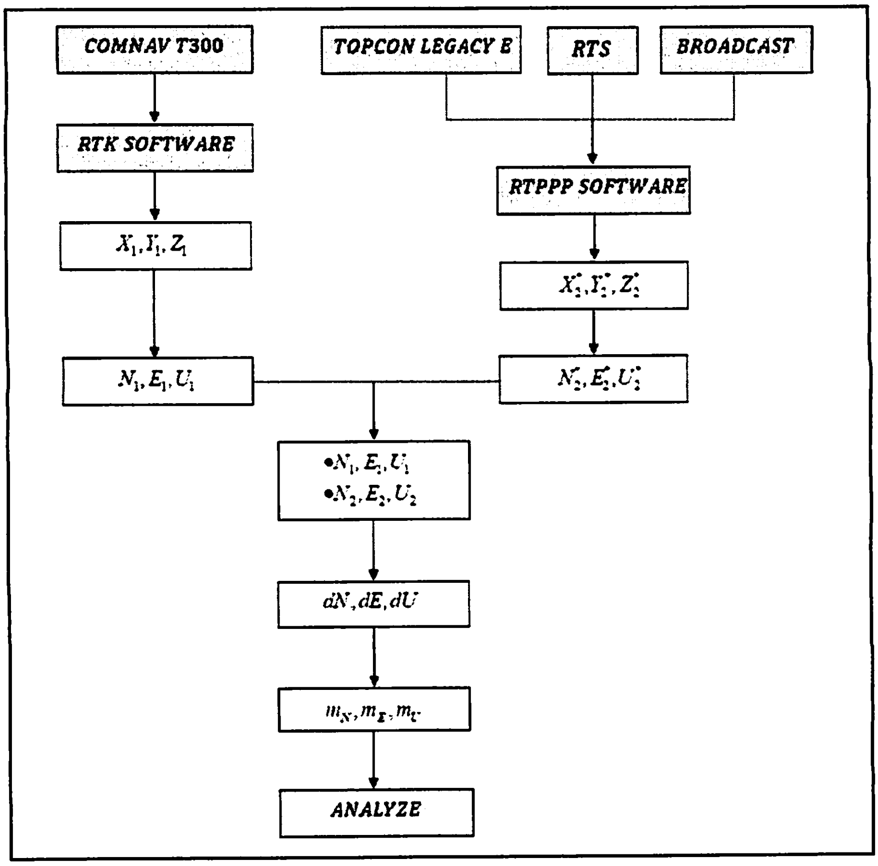

Figure 1. Flowchart for research methodology

To evaluate the accuracy of real time kinematic positioning by using PPP with IGS-RTS corrections, we conducted 2 types of techniques: RTK and RTPPP. The survey points by RTK techniques are used as reference points. According to [3], the accuracy of the RTK for fix solution is only a few cm, which is sufficient to refer to when evaluating the results of RTPPP. We designed two systems and installed them on the roof of a car as shown in **Figure 2**:

- *RTPPP system*: the Legacy-E antenna connected to the Topcon Legacy-E receiver. It collects measurements to transmit to the laptop, while the laptop is also connected to the Internet to get RTS corrections from the IGS, so that it can compute the coordinates of the Legacy-E antenna by the RTPPP technique.
- *RTK system*: the Comnav T300 receiver is connected to the controller via Bluetooth to receive corrections transmitted from the base station which is setup at the benchmark DNE02 in order to compute the coordinates of the rover antenna by RTK technique.

Figure 2. The antennas installed on the car roof.

Our Research used Topcon Legacy-E and Comnav T300 receivers (**Table 1**).

Table 1. The main equipment using for research.

Equipment	**Function**
Topcon Legacy-E Dual Frequency Receiver	Receive the GNSS satellites signal
Laptop with access to the Internet installed RTPPP software and connected to the Topcon Legacy-E Receiver by cable	Compute and collect survey point coordinates by RTPPP
Comnav T300 Dual Frequency Receiver	Receive the GNSS satellites signal
Controller connected to Comnav T300 Receiver by Bluetooth	Compute and collect survey point coordinates by RTK
The Car	Moving to collect the data

The reference coordinates of the benchmark DNE02 was processed by Static PPP method showed at **Table 2**. With the accuracy of Static PPP only at the level of mm-cm [5, 6, 9], so it is used as the basis for comparison with RTPPP results.

Table 2. Coordinates of the benchmark DNE02 in ITRF2014.

Benchmark	Duration	X (m)	Y (m)	Z (m)
DNE02	2 hours	-1800848.644	6000594.907	1191996.396

4. ANALYZE AND EVALUATE RESULTS

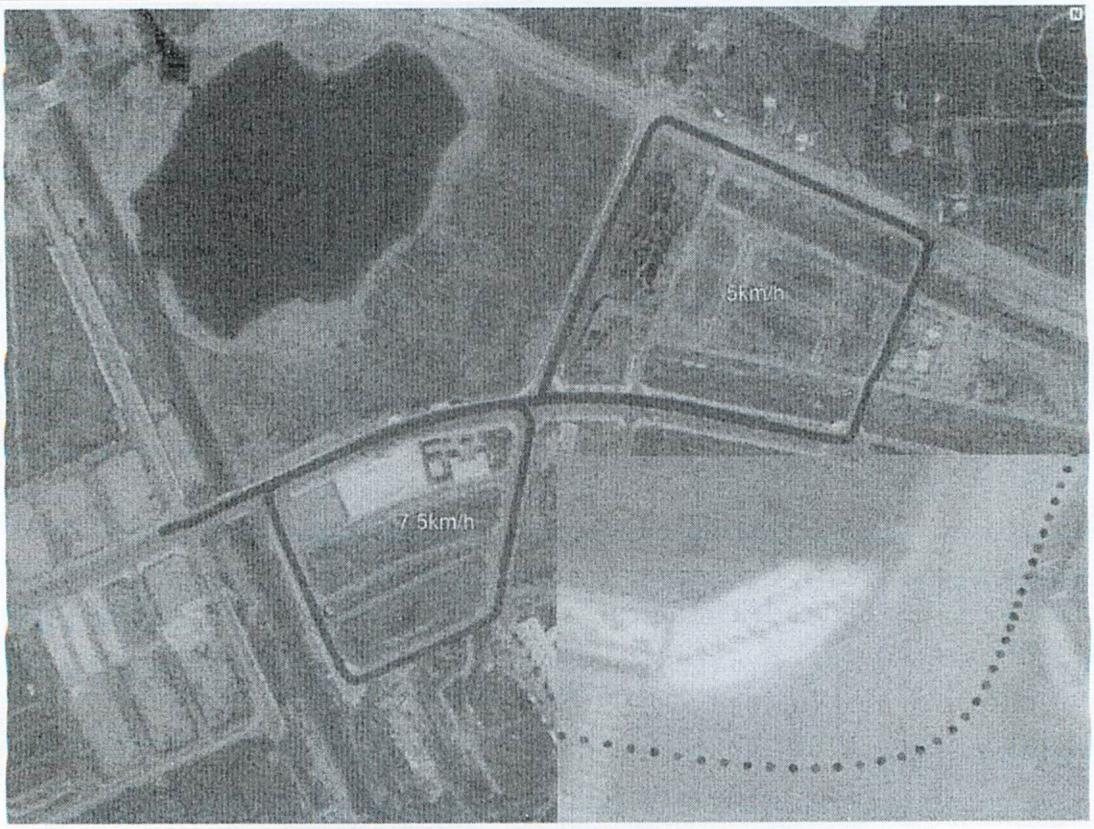

Figure 3. The positions of the survey points viewed on Google Earth.

Note:

- Red color points are the survey points by RTPPP
- Blue color points are the survey points by RTK.

Table 3. The accuracy of RTPPP using IGS-RTS corrections.

Case	M_E (m)	M_N (m)	M_U (m)	M_{3D} (m)
Straight lines	0.172	0.235	0.237	0.375
Curved lines	0.213	0.260	0.218	0.400
Average	0.193	0.247	0.227	0.387

Table 3 shows the accuracy of the RTPPP technique. Compared with the RTK technique, RTPPP gives the point accuracy about ~19 cm for Easting and ~25 cm for Northing, while the *accuracy for Up* component about ~23 cm.

Figure 3 shows the line shape created by the survey points by RTPPP (red color) is similar to the line shape created the survey points by RTK (blue color). In addition, the distances between the points measured by RTPPP and RTK at the same time is approximately equal to the distance between the two antennas installed the car roof.

5. CONCLUSION

The accuracy of RTPPP in East, North, Up components is (19, 25, 23) cm respectively when compared with the results of RTK techniques for kinematic cases in Vietnam. These accuracies are improved in East (78%), North (75%) and Up (89%) components compared with single point positioning using the broadcast ephemeris (0.87, 1.01, 2.14) m [16].

As the results of previous studies [1, 5], the RTPPP accuracy can be at the level of dm. These results provide better accuracy than our results. The reason for this difference is that the ambiguity parameters in the algorithm which we refer is are not integers, our GPS receivers and antennas are normal type, not as good as the receivers of IGS stations, so they are not as capable of reducing the multipath and noise as well as the IGS stations. Moreover, the coordinates when referred to the reference point in the kinematic case are also influenced by the azimuth angle computed from two consecutive epochs of the RTK results. In addition, the reference point coordinates used for comparing and evaluating positioning accuracy are obtained through the sending of observation data to online PPP processing services not the precise coordinates of IGS stations.

RTPPP is a new promising technique in position determining due to its efficiency and low cost. In general, RTPPP can provide results for kinematic cases with an accuracy of a few dm. With the accuracy of RTPPP it can be applied in precise navigation or bathymetric surveys.

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