Journal of the Korean Society of Surveying, Geodesy, Photogrammetry and Cartography, Vol. 31, No. 6-2, 539-547, 2013
http://dx.doi.org/**10.7848/ksgpc.2013.31.6-2.539**

The Suggestion of Effective Measurement Techniques for Positioning Under Poor GPS Reference Network Condition

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Abstract

This research is suggesting the most effective positioning method for GPS based positioning when no GPS reference point is available in the neighborhood. For this purpose, we carried out positioning of the IGS real-time observatories in Australia in various conditions. According to the research, we were certainly assured the one reference point with a short baseline length is more effective for differential positioning than multiple reference points with a long baseline distance beyond 1,000km and suggested the precise point positioning based positioning method can be an excellent substitute when no reference point is available around an unknown point. The research result may be used as the basic data for accurate positioning in poor reference point environments, especially in Antarctica.

Keywords : GPS, Precise positioning, Precise point positioning, Relative positioning

1. Introduction

Multilateral efforts have been made by national institutions, research center, and academia for GPS based applied researches on the 3 dimensional positioning system and the differential positioning method is commonly used for accurate positioning such as reference point survey whose accuracy has been validated through a number of researches(Beutler *et al*., 1989; Eckl *et al*., 2001; Soler *et al*., 2006; Pasi *et al*., 2008). Beutler, G. *et al*. studied the effect of the baseline distance on positioning and suggested the empirical formula between the baseline distance and the accuracy as a result of his study. Eckl M.C. *et al*. additionally analyzed the observation time accuracy besides the baseline distance and Soler *et al*.(2006) proposed the formula between the observation time and the positioning accuracy, applicable to at least 3 hour long observation based on his research on both factors. Meanwhile, Pasi *et al*.(2008) studied the effect of baseline distance, observation time, and orbit on positioning. To our regret, however, no research has been made to suggest the most effective GPS based positioning method when few GPS reference points are available around an unknown point and very long baseline processing is inevitable.

Differential positioning is commonly contained in ionospheric errors, tropospheric errors, and satellite visibility errors of the reference point. The error is occurring while a signal arrives as the receiver of a measuring point from the GPS satellite by the difference method and in the signal received by the reference point. and an arbitrary measuring point. It has an advantage of being eliminable but has a disadvantage that the error is in proportion to the baseline distance on the other hand on the assumption the quantity is maintained uniformly(Dach *et al*., 2007; Elliott *et al*., 2006; Kim *et al*., 2013). While, precise point positioning calculates the distance errors by using the error model formula for measuring point positioning and its positioning accuracy is

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dependent on the calculated distance error accuracy(Gao, 2006; Héroux *et al*., 2001; Tanaka *et al*., 1989; Zumberge *et al*., 1998).

Under this research, we selected Australia as the research target area to suggest the most effective positioning method under the poor reference point situation in which few GPS reference point are available around an unknown point and very long baseline processing is inevitable and we also used the IGS real-time observatory for GPS based positioning in various conditions. Fig. 1 shows the study flow diagram.

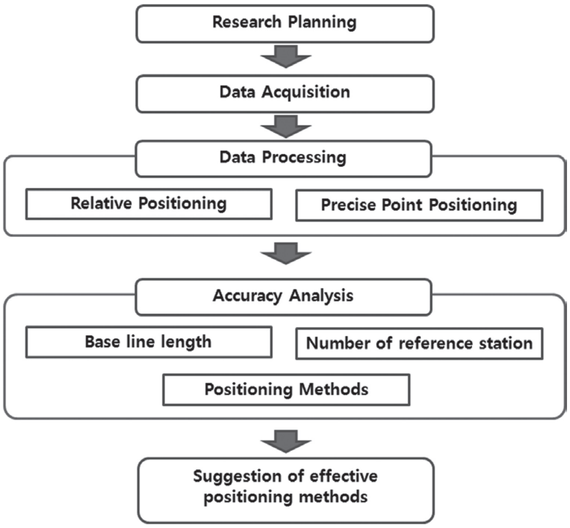

Fig. 1. Study flow diagram

2. Data Acquisition and Processing

Australia is one independent continent which may be divided into a continent and an ocean, along the coast of which are positioned IGS CORS. In Australia, there are 10 IGS CORS having an announced result on the reference of IGS05, Darwin (DARR), Jabiru (JAB1), Karratha (KARR), Alice Springs (ALIC), Cape Ferguson (TOW2), Dongara (YAR2), Perth (PERT), Ceduna (CEDU), Hobart (HOB2), and Canberra (TID1). Among those, DARR and JAB1 CORS are about 190km away and 3 CORS (KARR, ALIC, TOW2) are positioned at 1,000 to 2,000km away from DARR CORS and 5 CORS (YAR2, PERT, CEDU, HOB2, TID1) are at least 2,000km away from it. This regional characteristics convinced us of their usefulness for differential positioning and precise point positioning experiment, taking into account the baseline distance and the number of reference points in use. Fig. 2 shows the location map of IGS CORS in Australia.

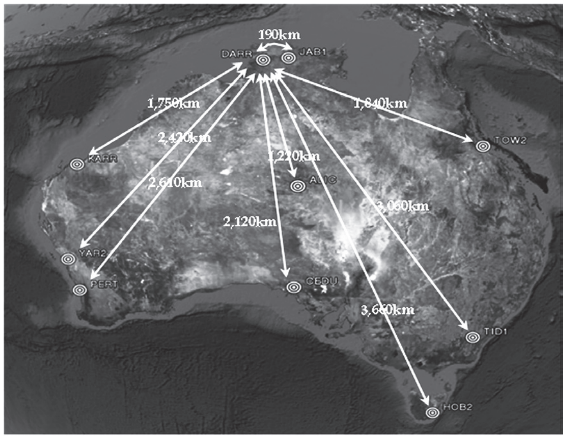

Fig. 2. IGS CORS in Australia.

Like in the research target area, we performed IGS CORS based differential positioning and precise point positioning experiment to suggest the most effective positioning method under poor reference point situations. Such an experiment was intended to judge the positioning efficiency under the reference point situation but long term data processing was not considered in this case. Given this situation, we collected GPS observational data over 4 days in total from January 1, 2008 through January 4, 2008, while considering some bad observation results might be included in the GPS

Table 1. GPS data

Location	ID	Date	Interval	Data Format
Jabiru	JAB1	2008. 01. 01 ~ 2008. 01. 04	30 sec	RINEX
Karratha	KARR			
Alice Springs	ALIC			
Cape Ferguson	TOW2			
Dongara	YAR2			
Perth	PERT			
Ceduna	CEDU			
Canberra	TID1			
Hobart	HOB2			

observational data at a particular time. The collected data were in RINEX format and collected every 30 seconds for 24 hours(ftp://cddis.gsfc.nasa.gov/). Table 1 shows the GPS observed data.

IGS has announced the coordinate result for each CORS and the 10 CORS results announced by IGS were used for this research as shown on Table 2.

Table 2. Coordinate information for selected CORS (http://igscb.jpl.nasa.gov/)

Station ID	3D Cartesian Coordinate (m)			Local Geodetic Datum
	X	Y	Z	
DARR	-4091358.9070	4684606.7121	-1408580.2927	IGS05
JAB1	-4236442.9028	4559929.5553	-1388624.4745	
KARR	-2713832.3938	5303935.1039	-2269514.8516	
ALIC	-4052051.9586	4212836.1050	-2545105.6805	
TOW2	-5054582.7913	3275504.4130	-2091539.5466	
YAR2	-2389025.6733	5043316.8902	-3078530.5734	
PERT	-2368687.1073	4881316.5395	-3341796.0076	
CEDU	-3753472.3711	3912741.0114	-3347960.7200	
TID1	-4460996.2402	2682557.0825	-3674443.5584	
HOB2	-3950071.4760	2522415.2101	-4311638.2398	

The GPS observational data collected from 10 stations were processed by differential positioning and precise point positioning on the reference of BPE. In the process of differential positioning, we assumed DARR CORS as an unknown point and divided the whole cases into 2 in consideration of the effect of the baseline distance and the number of reference points in use. BPE is an automated data processing program of which processing procedure is determined by PCF(Process Control File), and the user may adjust the option upon use of BPE or add or omit each script by a separate edit function. BPE has been used for global IGS Network data processing at IGS Analysis Center and is also being use dat GSI(Geographical Survey Institute) in Japan currently for nationwide GPS network data processing purpose(http://www.geonet.org.nz/).

For GPS data processing, we must eliminate all the deviations initiated by the physical movement of the earth by using a proper model and in the items subject to correction are included polar motion and atmospheric weight(McCarthy, 1996). BSV5.0 is designed to use the accurate orbit and all kinds of models supplied by NASA JPL(NASA Jet Propulsion Laboratory), AIUB(Astronomical Institut Universität Bern), and IGS(Internation GNSS Service) to eliminate such correction factors as above. As for tropospheric delay, we utilized Saastamoinen Model(Saastamoinen, 1972) and Niell Mapping Function(Niell, 1996) and edited PCF(Process Control File) to screen out and process only the observation data with the angle of altitude over 10° for multi-pass prevention. As for the positional information on the satellite, we utilized only the precise ephemeris from the Jet Propulsion Laboratory while we adopted the absolute correction model for antenna phase center offset correction. The absolute correction model may be used not only for calculating the correction value of the highly dense azimuthal direction but also providing the correction value for frequencies, L1 and L2 respectively. Table 3 is the summary of the GPS data processing strategy.

Table 3. Strategy of GPS data processing

Parameters	Description
Data Processing Methods	Relative Positioning, Precise Point Positioning
Observation Data	L1, L2 CODE and Phase
Satellite Ephemeris	Precise Ephemeris
Ambiguity Resolution	Quasi Ionosphere Free
Tropospheric Correction	Dry and Wet Niell Model
Earth Gravity Potential	JGM3
Sub-daily Earth rotation parameters	IERS2000
Nutation	IAU2000
Antenna Model	Absolute Model
Solar System Ephemerides	JPL DE200

3. Data Processing Result and Analysis

3.1 Analysis of Influence According to Baseline Length

The differential positioning method is most common for

GPS based positioning. Relative positioning requires at least two receivers set up at two stations usually one is known to collect satellite data simultaneously in order to determine coordinate differences. Relative positioning is an effective strategy for minimizing the effect of this bias. We analyzed the differential positioning results on the reference of the baseline distance and number of reference points to suggest the most effective positioning method when few reference points were available. As for differential positioning, the baseline distance is significantly affecting the coordinate result accuracy and the positioning error is in proportion to the baseline distance(Beutler *et al*, 1989; Eckl *et al*., 2001). Under this research, we executed differential positioning to figure out how the baseline distance affects differential positioning for the 3 categories of the distance to the reference point, up to 190km, 1,000km~2,000km, and over 2,000km. Table 4 is the summary of differential positioning results for each DARR CORS baseline distance assumed to be an unknown point.

Table 4. Differential positioning results for each DARR CORS baseline distance

Observation Date	Baseline Distance (km)	Used Reference Points	X(m) (RMSE)	Y(m) (RMSE)	Z(m) (RMSE)
2008. 1. 1	190	JAB1	-4091358.9113 (±0.0058)	4684606.7188 (±0.0053)	-1408580.3073 (±0.0014)
2008. 1. 2			-4091358.8995 (±0.0050)	4684606.7211 (±0.0047)	-1408580.3081 (±0.0013)
2008. 1. 3			-4091358.9206 (±0.0064)	4684606.7286 (±0.0059)	-1408580.3132 (±0.0017)
2008. 1. 4			-4091358.9126 (±0.0080)	4684606.7045 (±0.0079)	-1408580.3072 (±0.0021)
2008. 1. 1	1,000 ~ 2,000	KARR, ALIC, TOW2	-4091358.8415 (±0.0022)	4684606.6122 (±0.0023)	-1408580.2271 (±0.0011)
2008. 1. 2			-4091358.8344 (±0.0023)	4684606.6041 (±0.0024)	-1408580.2239 (±0.0012)
2008. 1. 3			-4091358.8290 (±0.0025)	4684606.5921 (±0.0026)	-1408580.2265 (±0.0013)
2008. 1. 4			-4091358.8130 (±0.0033)	4684606.5852 (±0.0034)	-1408580.2133 (±0.0018)
2008. 1. 1	over 2,000	YAR2, PERT, CEDU, TID1, HOB2	-4091358.7896 (±0.0039)	4684606.4836 (±0.0037)	-1408580.1368 (±0.0022)
2008. 1. 2			-4091358.7810 (±0.0038)	4684606.4635 (±0.0037)	-1408580.1238 (±0.0021)
2008. 1. 3			-4091358.7699 (±0.0037)	4684606.4502 (±0.0035)	-1408580.1263 (±0.0020)
2008. 1. 4			-4091358.7719 (±0.0045)	4684606.4372 (±0.0045)	-1408580.1122 (±0.0025)

Table 5 shows the deviation of coodinates in Table 2 with the results of DARR CORS relative positioning about the each occasion, Fig. 3 shows the graph about deviation of relative positioning according to baseline distance of DARR CORS.

Table 5. Deviation of relative positioning according to baseline distance of DARR CORS

Observation Date	Baseline Distance (km)	Used Reference Points	△X	△Y	△Z
2008. 1. 1	190	JAB1	0.0043m	-0.0067m	0.0146m
2008. 1. 2			-0.0075m	-0.0090m	0.0154m
2008. 1. 3			0.0136m	-0.0165m	0.0205m
2008. 1. 4			0.0056m	0.0076m	0.0145m
2008. 1. 1	1,000 ~ 2,000	KARR, ALIC, TOW2	-0.0666m	0.1010m	-0.0661m
2008. 1. 2			-0.0729m	0.1081m	-0.0685m
2008. 1. 3			-0.0759m	0.1173m	-0.0660m
2008. 1. 4			-0.0894m	0.1313m	-0.0779m
2008. 1. 1	over 2,000	YAR2, PERT, CEDU, TID1, HOB2	-0.1174m	0.2285m	-0.1559m
2008. 1. 2			-0.1260m	0.2486m	-0.1689m
2008. 1. 3			-0.1371m	0.2619m	-0.1664m
2008. 1. 4			-0.1351m	0.2749m	-0.1805m

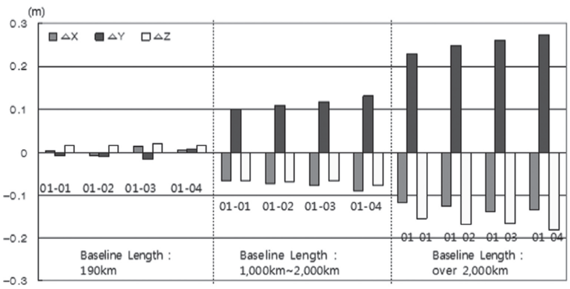

Fig. 3. Deviation of relative positioning according to baseline distance of DARR CORS

When we used JAB1 as a reference point which is 190km away from DARR CORS, the deviation was within the range of -0.0075m ~ 0.0205m on X, Y, and Z coordinates respectively. Meanwhile, when we used the reference point (KARR, ALIC, TOW2) with the distance of 1,000km ~

2,000km, the deviation was within the range of -0.0660m ~ 0.1313m and when we used the reference points(YAR2, PERT, CEDU, TID1, HOB2) with the distance over 2,000km, -0.1174m ~ 0.1805m respectively. This research also reconfirmed the error is in proportion to the baseline distance as in the previous research result. When the baseline distance was 190km, the shortest one, the maximum error was about 2cm but it was up to 27cm when the baseline distance exceeds 2,000km.

3.2 Analysis of Influence According to Number of Reference Station

It has been generally accepted the available multiple reference point is most effective for differential positioning. This research analyzed the effect of the number of the reference points in use on the coordinate result along with the effect of the baseline distance under a special reference point situation, especially in Antarctica to suggest the most effective positioning method when there is no reference point around an unknown point. For this sake, we used the observational data on January 1, 2008 in Australia and then assumed DARR to be an unknown point among 10 CORSs, added the remaining 9 CORSs from the closest JAB1 to HOB2 with the farthest baseline distance to the reference point, and executed differential positioning while increasing the number of reference points. Table 6 is indicating the result according to the number of the reference points in use of DARR CORS.

Table 6. Relative positioning results according to the number of the reference points in use of DARR CORS

No. of Reference Points	Reference Points	X (RMSE)	Y (RMSE)	Z (RMSE)
1	JAB1	-4,091,358.9113m (±0.0058m)	4,684,606.7188m (±0.0053m)	-1,408,580.3073m (±0.0014m)
2	JAB1, KARR	-4,091,358.8380m (±0.0040m)	4,684,606.6383m (±0.0044m)	-1,408,580.2739m (±0.0011m)
3	JAB1, KARR, ALIC	-4,091,358.8272m (±0.0036m)	4,684,606.6141m (±0.0039m)	-1,408,580.2545m (±0.0019m)
4	JAB1, KARR, ALIC, TOW2	-4,091,358.8446m (±0.0035m)	4,684,606.6214m (±0.0037m)	-1,408,580.2453m (±0.0018m)
5	JAB1, KARR, ALIC, TOW2, YAR2	-4,091,358.8155m (±0.0035m)	4,684,606.5814m (±0.0037m)	-1,408,580.2282m (±0.0018m)
6	JAB1, KARR, ALIC, TOW2, YAR2, PERT	-4,091,358.7953m (±0.0035m)	4,684,606.5559m (±0.0038m)	-1,408,580.2183m (±0.0020m)
7	JAB1, KARR, ALIC, TOW2, YAR2, PERT, CEDU	-4,091,358.7947m (±0.0035m)	4,684,606.5499m (±0.0038m)	-1,408,580.2116m (±0.0020m)
8	JAB1, KARR, ALIC, TOW2, YAR2, PERT, CEDU, TID1	-4,091,358.7987m (±0.0035m)	4,684,606.5467m (±0.0037m)	-1,408,580.2009m (±0.0020m)
9	JAB1, KARR, ALIC, TOW2, YAR2, PERT, CEDU, TID1, HOB2	-4091358.7986m (±0.0035m)	4684606.5374m (±0.0037m)	-1408580.1861m (±0.0019m)

Table 7 shows the relative positioning deviation with IGS coordinate information according to the number of the reference points in use of DARR CORS, Fig. 4 shows the deviation graph with coordinate information according to number of reference points.

Table 7. Relative positioning deviation according to the number of the reference points in use of DARR CORS

No. of Reference Points	Reference Points	△X	△Y	△Z
1	JAB1	0.0043m	-0.0067m	0.0146m
2	JAB1, KARR	-0.0690m	0.0738m	-0.0188m
3	JAB1, KARR, ALIC	-0.0798m	0.0980m	-0.0382m
4	JAB1, KARR, ALIC, TOW2	-0.0624m	0.0907m	-0.0474m
5	JAB1, KARR, ALIC, TOW2, YAR2	-0.0915m	0.1307m	-0.0645m
6	JAB1, KARR, ALIC, TOW2, YAR2, PERT	-0.1117m	0.1562m	-0.0744m
7	JAB1, KARR, ALIC, TOW2, YAR2, PERT, CEDU	-0.1123m	0.1622m	-0.0811m
8	JAB1, KARR, ALIC, TOW2, YAR2, PERT, CEDU, TID1	-0.1083m	0.1654m	-0.0918m
9	JAB1, KARR, ALIC, TOW2, YAR2, PERT, CEDU, TID1, HOB2	-0.1084m	0.1747m	-0.1066m

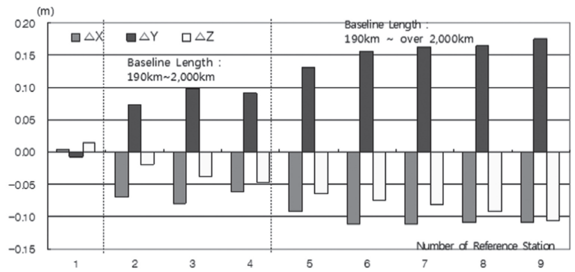

Fig. 4. Deviation with coordinate information according to number of reference points

According to the research result, the deviation of each component was in the range of -0.0067m~0.0146m, the smallest when we used one of the closest JAB1s for the unknown point but increased to the range of -0.0188m ~ 0.1747m when we used 2 to 9 multiple reference points. Generally speaking, it is more effective to use multiple reference points for differential positioning but as shown on Fig. 4, it was known to us it is more suitable to use one reference point with a short baseline distance than use multiple reference points with a baseline distance over 1,000km provided no reference point was available around an unknown point.

3.3 Analysis of Influence According to Number of Reference Station

The method of precise absolute positioning or Precise Point Positioning was first introduced for static applications(Zumberge *et al*, 1998). Precise point positioning is a good alternative for differential positioning for such areas without any available reference point around an unknown point as Antarctica since it has an advantage of unknown point positioning determination independently of the reference point in the neighborhood. This research tried to suggest the availability of precise point positioning when no reference point is available around an unknown point by using precise point positioning result analysis for the GPS observational data of Australian land CORS. The model used in PPP can be described as being an extension of the model used by the Standard Positioning Service offered by GPS. Important modification include the replacement of satellite orbits and satellite clock corrections with more precise estimates from e.g. IGS, the inclusion of the carrier phase as observable and modeling of satellite attitude and site displacement effects.

Here, we made use of the precise point positioning method to process the GPS observational data at 10 CORSs in the Australian land for CORS positioning and set the base point to January 1, 2000 to compare the process result with the IGS announced result. Precise point positioning is requiring diastrophism speed for base point control and therefore we used the diastrophism speed of each CORS supplied by IGS under this research. Table 8 is the summary of the crustal movement velocity for each CORS. Table 9 shows the precise point positioning result for each date of observation while Table 10 shows the deviation from the announced result.

As a result, we could achieve an accurate coordinate result in which the precise point positioning processing result had an RMSE of $\pm$0.0007m~$\pm$0.0058m on X, Y, and Z coordinates respectively. To estimate the accuracy of the precise point positioning data processing result, we also compared the precise point positioning processing result at 10 CORS with the IGS announced result. Fig. 5 ~ 8 show the graphs.

The deviation between the precise point positioning processing result and the published coordinates was within the range of -0.0398m ~ 0.0481m on X, Y, and Z coordinates respectively. The DARR deviation was within the range of -0.0222m ~ 0.0079m, almost the same with the differential positioning result having JAB1 as the reference point as seen in Table 6 and the deviation was also maintained below 0.05m according to the other CORS results. Such results are said to indicate precise point positioning may be available when no reference point is available in the neighborhood at the time of GPS based positioning.

Table 8. Crustal movement velocity of CORS

CORS	VX(m/year)	VY(m/year)	VZ(m/year)
DARR	-0.0350	-0.0146	0.0569
JAB1	-0.0353	-0.0132	0.0592
KARR	-0.0445	0.0014	0.0540
ALIC	-0.0395	-0.0056	0.0541
TOW2	-0.0321	-0.0136	0.0522
YAR2	-0.0476	0.0094	0.0499
PERT	-0.0468	0.0059	0.0529
CEDU	-0.0417	0.0007	0.0511
TID1	-0.0371	0.0006	0.0455
HOB2	-0.0403	0.0087	0.0408

Table 9. PPP results of IGS CORS in Australia

Date	CORS	X(RMSE)m	Y(RMSE)m	Z(RMSE)m
2008. 1. 1	ALIC	-4052051.9635 (±0.0017)	4212836.1233 (±0.0015)	-2545105.6856 (±0.0009)
	CEDU	-3753472.3683 (±0.0015)	3912741.0083 (±0.0013)	-3347960.7184 (±0.0010)
	DARR	-4091358.8938 (±0.0018)	4684606.7343 (±0.0018)	-1408580.2972 (±0.0006)
	HOB2	-3950071.4981 (±0.0014)	2522415.2184 (±0.0011)	-4311638.2457 (±0.0012)
	JAB1	-4236442.8812 (±0.0034)	4559929.5466 (±0.0031)	-1388624.4601 (±0.0011)
	KARR	-2713832.3996 (±0.0015)	5303935.1406 (±0.0019)	-2269514.8752 (±0.0009)
	PERT	-2368687.0776 (±0.0038)	4881316.4914 (±0.0052)	-3341795.9912 (±0.0036)
	TID1	-4460996.2642 (±0.0020)	2682557.0953 (±0.0014)	-3674443.5609 (±0.0014)
	TOW2	-5054582.8108 (±0.0018)	3275504.4381 (±0.0013)	-2091539.5481 (±0.0008)
	YAR2	-2389025.6778 (±0.0013)	5043316.9263 (±0.0016)	-3078530.6039 (±0.0010)
2008. 1. 2	ALIC	-4052051.9651 (±0.0017)	4212836.1263 (±0.0015)	-2545105.6851 (±0.0009)
	CEDU	-3753472.3767 (±0.0016)	3912741.0084 (±0.0014)	-3347960.7226 (±0.0011)
	DARR	-4091358.8941 (±0.0018)	4684606.7312 (±0.0018)	-1408580.2951 (±0.0007)
	HOB2	-3950071.4977 (±0.0014)	2522415.2169 (±0.0011)	-4311638.2434 (±0.0012)
	JAB1	-4236442.8871 (±0.0034)	4559929.5612 (±0.0032)	-1388624.4597 (±0.0011)
	KARR	-2713832.4026 (±0.0015)	5303935.1402 (±0.0019)	-2269514.8765 (±0.0009)
	PERT	-2368687.0972 (±0.0041)	4881316.5227 (±0.0058)	-3341796.0076 (±0.0040)
	TID1	-4460996.2606 (±0.0018)	2682557.0885 (±0.0013)	-3674443.5591 (±0.0013)
	TOW2	-5054582.8155 (±0.0019)	3275504.4369 (±0.0014)	-2091539.5469 (±0.0008)
	YAR2	-2389025.6743 (±0.0015)	5043316.9300 (±0.0017)	-3078530.6060 (±0.0011)
2008. 1. 3	ALIC	-4052051.9645 (±0.0017)	4212836.1189 (±0.0015)	-2545105.6860 (±0.0009)
	CEDU	-3753472.3775 (±0.0016)	3912741.0049 (±0.0014)	-3347960.7239 (±0.0011)
	DARR	-4091358.8930 (±0.0019)	4684606.7216 (±0.0019)	-1408580.2983 (±0.0007)
	HOB2	-3950071.5063 (±0.0015)	2522415.2141 (±0.0011)	-4311638.2496 (±0.0013)
	JAB1	-4236442.8790 (±0.0034)	4559929.5457 (±0.0032)	-1388624.4568 (±0.0012)
	KARR	-2713832.4044 (±0.0016)	5303935.1386 (±0.0020)	-2269514.8781 (±0.0009)
	PERT	-2368687.0911 (±0.0039)	4881316.5150 (±0.0054)	-3341796.0086 (±0.0037)
	TID1	-4460996.2606 (±0.0020)	2682557.0841 (±0.0014)	-3674443.5633 (±0.0014)
	TOW2	-5054582.8130 (±0.0019)	3275504.4288 (±0.0014)	-2091539.5463 (±0.0008)
	YAR2	-2389025.6826 (±0.0014)	5043316.9225 (±0.0017)	-3078530.6076 (±0.0010)
2008. 1. 4	ALIC	-4052051.9564 (±0.0018)	4212836.1250 (±0.0016)	-2545105.6865 (±0.0010)
	CEDU	-3753472.3737 (±0.0017)	3912741.0095 (±0.0015)	-3347960.7253 (±0.0011)
	DARR	-4091358.8916 (±0.0023)	4684606.7308 (±0.0023)	-1408580.3006 (±0.0008)
	HOB2	-3950071.4919 (±0.0015)	2522415.2163 (±0.0012)	-4311638.2477 (±0.0013)
	JAB1	-4236442.8671 (±0.0039)	4559929.5410 (±0.0035)	-1388624.4531 (±0.0012)
	KARR	-2713832.3947 (±0.0017)	5303935.1379 (±0.0021)	-2269514.8775 (±0.0010)
	PERT	-2368687.0874 (±0.0038)	4881316.5051 (±0.0050)	-3341796.0011 (±0.0035)
	TID1	-4460996.2548 (±0.0019)	2682557.0877 (±0.0014)	-3674443.5597 (±0.0014)
	TOW2	-5054582.8060 (±0.0020)	3275504.4308 (±0.0014)	-2091539.5431 (±0.0008)
	YAR2	-2389025.6813 (±0.0015)	5043316.9211 (±0.0018)	-3078530.6075 (±0.0011)

On the reference of this research, we were able to verify differential positioning is effective by using one reference point with a short baseline distance from an unknown point under poor reference point situation while precise point positioning based positioning is very effective when we are using a reference point with a baseline distance over 1,000km.

Table 10. Deviation PPP results with announced result of IGS CORS in Australia

Date	CORS	dX(m)	dY(m)	dZ(m)
2008. 1. 1	ALIC	0.0049	-0.0183	0.0051
	CEDU	-0.0028	0.0031	-0.0016
	DARR	-0.0132	-0.0222	0.0045
	HOB2	0.0221	-0.0083	0.0059
	JAB1	-0.0216	0.0087	-0.0144
	KARR	0.0058	-0.0367	0.0236
	PERT	-0.0297	0.0481	-0.0164
	TID1	0.0240	-0.0128	0.0025
	TOW2	0.0195	-0.0251	0.0015
	YAR2	0.0045	-0.0361	0.0305
2008. 1. 2	ALIC	0.0065	-0.0213	0.0046
	CEDU	0.0056	0.0030	0.0026
	DARR	-0.0129	-0.0191	0.0024
	HOB2	0.0217	-0.0068	0.0036
	JAB1	-0.0157	-0.0059	-0.0148
	KARR	0.0088	-0.0363	0.0249
	PERT	-0.0101	0.01680	0.0000
	TID1	0.0204	-0.0060	0.0007
	TOW2	0.0242	-0.0239	0.0003
	YAR2	0.0010	-0.0398	0.0326
2008. 1. 3	ALIC	0.0059	-0.0139	0.0055
	CEDU	0.0064	0.0065	0.0039
	DARR	-0.0140	-0.0095	0.0056
	HOB2	0.0303	-0.0040	0.0098
	JAB1	-0.0238	0.0096	-0.0177
	KARR	0.0106	-0.0347	0.0265
	PERT	-0.0162	0.0245	0.0010
	TID1	0.0204	-0.0016	0.0049
	TOW2	0.0217	-0.0158	-0.0003
	YAR2	0.0093	-0.0323	0.0342
2008. 1. 4	ALIC	-0.0022	-0.0200	0.0060
	CEDU	0.0026	0.0019	0.0053
	DARR	-0.0154	-0.0187	0.0079
	HOB2	0.0159	-0.0062	0.0079
	JAB1	-0.0357	0.0143	-0.0214
	KARR	0.0009	-0.0340	0.0259
	PERT	-0.0199	0.0344	-0.0065
	TID1	0.0146	-0.0052	0.0013
	TOW2	0.0147	-0.0178	-0.0035
	YAR2	0.0080	-0.0309	0.0341

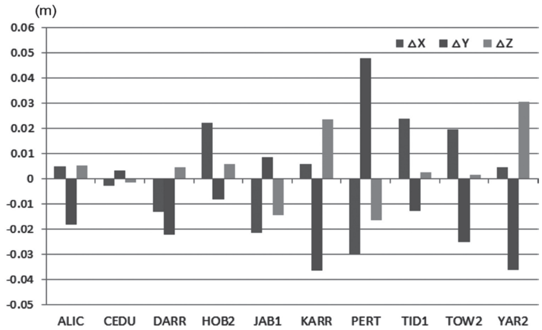

Fig. 5. Deviation of PPP results - 2008.01.01

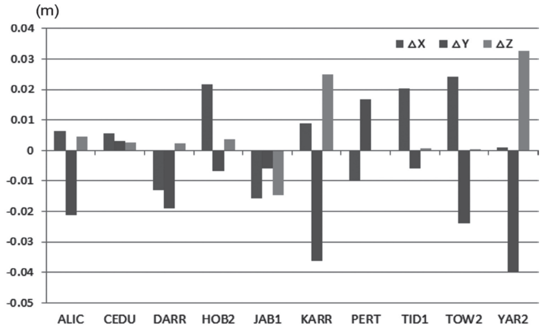

Fig. 6. Deviation of PPP results – 2008.01.02

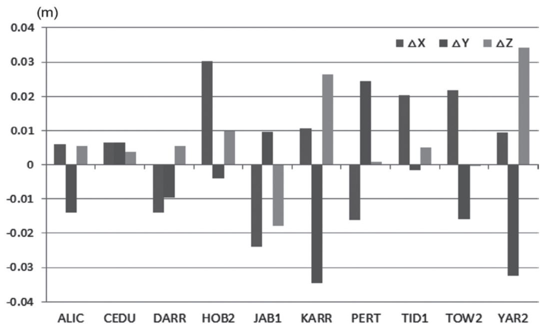

Fig. 7. Deviation of PPP results - 2008.01.03

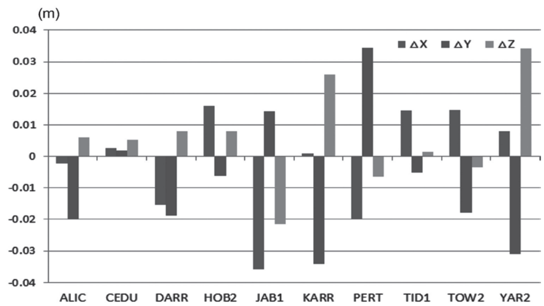

Fig. 8. Deviation of PPP results- 2008.01.04

4. Conclusion

This research tried to suggest an effective positioning method for the Australian land with few available reference points around an unknown point and requiring very long baseline processing in consideration of the regional characteristics. For this purpose, we carried out GPS based positioning in various conditions. According to the research result, it was revealed it is more effective to use one reference point with a short baseline distance than to use multiple reference points with a long baseline distance during GPS differential positioning when the baseline distance is longer than 1,000km and the precise point positioning based positioning method is an excellent substitute provided there is no reference point is available around an unknown point. This kind of research result is expected to be greatly useful for the basic data of accurate positioning for the regions with few available reference points like Antarctica.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Science, ICT & Future Planning(NRF-2012R1A1A1004414)

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(Received 2013. 11. 08, Revised 2013. 12. 04, Accepted 2013. 12. 30)